THE WORLD BANK

ESMAP
Energy Sector Management Assistance Programme

Handbook for the Preparation of Landfill Gas to Energy Projects in Latin America and the Caribbean

The World Bank - ESMAP

Prepared by:

Conestoga-Rovers & Associates
651 Colby Drive
Waterloo, Ontario
N2V 1C2

January 2004
Ref. No. 019399 (6)

CONTENTS

CONTENTS

CONTENTS

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES

LIST OF BOXES

APPENDIXES

THE FOLLOWING RELATED LANDFILL GAS TO ENERGY CASE STUDIES ARE PUBLISHED UNDER SEPARATE COVER

ACKNOWLEDGEMENTS

The Handbook has been prepared by Conestoga Rovers & Associates (Waterloo, Ontario, Canada) on behalf of the World Bank as a key element in its programs to support the development of modern and sustainable waste management systems in LAC and the Caribbean. Funding support has been provided through the Canadian trust funds contributed by the Canadian International Development Agency (CIDA) and through the Environment Sector Management Assistance Program (ESMAP). The ESMAP is assisting in the development, testing and dissemination of LFG management approaches. A component of the ESMAP funds have been allocated for the preparation of this Handbook and associated case studies of experiences with Landfill Gas (LFG) Management and Landfill Gas to Energy (LFGTE) systems in LAC and selected cities elsewhere.

Horacio Terraza has been the World Bank's Task Manager for the project, assisted by Andrea Semaan, Gloria Leiva and Erica Felix. Kulsum Ahmed provided insight and support to develop the original concept and frame of reference for developing the Handbook. Mr. Carl Bartone provided his encouragement, insight and review comments to develop the Handbook in a manner that will make it a useful tool for encouraging and supporting the development of LFG and LFGTE projects in LAC and the Caribbean. Sandra Greiner, Franck Lecocq, and Johann Heister provided valuable insight and comment to the Handbook from the perspective of the Prototype Carbon Fund.

A series of case studies were written for the World Bank to support and provide representative project examples of LFG and LFGTE projects. Valuable insight and support was provided by the authors of the case studies including: Dr. Robert Eden of The Barclay Centre (Turkey); Mr. J.H. Penido Monteiro (Brazil); Mr. Quentin Hurt and Mia Antoni of Ecoserv (South Africa); Dr. Hans Willumsen of LFG Consultant (Latvia and Poland); Frederick Mosher and Meagan Wheeler of Conestoga Rovers & Associates (Canada); Avila Rueda (Mexico), and Dr. Sebastian Valdes (Chile).

The sourcebook benefited greatly from the input received at a large workshop session held in Monterey, Mexico. The attendance and active participation of all of the attendees at the workshop are appreciated and any comments made on the draft Handbook have been incorporated into the final document.

ACRONYMS AND ABBREVIATIONS

AE	Applicant entities
CDM	Clean development mechanism
CER	Certified emission reductions
CH_4	Methane
CIDA	Canadian International Development Agency
CO_2	Carbon dioxide
COP/MOP	Conference of Parties/Meeting of Parties
DOE	Designated operational entities
DNA	Designated national authority
EB	Executive board
eCO_2	equivalent carbon dioxide (this is the currency for discussing GHG emission reductions)
EIT	Economies in Transition
ELECTROBRAS	Brazilian government electrical utility, made up of a consortium of large electricity generators
ERs	Emission reductions (not always GHGs)
ERU'S	Emission reduction units
ERPA	Emissions reductions purchase agreement
ESMAP	Energy Sector Management Assistance Program
GHG	Green House Gas (note that there are many, but carbon dioxide equivalents are the common currency used for evaluation)
GWP	Global Warming Potential
H_2S	Hydrogen sulfide
Handbook	Handbook for the Preparation of Landfill Gas to Energy Projects
HCA	Host country agreement
IC&I	Industrial, commercial and institutional (category of waste type)
IPP	Independent power producers
IRR	Internal Rate of Return
IPCC	International Panel on Climate Change

ACRONYMS AND ABBREVIATIONS

JI	Joint implementation
k	Rate constant used in LFG modeling
kWh	Kilowatt hour
LAC	Latin America and the Caribbean
LBT	Landfill bioreactor technology
LDC	Late developing country
LFG	Landfill Gas
LFGTE	Landfill Gas to Energy
MSW	Municipal Solid Waste
MW	Megawatt
NGO	Non-governmental organization
O_2	Oxygen
O&M	Operating and Maintenance
PCF	Prototype Carbon Fund
PDR	Preliminary Design Report
PP	Project participants
ppb	Parts per billion (used for defining gas and liquid concentrations)
ppm	Parts per million (used for defining gas and liquid concentrations)
PROINFA	Program to foster alternative sources of electrical power in Brazil
PVM	Preliminary validation protocol
ROI	Return on Investment
SP	Sub-project
UNFCCC	United Nations Framework Convention on Climate Change
U.S. EPA	United States Environmental Protection Agency

UNITS OF MEASURE, U.S. EQUIVALENTS AND CONVERSION FACTORS

Unit of Measurement	*Conversion to U.S. equivalent*
1 millimeter (mm)	0.039 inch (in)
1 meter (m)	3.281 feet (ft)
1 m^3/hour (m^3/hr)	0.589 ft^3/minute (cfm)
1 hectare (ha)	2.471 acres
1 tonne	1.102 short ton
0 degrees Celsius (°C)	32 degree Fahrenheit (°F)
1 megawatt (MW)	3,412,141.635 Btu/hour

Note: All monetary amounts mentioned in the text are provided in United States dollars (US$) unless specifically noted otherwise.

PREFACE

This Handbook has been developed for the World Bank to facilitate the development of landfill gas (LFG) management and landfill gas to energy (LFGTE) projects in Latin America and the Caribbean (LAC).

The World Bank and ESMAP have embarked on a project to promote LFG management initiatives in LAC region to enable stakeholders to recognize the potential demand for LFG investments and corresponding energy supplies, and carbon emissions reductions. There is emerging potential for LFG management projects to create incentives that will improve the design and operation of the landfill, and as an additional benefit could provide a source of "green" energy for adjacent neighbors of the landfill. The overall World Bank/ESMAP project focuses on the LFG management side of the equation, namely to:

- document the existing experiences in LAC and selected cities elsewhere;
- assess the current constraints to increased LFG capture and destruction or utilization in LAC cities; and
- identify the minimum conditions and preferred institutional arrangements for successful LFG management and utilization projects;
- develop outreach activities to promote this environmentally sound non-conventional energy source; and
- contribute to the implementation of a regional approach aimed at reduction of methane emissions and to develop carbon-trading opportunities.

The overall World Bank initiative takes a phased approach. The first phase aims to assist LAC client countries to better understand the best practice business models and institutional arrangements for development of non-conventional energy sources at large landfills in LAC region by means of LFG recovery and utilization systems.

It is expected that the Handbook will be used by those who, own, operate, engineer and regulate landfill sites in LAC as a roadmap for the assessment of candidate projects and to initiate development of LFG management projects. The Handbook is intended as a practical guideline that uses background information and a number of instructive tools to educate, guide and establish a basis for decision-making, technical feasibility assessment, economics assessment, and market evaluation of all aspects necessary for developing successful LFG management projects. While this Handbook is targeted to the LAC region, the principles can be applied to any region of the globe with the adjustment of a few parameters to take into consideration climatic and geographical differences as well as the local economic factors and influences.

DISCLAIMER

EXECUTIVE SUMMARY

Latin America and the Caribbean (LAC) is highly urbanized with, on average, 75 percent of its 500 million inhabitants living mainly in large cities, leading to the concentration of solid waste and corresponding waste management problems. Many LAC cities still dispose of their municipal solid waste in open dumps creating problems with leachate contamination of surface and groundwater, and the release of landfill gas (LFG) to the atmosphere. LFG is approximately 50 percent methane and 50 percent carbon dioxide and is therefore considered a powerful greenhouse gas (GHG). The more important and prosperous cities in LAC have begun to improve disposal practice and have introduced sanitary landfills. Notwithstanding the trend in LAC toward improved landfills, only a few cities in Chile and Mexico actively collect LFG and utilize the energy value inherent in the LFG, or are planning to do so (with Global Environment Fund (GEF) support), such as in Nova Gerar, Brazil and Maldonado, Uruguay. In contrast to this limited beneficial use of LFG in LAC, the experience in North America and Europe is that there are several hundred landfill gas (LFG) management and landfill gas to energy (LFGTE) projects in existence and many more coming on-line each year. Thus, there is a significant opportunity to increase LFG recovery and utilization at landfills in LAC, provided that the appropriate market conditions exist. The revenue generated from LFG management projects can provide a great incentive to improve the design and operation of landfills, and to advance the overall waste management system in LAC cities.

LFG management could successfully be undertaken and implemented at most landfills in LAC and the Caribbean. The capital cost of LFG collection and utilization infrastructure and the infancy of the carbon and renewable energy markets makes the development of these projects most applicable to large and deep landfills (generally greater than 1 million tonnes of waste in place with a depth of more than 15 meters). However, each potential LFG management project should be evaluated based on local conditions including the conditions at the landfill, the opportunity to sell carbon credits, the price of energy, available tax credits, and available "green" incentives. Smaller LFG management projects become much more viable as the value of CER's increase and as the value of energy products increase. In Europe, the energy pricing can support projects of less than 0.5 MW and less than 1 million tonnes of waste in place.

It is necessary that a LFGTE project can be interconnected to an urban power grid or gas distribution network, or is close to a suitable energy end user. In the case of current LAC conditions, this would make the most promising applications to the large and intermediate-sized cities. In LAC, there are currently 117 cities with a population greater than 500,000 people. All together these cities account for a total population of 225 million inhabitants and a cumulative waste generation rate of some 74 million tonnes of solid waste per year. Assuming that one-half of these cities would meet the general criteria for feasible LFGTE projects, there is the potential to generate the equivalent of more than 800 MW of electrical power. This estimate assumes steady state rate of waste

generation and 35 percent conversion energy efficiency, both of which are conservatively low assumptions for LAC.

Of equal or possibly greater importance, is the potential to achieve annual emission reductions of more than 40,000,000 equivalent tonnes of carbon dioxide (eCO_2) annually. As the international carbon market evolves, the incentive to generate emission reductions from LFG capture and use will be high in LAC cities. There are potential emission reduction benefits associated with reducing LFG emissions to the atmosphere, but also additional emission reduction benefits can be realized by displacing fossil fuel use if the LFG is used for its inherent energy value. Currently, the international carbon market is in its infancy and there is still uncertainty surrounding the future value of emission reductions generated by LFG management projects. However, current projections for the value of emission reductions from LAC landfills could exceed $100 million USD annually.

Waste composition is the most important factor in assessing the LFG generation potential of a landfill site. The potential volume of LFG is dependent on the quantity and type of organic content within the waste mass (Environment Canada, 1996) since decomposing organic wastes are the source for all LFG produced. Other key factors that influence the rate of LFG production include: moisture content; nutrient content; bacterial content; pH level; temperature; and the site design and operations features of the landfill site.

LFG generation assessments are based on a variety of LFG modeling techniques and pumping field testing programs. LFG modeling is dependent on the model input including input data such as annual waste-in-place quantities, forecasted waste deposition, waste composition, moisture content, and climate. LFG pumping test data may be used in conjunction with the LFG modeling to demonstrate current LFG quality and quantity as well to support projections of the future resource.

All LFG utilization facilities require an effectively designed and operated LFG collection system that provides a reliable fuel supply. The key objectives for effective LFG control are compatible with LFG utilization objectives. Although the emphasis on the various objectives can vary based on site specific and location specific conditions, collectively the objectives for these two systems are:

- to protect against odor emissions;
- to protect against gas migration impacts through the native soils into buildings and services;
- to prevent any acute localized ambient air quality concerns associated with LFG emissions;
- to reduce GHG emissions to the atmosphere; and
- to optimize LFG recovery for use as a fuel or energy product.

Both the LFG collection and utilization systems should be capable of handling the high moisture content inherent in LFG, which typically may cause serious operational issues that can either limit the ability to extract and/or use the LFG efficiently. Depending upon the application, the raw LFG may require some level of gas processing prior to being utilized in order to address these concerns.

The extraction and utilization of LFG requires ongoing diligence through the entire service life of a project because of the heterogeneous nature of the waste producing the LFG and the changing characteristics of the LFG over time. Therefore, LFG management projects are somewhat more sensitive than typical infrastructure projects and must be operated and managed carefully. The fuel resource recovery is, in most cases, a secondary activity on a large waste management site. Understanding this factor is critical to the success of a project. It is critical to the success of the LFG management industry that the operations and interaction with the waste management activities for each candidate site be considered as crucial to the effective and successful performance of the systems.

When assessing the feasibility of a project, it is not only important to consider the technical options for the project, but also to analyze the potential markets and related legislation to ensure that the project will be economically viable. The Handbook provides a summary of pertinent background materials that are then used as the basis for integrating the business and financial models with the appropriate input data and information specifically for LFG management projects.

Governments may significantly influence LFG management and LFGTE project development through the use of the tax structure that encourages innovation and project development. Competitive access to the energy market and consumers is an additional factor particularly for having a successful LFGTE project. Some countries in LAC, such as Argentina, have a very competitive energy market with ongoing privatization. Opportunity for consumers to choose green power, and monetary incentives to purchase this power, add to the financial incentives that can help to make LFGTE projects financially viable.

The Kyoto Protocol established the rationale and target objectives for a global emission reduction strategy. When assessing a potential LFG management project, it is crucial that one is aware of all of the current and pending energy sector and environmental regulations that could potentially affect the viability of the project. Prominent issues in the development of solid waste policy include:

- reduction of wastes;
- maximisation of waste reuse and recycling;
- promotion of healthy environmental waste deposition and treatment; and
- extension of waste services.

The international carbon markets are still developing and evolving. The future value of emission reductions generated by LFG management is speculative. However with the United Nations Framework Convention on Climate Change (UNFCCC) development of the Clean Development Mechanism (CDM) project cycle, there may be ways to obtain value from LFG management projects as an incentive to improve landfill design and operation. As an additional benefit, the development of this market could also supplement LFGTE projects to make them more financially viable.

LFG management projects are part of a sustainable integrated waste management policy and act to reduce the GHG emissions from the landfill. By introducing a financial incentive mechanism into the waste management system, they can aid in improving the overall performance of the system. While an aggressive strategy for LFG recovery and utilization in LAC is warranted, success depends on having good local capacity for urban waste management along with effective national policy frameworks for non-conventional energy and environmental management, and for carbon trading.

LFG management projects are typically expected to operate in excess of twenty years to allow the financial viability of the project. Each project must be analyzed separately to determine the particular circumstances for the potential project site. Expanding and maintaining the well field and piping to collect the gas is an ongoing responsibility that must be clearly defined to protect and secure the revenue streams. An understanding of how the landfill site is built and operated is also necessary to determine the nature, scope and costs for a system to collect the LFG as a fuel resource. This factor is sometimes not given the attention and priority that it deserves. Simply stated, it is necessary to understand how much LFG is likely being generated, but it is just as important to understand the physical conditions in the landfill to assess the ability to efficiently collect the LFG fuel for a long project service life.

The major capital cost element of a candidate LFGTE project is the equipment and facilities to use the LFG as an energy resource. For illustrative purposes, the Handbook will use, as an example, the conversion of LFG into electrical power for sale to the respective power grid.

Using all of the information provided in the Handbook, a project team for a potential project at a candidate site should be equipped with the information and background knowledge to assess the potential of a LFG management project. Any economics assessment undertaken should be based on a full life cycle cost analyses for the candidate site and potential project.

The Handbook provides the information noted above in a format that is intended to provide a user-friendly reference document to assist a site-specific project team that is contemplating developing a candidate LFG management project in LAC. The World Bank and the authors of the Handbook have tried to make this document a broadly based reference tool able to provide some of the background and information needs to assist developers, agencies, governments and others in setting up assessments and developing LFG management projects. The use of this manual is not intended to take the place of, or assume the responsibility for, a site-specific due diligence review and business plan for a candidate project.

1

Introduction to the Handbook

Successful use of this Handbook is dependent upon the provision of an information base in all aspects of the LFG management and utilization systems for solid waste landfills and a strong business/financial understanding of these projects specific to LAC markets. To meet the objectives for the Handbook, it has been organized and presented in three distinct parts, with each part comprised of a number of sections.

Section 1 provides an introduction to the overall format of the Handbook and a brief description of the Sections that comprise Part I, Part II and Part III. It also provides the prospective team with a summary of expected information needed to take the project to the Contract Execution Phase.

1.1 Part I - Understanding the LFG Resource and Potential Applications

Part 1 is comprised of sections that allow the reader to gain a technical understanding of the LFG resource and potential use of the fuel and is organized to provide a basic understanding of both the LFG resource and all of the elements. Part 1 is intended to be broadly applicable to all potential projects within LAC. The extent of the materials discussed will, of necessity, be quite broad and there will be some presumed pre-knowledge for users of the Handbook. Reference materials that provide more detailed background regarding the individual topics presented throughout the Handbook will be identified for those readers that may require additional information regarding specific subject materials. Part 1 of the Handbook comprises the following two Sections:

Section 2: Landfill Gas – Understanding the Resource; and

Section 3: Landfill Gas Utilization Technologies

1.2 Part II - Understanding Pertinent Regulations, Energy Markets and International Carbon Finance

Part II looks at the energy and environmental policies, legislation, regulations and the current energy markets. It also provides an insight into the policies that help mitigate environmental and social problems resulting from existing solid waste management practices and to implement systems that minimize the potential future issues. Legislation for solid waste management has to balance protection and conservation with excessive controls that inhibit economic development. This part also examines the Kyoto Protocol mechanisms for the development of the carbon markets, which could benefit LAC countries. Part II comprises the following Sections:

Section 4: Energy Policies, Legislation, Regulation, and Markets;

Section 5: Environmental Policies, Legislation, and Regulation; and

Section 6: International Carbon Finance.

1.3 Part III - Assessing and Developing LFG to Energy Projects

Following review and assimilation of the materials provided in Part 1 & Part II, it is expected that the reader will have an appreciation of all of the factors and inputs that will need to be considered for developing a project specific feasibility assessment and business case for a LFG management project. The information presented in Parts 1 and II is not intended to be site or country-specific but are focused towards preparing the reader with the pertinent understanding and background to allow a project to be assessed. It is expected that the Handbook will be used by all sectors of the industry and may be used by individual project team members with differing areas of interest and expertise to help identify key questions that must be addressed for every project.

Part III of the Handbook presents the possible approaches and information necessary for assessing LFG management projects at landfill sites and to provide specific guidance for the assessment and development for a specific project in LAC. Pre-investment studies that collectively constitute the feasibility study and market assessment for a prospective project are outlined in detail. After completing the activities and studies as described in the Handbook, the viability of a potential project and its basic business structure can be established, subject to verification of information and assumptions that may have been used for the analysis.

A project that has met the requirements would then proceed to the detailed development phase. Essentially this phase will take the information that has been assembled, and develop it as the basis for contract execution for all of the various agreements that will be necessary to undertake a specific project. Part III comprises of the following sections:

Section 7: Risk Factors Related to Environmental, Financial, and Resource Management Aspects of LFG Management Projects;

Section 8: Pre-investment Studies; and

Section 9: Project Development.

1.4 Expected Outputs

Upon completing the scope of work as outlined in this Handbook, it is expected that a reader will be in a position to be able to:

- understand the characteristics of the resource, specifically culminating in a projection of the LFG quantity/quality generation over time;
- develop an understanding of the jurisdiction's specific energy policies and assess their implications for the project and the market value of applicable energy products;
- develop an understanding of any environmental policies or regulations that may pose constraints to the project;
- undertake a market value assessment and sensitivity analyses for the various options to utilize the LFG from the specific site;
- develop a conceptual design for the LFG capture and destruction or utilization system for the preferred approach for the specific site;
- develop preliminary capital and operating cost estimates to build, operate and maintain the proposed system;
- identify and assess all permits and approvals that may be necessary to construct and operate the proposed facility;
- develop a preliminary project schedule;
- develop a business structure and financial plan to implement the potential project;
- identify all other criteria and constraints that may exist for a specific project; and
- understand the principles of conditional rights to the LFG at the specific site to allow the project to proceed to the next phase.

It is expected that the reader and the organization represented may need to obtain support and expertise in various areas necessary to undertake LFG management, particularly LFGTE projects. However, the Handbook should be an invaluable tool for assisting in identifying areas of support that are needed and framing the scope of services or nature of any partners that may be necessary to assess the viability of a prospective project in LAC.

1.5 Background

The LAC region is highly urbanized with, on average, 75 percent of its 500 million inhabitants living in cities, mainly large cities, thus leading to the concentration of solid waste and corresponding waste management problems. Many LAC cities still dispose of municipal solid waste (MSW) in open dumps, creating problems of leachate contamination of surface and groundwater, and release of LFG to the atmosphere, including significant volumes of methane, a powerful GHG. The more important and prosperous cities in LAC have begun to improve disposal practices and have introduced sanitary landfills. Notwithstanding the trend in LAC toward improved landfills, only a few cities in LAC actively collect LFG and utilize the energy value inherent in the LFG, or are planning to do so (with GEF support), such as in Monterrey, Mexico and Maldonado, Uruguay. In contrast to this limited beneficial use of LFG in LAC, the experience in North America and Europe is that there several hundred LFG plants for energy recovery and utilization purposes or flare their LFG as management, and many more plants coming on-line each year. Thus, there is a significant opportunity to increase LFG recovery and utilization at landfills in LAC region, provided that the appropriate market conditions exist, or can be developed.

Feasible LFG collection and utilization is normally limited to large and deep landfills (for example, over 1 million tonnes of waste in place with a depth of more than 15 meters), however the conditions for each site must be analyzed individually for potential carbon credit sale, energy pricing, tax credits, and other "green" incentives that might be available. For LFGTE projects, it is also necessary that the potential exists to connect the LFG project to an urban power grid or fuel distribution network, or is close to some energy end user (construction of a special purpose gas pipeline is normally limited to 3 km). In the case of LAC, this would limit promising LFGTE applications to the large and intermediate cities. In LAC, there are currently 117 cities of greater than 500,000 population, with a total of 225 million inhabitants and presently generating some 74 million tons per year of solid waste that is deposited in identifiable sites. Assuming that one-half of these cities would meet the above general criteria for feasible LFGTE projects, there is the potential to generate the equivalent of more than 800 MW of electrical power (assuming steady state and 35 percent conversion efficiency).

Of equal, or possibly greater importance, is the potential to achieve annual emission reductions of more than 40,000,000 tonnes of equivalent carbon dioxide (eCO^2) emissions annually. As an international carbon market evolves, the incentive to generate emission reduction credits from LFG capture and use will be high in LAC cities. There would not only be benefits by reducing GHG directly by reducing methane emissions to the atmosphere, and for LFGTE projects also by displacing fossil fuel which would otherwise be utilized for energy purposes. The potential international carbon market in LAC from LFG exploitation could substantively exceed US $100 million a year.

While an aggressive strategy for LFG recovery and utilization in the region is warranted, success will depend on having good local capacity for urban waste management along with effective national policy frameworks for non-conventional energy and environmental management, and for carbon trading.

A series of LFGTE case studies are being provided as Annexes to the Handbook. These independently prepared case studies will be used to help illustrate the concepts, constraints, and methodologies that have been successfully used to develop LFGTE projects around the world.

The development of LFG as a resource relies heavily on the operation and maintenance of the project in order to achieve success. The extraction and destruction or utilization of

LFG requires diligence because of the heterogeneous nature of the waste producing the LFG and the changing characteristics of the LFG over time. Therefore, LFG management projects are somewhat more sensitive than typical infrastructure projects and must be operated and managed carefully. The fuel resource recovery is, in most cases, a secondary activity on a large waste management site. Understanding this factor is critical to the success of a project. It is critical to the success of the LFG management industry that the operations phase of projects and interaction with the waste management activities for each candidate site is considered as crucial to the performance of the systems.

PART 1 – UNDERSTANDING THE LANDFILL GAS RESOURCE AND POTENTIAL APPLICATIONS

2

Landfill Gas – Understanding the Resource

2.1 LFG Generation and Generation Factors

LFG is generated as a result of physical, chemical, and microbial processes occurring within the refuse. Due to the organic nature of most waste, it is the microbial processes that govern the gas generation process (Christensen, 1989). These processes are sensitive to their environment and therefore, there are a number of natural and man-made conditions, which will affect the microbial population and thus, the LFG production rate. Short-term studies done on full-size landfills, using data from LFG extraction tests, indicate a range of LFG production between 0.05 and 0.40 m^3 of LFG per kilogram of waste placed into a landfill (Ham, 1989). The mass of waste accounts for both solid materials (75-80% by mass) and moisture (20-25% by mass). This range is a function of the organic content of the waste that is placed into the landfill. The range in LFG production values may at first glance not appear to be large. However, using the population base in LAC and the fuel value of the LFG, the annual quantity of LFG fuel is equivalent to tens of millions of cubic metres of natural gas each year. Typical pipeline grade natural gas has approximately double the heating value or fuel content of a typical LFG.

Waste composition is the most important factor in assessing the LFG generation potential of a site. The maximum potential volume of LFG is dependent on the quantity and type of organic content within the waste mass (Environment Canada, 1996) since the decomposing organic wastes are the source for all LFG produced. Other factors that influence the rate of LFG production include moisture content; nutrient content; bacterial content; pH level; temperature; and the site-specific design and operations plans. Wastes produced in LAC typically have higher organic content and moisture content than most North American or European waste and therefore would be expected to generate LFG at equivalent or higher rates.

Moisture is the primary limiting factor in the rate of waste decomposition (McBean et al., 1995; Reinhart, 1996). The moisture conditions within the landfill are a function of many factors. Landfills are typically constructed and filled in sequential layered pattern. This factor is important in understanding how moisture moves into and through the waste. The layering effect tends to result in substantially different flow characteristics for the movement of leachate and infiltration water into the landfill. Controlling the moisture content and other factors which influence the microbial population that produces LFG can have a great impact on the percentage of potential total LFG that is produced, and the rate at which it is produced. It is possible to somewhat control the rate of LFG production through engineered waste management systems. Conventional sanitary landfills as practiced in North America in the 1970s and 80s are generally referred to as "dry tombs" because the approach taken in designing them was to minimize water contacting the waste with a view toward minimizing excursions of the resulting leachate into the groundwater. However, this practice also limits the rate of anaerobic activity within the waste. The current trend is towards Landfill Bioreactor Technology (LBT) systems, which augment the amount of water contacting the waste, to rapidly stabilize the wastes. This technique can produce large initial LFG generation rates while decreasing their rate of generation sharply after a few years.

For the purpose of an initial site characterization, LFG production can be simplified as a function of the size and age of the waste volume, waste type, and moisture content. The volume of greenhouse gases released is directly proportional to the LFG-generating potential. It is also relevant to other potential impacts such as odor complaints and hazardous situations. In general, the more gas that is produced, the higher the likelihood that health, safety and odor nuisance issues will be raised, and equally importantly, that for economically feasible LFG utilization to exist.

Figure 2.1 provides a method of characterizing a site based on its LFG production potential. The first step is to determine the tonnage adjustment factor based on waste composition. This correction factor accounts for the proportion of inert wastes in the landfill, which will not produce LFG, and the proportion of industrial/commercial/institutional (ICI) wastes in the landfill that will produce less LFG than typical domestic wastes. The adjustment factor is determined from the triangle diagram shown in Figure 2.1 based on the proportion of waste types that are in place or

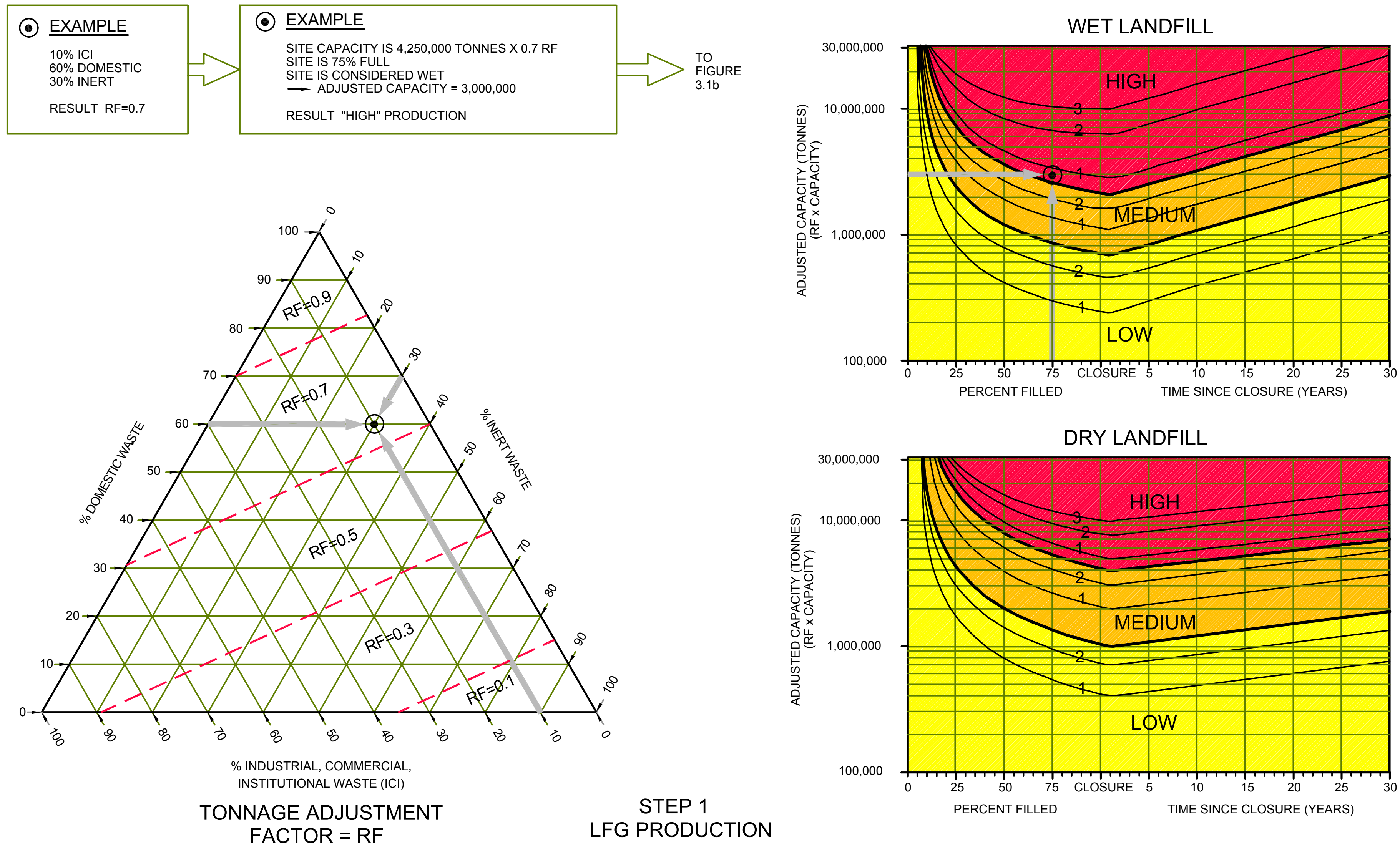


figure 2.1

PRELIMINARY SITE LFG CHARACTERIZATION
HANDBOOK FOR THE PREPARATION OF
LANDFILL GAS TO ENERGY PROJECTS
The World Bank

NOTE

A LANDFILL SITE IS CONSIDERED 'WET' UNLESS IT IS EQUIPPED WITH A LOW PERMEABLE COVER OR IT IS IN AN AREA WHICH RECEIVES LESS THAN 635mm OF PRECIPITATION ANNUALLY.

SOURCE: CONESTOGA-ROVERS & ASSOCIATES LIMITED

19399-10(006)GN-WA007 OCT 16/2003

will be accepted at the landfill. The landfill capacity is multiplied by the tonnage adjustment factor to determine the adjusted site capacity.

The landfill is then classified as dry or wet. A dry landfill will decompose more slowly than a wet landfill and hence the LFG production rate will be lower, and the production time will be longer. Some of the factors that influence the moisture content of a landfill include precipitation and temperature at the site, type of landfill cover, condition of cover (i.e., slope, integrity), type of leachate collection system, and type of landfill base or natural liner. The classification of the site as dry or wet is mainly a function of the amount of precipitation that infiltrates into the waste mass. A conservative approach to classifying a site as wet or dry based on the average annual rainfall. A landfill where a significant portion of the waste is located within a groundwater/leachate mound should also be considered a wet site. For general discussion within this Handbook, sites located in areas with: less than 500 mm/year will be classified as relatively dry sites; more than 500 but less than 1000 mm/year as relatively wet sites; and sites located in areas with more than 1000 mm/year as wet sites. Most LAC landfills are considered to be relatively wet or wet sites. Further discussion regarding the importance of this aspect of LAC sites will be provided with the modeling discussions and the applicable parameter assignments.

The adjusted site capacity is located on the left axis of the wet or dry landfill chart. This addresses the effect that the size of the site (small, medium, large) has on gas production. The current status of site filling is located on the bottom axis. This is defined as the percentage that the site is filled or the number of years since closure of the site. This addresses the age of the site.

LFG production is determined by the intersection of the adjusted site capacity and the current filling status. LFG production is categorized as "high", "medium" or "low". Each category is delineated by numbers, which indicate an increasing level of severity within the category. The maximum LFG production typically occurs within two years of site closure if the site has had a fairly uniform annual filling schedule. It is important to consider future LFG production potential in assessing and planning the need for LFG controls. Figure 2.1 demonstrates that a site's LFG production increases as it is filled, and then slowly declines after site closure.

Other issues related to the production of LFG, which are of concern, include the LFG subsurface migration hazard and the impact of LFG on air quality.

The primary factors that influence the distance gas migrates from the wastes into adjacent soils are the permeability of the soil adjacent to the landfill and the type of ground surface cover around the landfill. Generally, the greater the permeability of the soil adjacent to the landfill, the greater the possible migration distance. The water content of the soil has an important effect on its permeability with respect to LFG flow. As the water content increases, the effective soil or waste transmissivity to gas flow decreases. In addition, the type of ground surface cover affects the venting of LFG that can escape to the atmosphere. Frozen or paved ground surfaces limit venting of gas to the atmosphere and hence increase the potential migration distance. A landfill liner can greatly reduce the potential for subsurface migration. The presence of heterogeneous soils around the site or sewers and other buried utility service will increase the potential migration distance along those corridors. LFG can migrate a significant distance from the landfill in sewers or sewer bedding. When evaluating the potential for subsurface migration from a site these factors should be considered.

The primary determinants of air quality impacts are the quantity of LFG emitted to the atmosphere, the concentration of trace gas compounds in the LFG, the proximity of the receptor to the site and meteorological conditions.

2.2 The Scholl-Canyon Model

Mathematical models are a useful and economical tool for estimating the LFG generation potential at the site. The results of the model can be used to assess the potential for hazardous LFG emissions/migration, and for assessing the feasibility of the LFG management project.

There are numerous models available to calculate LFG production. All of these models can be used to develop an LFG generation curve that predicts the gas generation over time. The total gas yield and rate at which the gases are generated can vary somewhat with the different models but the most important input parameter that is common to all models is the quantity of decomposable waste that is assumed. The other input parameters can vary depending on the model used, and are influenced by a number of variables including those factors influencing LFG generation, uncertainties in the available information for the site, and how the management of LFG extraction affects LFG generation by inducing any air infiltration. Another important factor is the assumed lag time between the placement of waste and the beginning of the anaerobic decomposition or methanogenic phase within the waste mass. (Augenstein, 1991.)

The heterogeneous and time-variable nature of all landfills lends an inherent difficulty with collecting accurate data from a site without a large ongoing cost outlay. Any model output is only as good as the input data and often there are very broad assumptions necessary with respect to estimating waste quantities and types. Therefore, it is appropriate to use a simple model, which employs fewer parameters that can be more reasonably assigned according to specific site conditions. The predictive success of any model is dependent mostly on the degree of accuracy needed, the reliability of the input data, the experience of the individual analyzing the data, and the degree of similarity between the subject site and other sites which have been successfully modeled. (Zison, 1990.)

All models used for determining the estimated LFG production rate of the site should be subject to a thorough sensitivity analysis to determine a range of potential outcomes and analyze which parameters have the greatest influence on LFG production values. Identification of sensitive parameters can lead to directed data collection and future improvement in LFG production predictions. Given the heterogeneous nature of the conditions within the landfill and the typical limitations in the input data that is most often available for a candidate site, it is recommended that a range of values and a sensitivity assessment be established for the LFG generation assessment. Using the upper and lower bounds of a LFG generation versus time profile based on the likely conditions within the landfill, it is possible to assign values and design inputs that are suitable for use in assessing the potential for a site and any risk factors that may be applicable.

First-order kinetic models are frequently used to estimate the production of methane over the life of a landfill. These models are tailored to specific landfills by a number of assumptions about conditions at the site. The empirical, first-order decay model most widely accepted and used by industry and regulatory agencies, including the U.S. EPA, is the relatively simple and straightforward Scholl Canyon Model. This model is based on the assumption that there is a constant fraction of biodegradable material in the landfill per unit of time. The first-order equation is given below:

$Q_{CH4i} = k * L_o * m_i * e^{-kt}$ [1]

Q_{CH4i} = methane produced in year i from the ith section of waste

k = methane generation constant

L_o = methane generation potential

m_i = waste mass disposed of in year i

t_i = years after closure

It is typical practice to assume that the LFG generated consists of fifty percent methane and fifty percent carbon dioxide so that the total LFG produced is equal to twice the quantity of methane calculated from Equation [1].

Equation [1] is the basis for the U.S. EPA's LFG Emissions Model (LandGEM), which is available from the United States Environmental Protection Agency (U.S. EPA) website (http://www.epa.gov/ttn/atw/landfill/landflpg.html). The Scholl Canyon Model predicts LFG production over time as a function of the LFG generation constant (k), the methane generation potential (L_0), and the historic waste filling records and future waste projections at a site. The U.S. EPA assigns default values for each of these parameters for a conservative preliminary site assessment. However, these input parameters must be selected with knowledge of the specific site conditions and geographic location. In LAC, differences in the organic content of the waste, the presence of moisture, or the level to which the waste is compacted will vary and in most cases increase the potential for LFG generation from that typically found in the North America and Europe. This model has been selected for use in this Handbook not because it is the only available model, or even the best model available. However, the Scholl Canyon Model: is adequate for the purpose intended; is the most commonly employed and accepted model in North and South America; and has the best available data base for sites in LAC. The Scholl Canyon Model is also simple to understand and apply, and is generally accepted by those financing agencies and institutions that are interested in supporting these types of projects in North America and LAC.

BOX 1: IMPORTANCE OF LFG GENERATION MODELING & ASSESSMENT OF FUEL RESOURCE POTENTIAL

There are 2 major aspects to the LFG assessment. Firstly it must be estimated how much LFG there is being produced at a landfill. Secondly, but much more important, it is necessary to assess what proportion of the LFG can reasonably and reliably be collected over the long life of a project (>20 years).

For example, the Brazilian case study encompasses two sites, the old Marambaia open dump and the new Adrianopolis Landfill. The Marambaia site ceased excepting waste in January 2003 and has a total of approximately 2 million tonnes of waste in place. The Adrianopolis site began operations in February 2003 and is expected to close in 2022. The following picture provides and aerial view of the existing and new landfill disposal areas.

Modeling was undertaken at both sites to evaluate the volume of LFG that each site is expected to generate using the Scholl Canyon Model. The waste disposal volumes were based on historical data for the Marambaia site and projected values for the Adrianopolis site. The results of the modeling indicate that it is possible to collect LFG at the Marambaia site, but as would be expected the LFG generation is presently at its peak and starting into a progressive decline. The Adrianopolis has just opened, and although it has good long-term potential for recovery, it is not yet generating significant quantities of LFG to collect and utilize. These and all of the other case studies consistently reinforce the benefits of early identification and commitment to the development of LFG control systems. If you wait until a site closes to decide to develop the resource, it may be too late. It should also be noted that it may be possible to coordinate the use and transfer of equipment and systems between 2 sites under the control of the same owner. As the LFG in one of the sites is progressively declining and the other increasing, it may be possible to coordinate the use and transfer of some of the resources and facilities, assuming that the contractual arrangements for the LFG control allows this type of coordination.

Figure 2.2 illustrates the LFG generation curve produced using the Scholl Canyon Model with the U.S. EPA default values (k=0.05, Lo=170 m^3 of methane per tonne of waste) for a landfill site with a constant fill rate of 500,000 tonnes per year for 25 years (from 1990 to 2015). Figure 2.2 will be used throughout this Handbook as an illustrative example for the various principles, spreadsheet models and other information that is being provided to assist the reader in understanding and applying the principles being outlined. The graph shows two curves, the theoretical total amount of LFG produced and the LFG collected assuming a typical collection system efficiency of 75 percent. A LFG generation assessment that assumes 75 percent of the fuel can be collected is not unreasonable but would be considered relatively aggressive. A recovery percentage of 50 percent of the fuel is considered conservative and readily achievable, assuming that both the waste characterization and modeling exercise are based on reasonable data and assumptions.

The methane generation rate constant (k) represents the first-order biodegradation rate at which methane is generated following waste placement. This constant is influenced by moisture content, the availability of nutrients, pH, and temperature. As mentioned previously, the moisture content within a landfill is one of the most important parameters affecting the gas generation rate. Moisture serves as a medium for transporting nutrients and bacteria. The moisture content within a landfill is influenced primarily by the infiltration of precipitation through the landfill cover. Other factors that affect the moisture content in the waste and the rate of gas generation include the initial moisture content of the waste; the amount and type of daily cover used at the site; the permeability and time of placement of final cover; the type of base liner; the leachate collection system; and the depth of waste in the site. Typical k values range from 0.02 for dry sites to 0.07 for wet sites. The default value used by the U.S. EPA for sites with greater than 25 inches (625 mm) of precipitation per year is 0.05 (U.S. EPA, 1994). This value is considered to produce a reasonable estimate of methane generation in certain geographic

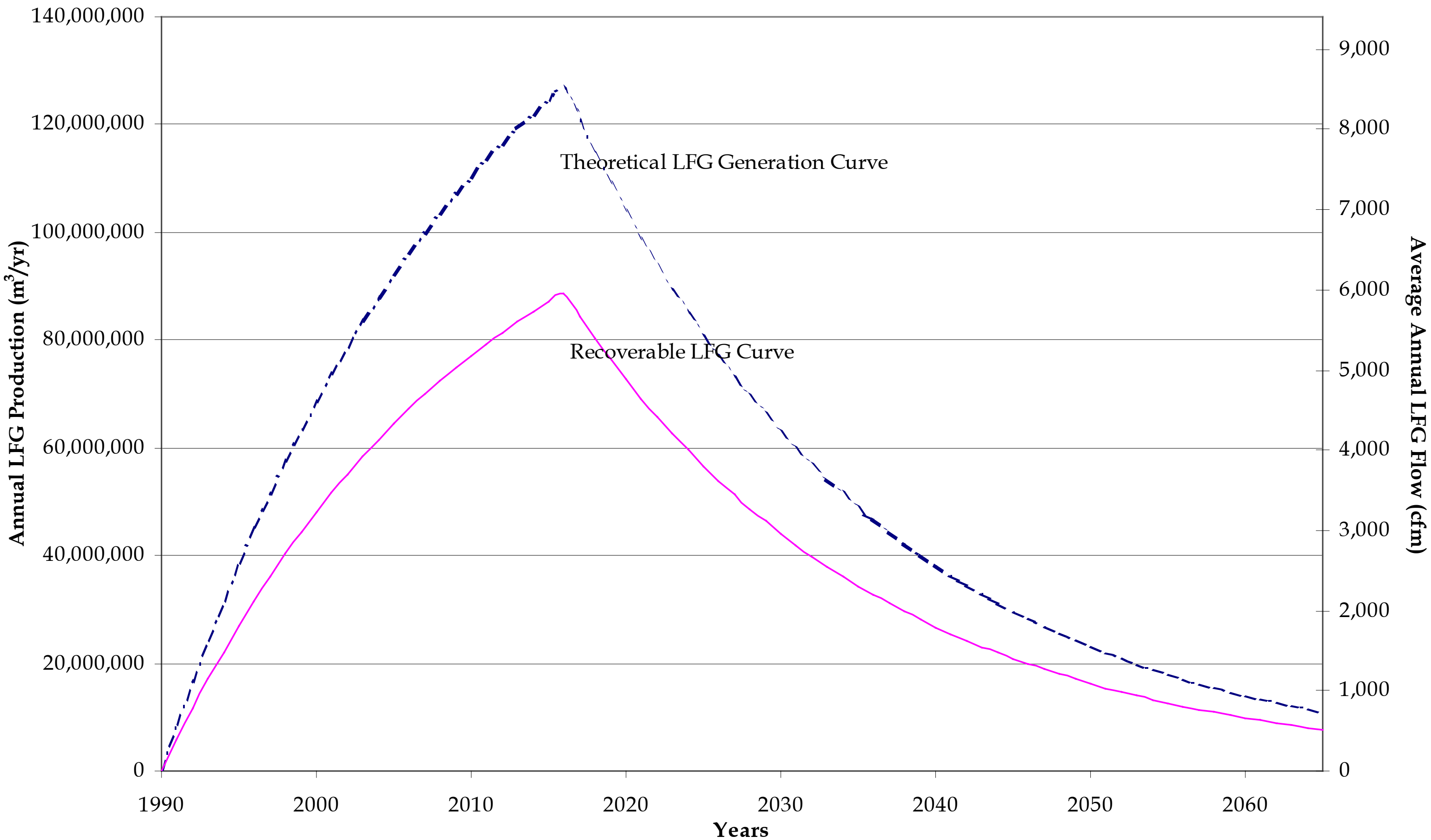


figure 2.2

EXAMPLE LFG GENERATION CURVES
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

regions and under certain site conditions. The following table presents suggested ranges and recommended parameter assignment for the rate constant.

Suggested k Value Ranges for Corresponding Annual Precipitation

Annual Precipitation	*Range of k Values*		
	Relatively Inert	*Moderately Decomposable*	*Highly Decomposable*
<250 mm	0.01	0.02	0.03
>250 to <500 mm	0.01	0.03	0.05
>500 to <1000 mm	0.02	0.05	0.08
>1000 mm	0.02	0.06	0.09

The methane generation potential (L_o) represents the total yield of methane (m^3 of methane per tonne of waste). The L_o value is dependent on the composition of the waste, and in particular, the fraction of organic matter present. The L_o value is estimated based on the carbon content of the waste, the biodegradable carbon fraction, and a stoichiometric conversion factor. Typical values for this parameter range from 125 m^3 of methane/tonne of waste to 310 m^3 of methane/tonne of waste. Increased compaction of the waste has no direct effect on the L_o parameter. However, compaction and density of waste do have a direct bearing on the mass of waste in a given volume, and therefore on the potential LFG quantity that can be produced over time, as well as the performance characteristics of the systems that will be necessary to collect the LFG.

There has also been a perception that as recycling and composting programs increase and improve, more organic material, such as food waste and paper, may be diverted from the landfill reducing the quantity of LFG produced. However, recycling initiatives have had more success to date at removing inorganic materials from the waste stream, in both developed and developing countries. As a consequence, typical practice has not seen the applicable L_o value decreased significantly. The U.S. EPA uses a default L_o value of 170 m^3 of methane/tonne of waste. (U.S. EPA, 1994). The model user may increase or decrease the L_o to reflect specific knowledge of the waste characterization with either higher or lower organic waste contents. The amount (in tonnes) of typical waste landfilled in a particular year is represented by "m" in the Scholl Canyon Model equation. In landfills where there are good data indicating that there is a significant portion of the waste that is inert (will not decompose) such as construction and demolition debris, this parameter could be reduced to represent only the amount of waste that is not inert. However, in many cases there is insufficient data to determine the percentage of the waste that is inert.

It is only recommended that the L_o parameter be reduced or the quantity of contributing waste be decreased if there is clear and concise data quantifying the inert or relatively inert waste stream. As noted earlier, the L_o parameter already is well reduced from the theoretical value that would reflect pure organic waste in recognition of the fact that there is moisture and inorganic materials that comprise some portion of any waste stream. A specific reduction should only be made if there is a readily discernible portion of the waste that is different from the typical waste received at most conventional mixed solid waste landfills. The default assignment of L_o already recognizes that there is a mixture of decomposable organic wastes and inorganic wastes being deposited in a typical fill site. If there is good data regarding waste quantities and types, it may be possible to refine the modeling assessment using the following as guideline parameter assignments for the Lo factor. It would be necessary to make the overall LFG generation assessment a sum of the curves generated for the various types of waste.

Suggested Lo Values by Organic Waste Content

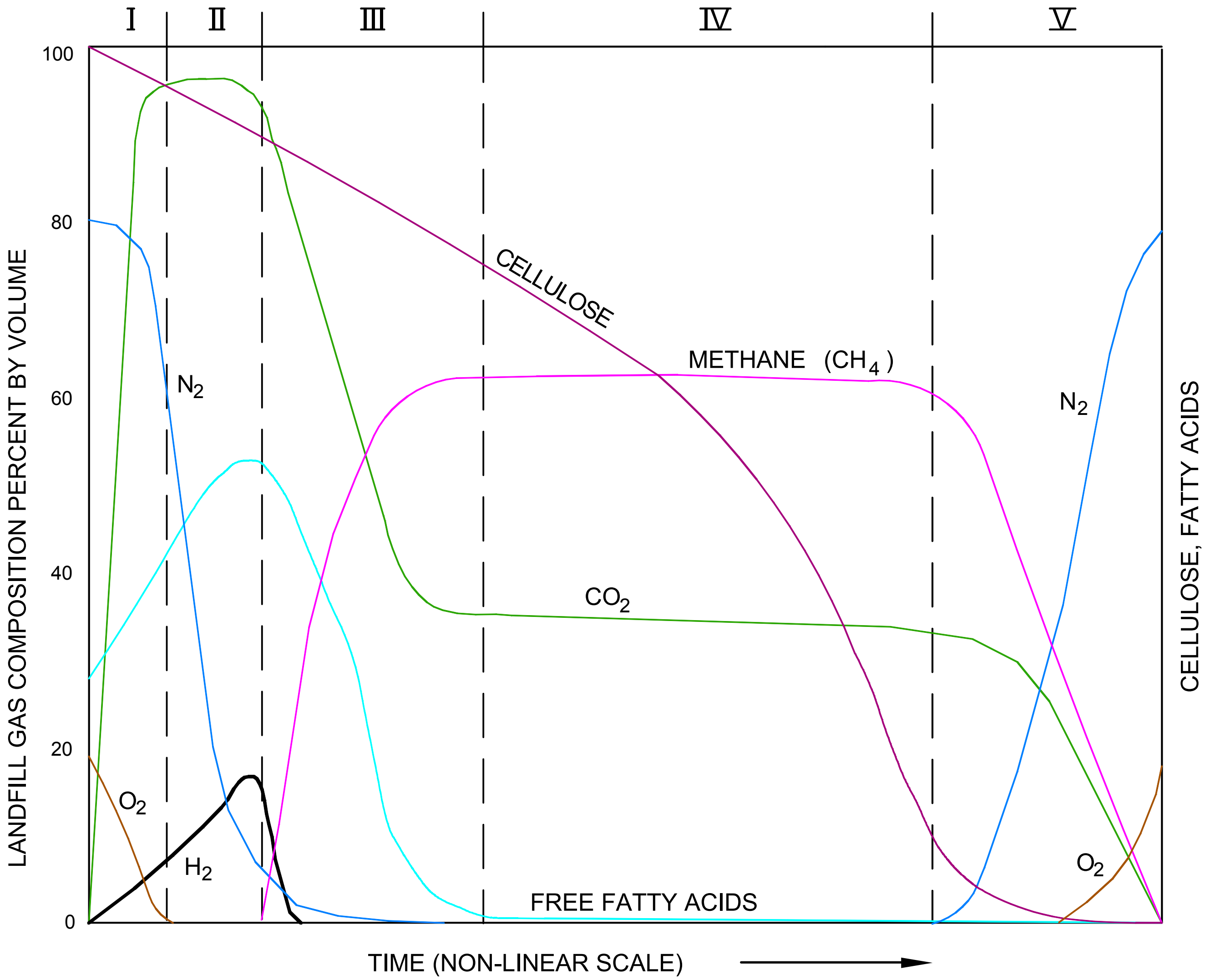
Waste Categorization	***Minimum Lo Value***	***Maximum Lo Value***
Relatively Inert Waste	5	25
Moderately Decomposable Waste	140	200
Highly Decomposable Waste	225	300

2.3 LFG Composition

The quality of the LFG depends on the microbial system, the substrate (waste) being decomposed, and site-specific variables such as oxygen access to the waste and moisture content (Ham, 1989). LFG is typically described as consisting of approximately 50 percent methane and 50 percent carbon dioxide with less than 1 percent other trace gas constituents, including hydrogen sulfide (H_2S) and mercaptans.

There are four LFG production phases that occur throughout the life of a landfill. Farquhar and Rovers predicted generation of gas in a landfill for typical municipal solid waste (MSW) in the 1970s. A graph of the LFG generation phases is shown as Figure 2.3. The duration of each of these phases is dependent on a number of factors including the type of waste, moisture content, nutrient content, bacterial content, and pH level. Some general guidelines regarding the length of the decomposition cycle for the various categories of waste are provided in the following table. Note that this is a general guideline only. The extreme heterogeneity of the waste in a typical landfill site, together with the environment in a specific landfill has a significant bearing on this factor such that it can not be simply provided on a generic basis.

LANDFILL GAS PRODUCTION PATTERN
PHASES



PHASES	CONDITION	TIME FRAME - TYPICAL
I	AEROBIC	HOURS TO 1 WEEK
II	ANOXIC	1 TO 6 MONTHS
III	ANAEROBIC, METHANOGENIC, UNSTEADY	3 MONTHS TO 3 YEARS
IV	ANAEROBIC, METHANOGENIC, STEADY	8 TO 40 YEARS
V	ANAEROBIC, METHANOGENIC, DECLINING	1 TO 40+ YEARS
TOTAL		10 TO 80+ YEARS

SOURCE:

FARQUHAR AND ROVERS, 1973,
AS MODIFIED BY REES, 1980,
AND AUGENSTEIN & PACEY, 1991.

figure 2.3

TYPICAL LFG PRODUCTION STAGES
HANDBOOK FOR THE PREPARATION OF
LANDFILL GAS TO ENERGY PROJECTS
The World Bank

Half-Lives of Biodegradation Byproducts

Waste Category	Minimum Half-Life	Maximum Half-Life
Rapidly Decomposable (food & garden wastes etc.)	½ year	1 ½ year
Moderately Decomposable (paper etc.)	5 years	25 years
Poorly Decomposable (some portions of construction & demolition wastes etc.)	10 years	50 years

The first phase, aerobic decomposition, occurs immediately after the waste has been placed, while oxygen is present within the refuse. Aerobic decomposition produces carbon dioxide, water, and heat. The next stage is the anoxic, non-methanogenic phase where acidic compounds and hydrogen gas are formed and while there is continued carbon dioxide production. The third phase is the unsteady methanogenic phase. During this phase, the carbon dioxide production begins to decline because waste decomposition moves from aerobic decomposition to anaerobic decomposition. Anaerobic decomposition produces heat and water, but unlike aerobic decomposition, it also produces methane. During the fourth phase methane is generated at between 40 and 70 percent of total volume (McBean, 1995). Typically, the waste in most landfill sites will reach the stable methanogenic phase within less than 2 years after the waste has been placed. Depending on the depth of the waste lifts, and the moisture content of the waste, the methanogenic phase might be reached as early as six months after placement. LFG may be produced at a site for a number of decades with emissions continuing at declining levels for up to 100 years from the date of placement. This can be seen in Figure 2.2, which will be used for discussion purposes in the Handbook as a typical representation of a moderately sized site in LAC.

2.4 Potential LFG Impacts

The emission rate at which the release of LFG becomes an issue with regulatory authorities and neighboring property owners is related to a number of physical parameters including: the location of the landfill; the surrounding topography; adjacent land uses; ambient meteorological conditions; and the site characteristics that impact LFG generation and collection (Mosher, 1996).

It is generally the trace constituents, hydrogen sulfide (H_2S) and mercaptans, which are the primary compounds that are associated with nuisance odor emissions from landfills. These compounds typically constitute less than 1 percent of LFG, but odors are compound-specific and can be detected for specific chemical concentrations of as little as

0.001 to 0.005 parts per million (ppm). The level at which these chemicals might be of harm to human-health varies, but is typically orders of magnitude greater than those referenced. This means that the detection of odor is not necessarily an indication of a health concern but it can be a real nuisance and an adverse condition with regard to the quality of life in the area of the landfill.

Odor resulting from the release of LFG operates on a threshold principle. Thus, if the amount of LFG exceeds the threshold level for the particular conditions at the landfill, there will be odor related to the production of LFG. The following analogy can be used to better understand the concept of an odor threshold. Let the volume of a cup represent the total amount of LFG that can be released before reaching the odor threshold. The size of this "cup" for each landfill is determined by a number of factors, including the landfill location, surrounding topography and ambient meteorological conditions. Let water poured into the cup represent the release of untreated LFG. The cup can be "full to the brim" and still not spill any liquid. However, if the capacity of the cup is exceeded, by even one drop, it will overflow and liquid will spill out. Therefore, the amount of water in the cup can vary up to the capacity of the cup, so long as that threshold volume is not exceeded. This concept is analogous for LFG odor emissions. To ensure that nuisance odor is not a concern, the amount of LFG released would need to be lower than the odor threshold of the landfill site, for the given meteorological and other conditions. Therefore, in the situation where LFG odor is a major concern, it is less important how much LFG is collected in comparison with how much LFG is released from the landfill (Mosher, 1996), and whether or not that amount of LFG released exceeds the site's threshold. This issue is somewhat complicated by the fact that the threshold limit is not a fixed number. It varies depending upon time sensitive meteorological conditions and separating distance between the landfill and odor receptors (e.g., residents).

The most important component of LFG from most perspectives is methane, which constitutes approximately 50 percent of the LFG volume produced. Methane is a potential hazard since it is combustible and explosive at concentrations between 5 and 15 percent in air. LFG can migrate below ground surface in the unsaturated soil zones, especially during winter and spring months when the ground is frozen or saturated with moisture at surface. LFG can then accumulate in enclosed structures causing a potential hazard. Methane has no odor and, is therefore, impossible to detect without proper instrumentation.

Methane released from landfills has also been identified as a significant contributor to greenhouse gas (GHG) emissions, which contribute to global warming. Over a 100-year time horizon, in comparison with carbon dioxide, methane is considered to be 21 times more efficient at trapping heat within the atmosphere (IPCC, 1995). This value is currently under review and could potentially be revised upwards in the future, further increasing the incentive for LFG management projects. Methane generated from solid waste and wastewater, through anaerobic decomposition, represents about 20 percent of human-induced methane emissions (IPCC, 1999). LFG emissions to the atmosphere can be reduced through traditional waste reduction measures, such as recycling and composting. Emissions can also be reduced by capturing and flaring the LFG at a high temperature, converting the methane fraction of the gas into less harmful carbon dioxide and water vapor.

2.5 Potential LFG Benefits

Although there are several negative issues that can arise from the presence of LFG, there are also a number of benefits associated with the proper management of LFG, and its potential for use as an energy source. LFG management projects that collect and flare the LFG have the potential to generate revenue through the sale and transfer of emission reduction credits, which provide an incentive and means to improve the design and operation of the landfill and to develop a better overall waste management system.

LFG is approximately 50 percent methane, and can be considered a low/medium grade fuel. This resource can be harnessed in a number of applications including direct fuel use for heating, electrical generation, and commercial chemical byproducts. In addition to mitigating LFG migration and odor concerns, LFG utilization can also generate revenues from the sale of "green power" and other LFG products that can defray the costs of landfill operation and maintenance and provide incentive to improve landfill design and operation.

Emission reductions represent the global and national objectives for improving global air quality. Emission Credits (GHG Credits) and Green Power energy premiums are two of the key mechanisms that are being proposed to help to achieve the goal of "Emission Reductions". The sale of these credits can be used to improve the economics of a potential project. There is differing terminology used to refer to the emission reductions such as ERs, CERs and GHG credits. These terms refer essentially to the same item, which is best defined as the quantity of emission reductions converted and presented in the common unit of equivalent tonnes of carbon dioxide emission reductions. For the balance of the Handbook, the term CER will be used and the unit of definition will always be equivalent tonnes of carbon dioxide. The CER designation assumes that the emission reductions have been certified to meet a specific set of standards and requirements. There may be other certifying agencies or bodies that may use different acronyms but the principles and underlying basis for recognition and quantification will remain the same.

Before any LFG management project is undertaken, the LFG emissions and resulting CERs must be carefully assessed and the potential markets explored. This is discussed in much more detail in later sections.

2.6 LFG Collection System

There are extensive reference materials and information with respect to the successful means and methods to collect and flare LFG that are generally beyond the scope of this Handbook. However, a basic understanding of the nature and operation of the LFG collection systems is necessary to understand the fundamental elements of a LFG management project and risk factors inherent in the management of the LFG resource. To appreciate the interconnection and interdependence issues, a brief outline of the elements of a collection system is being provided. A typical LFG collection system is comprised of the following components:

- LFG collection field (wells and trenches);
- Collection piping (laterals, subheaders, headers, etc.);
- Condensate drop-out and disposal system;
- Blower system and related appurtenances; and
- LFG flare.

LFG management can be achieved through the use of these components and there is potential, through the development of the international carbon market, for this type of system to generate revenue through the creation of GHG emission reduction credits. Revenue provided by such a system creates an incentive for better landfill design and management, and a contribution towards improvement of the overall waste management system.

Appendix A provides a number of figures illustrating various components of a typical LFG collection and flaring system for review and reference.

LFG Collection Field

A network of vertical LFG extraction wells and/or horizontal LFG collection trenches are installed into the waste to collect the LFG. The basic operating principle is quite simple, apply a vacuum to extract the gases from the waste mass as closely matched to the rate at which the gas is being generated within the influence area of the well or trench as is practical. The idealized target objective is to establish a neutral pressure/vacuum gradient continuously over the entire surface of the landfill. It is important to recognize that the ideal condition cannot be achieved at reasonable cost and therefore, it is important to balance the cost-benefit of installing additional wells in a tighter grid of wells together with a complementary cap system versus the value inherent in the fuel recovery.

The cost increase to extract LFG up to approximately 75 percent of the actual LFG being generated is considered relatively linear in nature. However, to achieve very high recovery efficiencies, it may be necessary to employ a very tight grid of extraction wells/trenches and/or a synthetic cover system, which would result in major capital cost increases relative to the gain in LFG recovery. Figure 2.4 illustrates the relationship between the efficiency of the LFG collection system and the relative cost.

Vertical wells are typically installed in a landfill once filling operations have been completed. Figure 2.5 shows the construction of a typical vertical LFG extraction well. Figure 2.6 shows the construction of a typical horizontal LFG extraction trench. Using vertical LFG extraction wells has the following advantages:

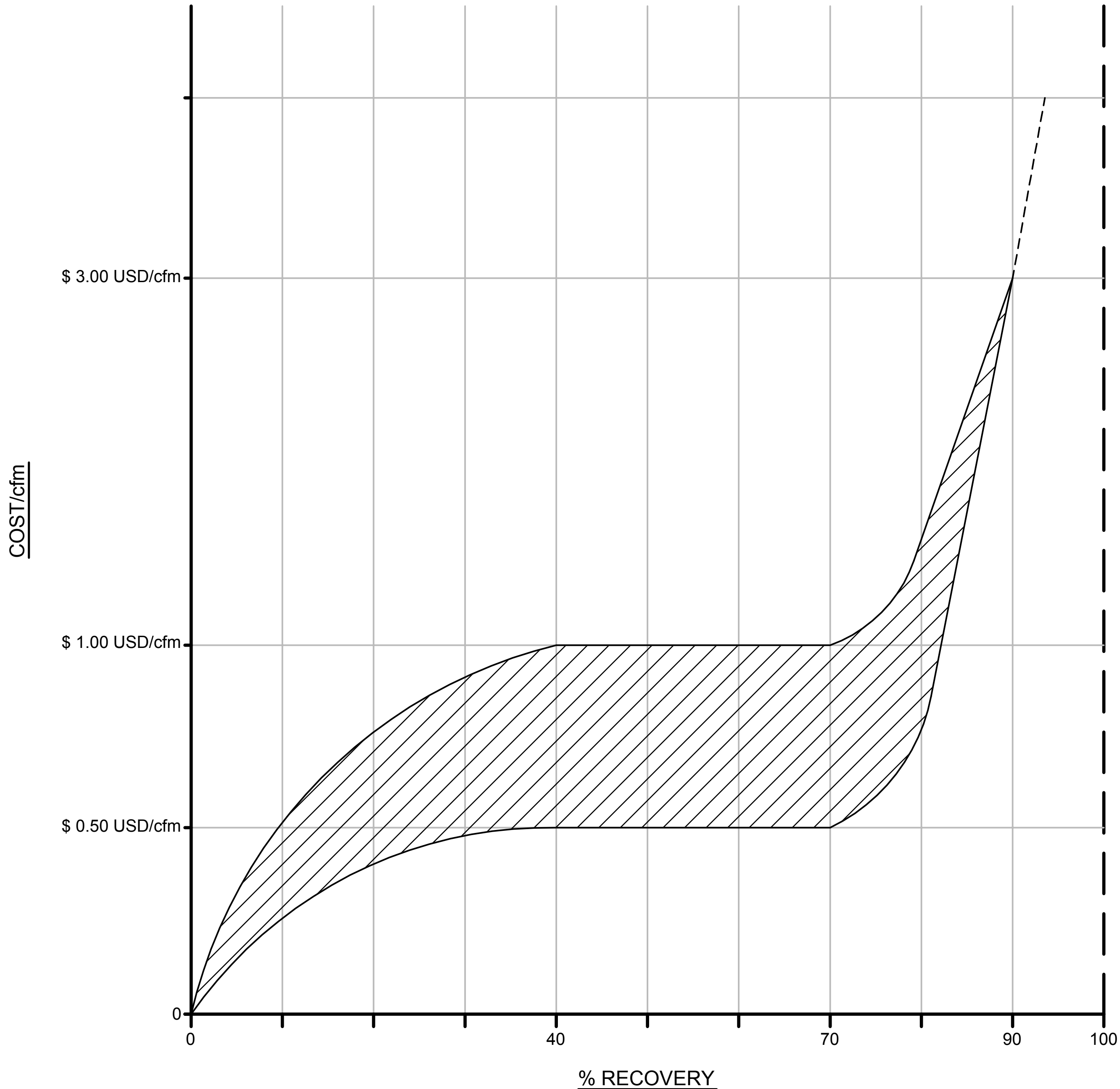


figure 2.4

COST VERSUS RECOVERY EFFICIENCY
HANDBOOK FOR THE PREPARATION OF
LANDFILL GAS TO ENERGY PROJECT
The World Bank

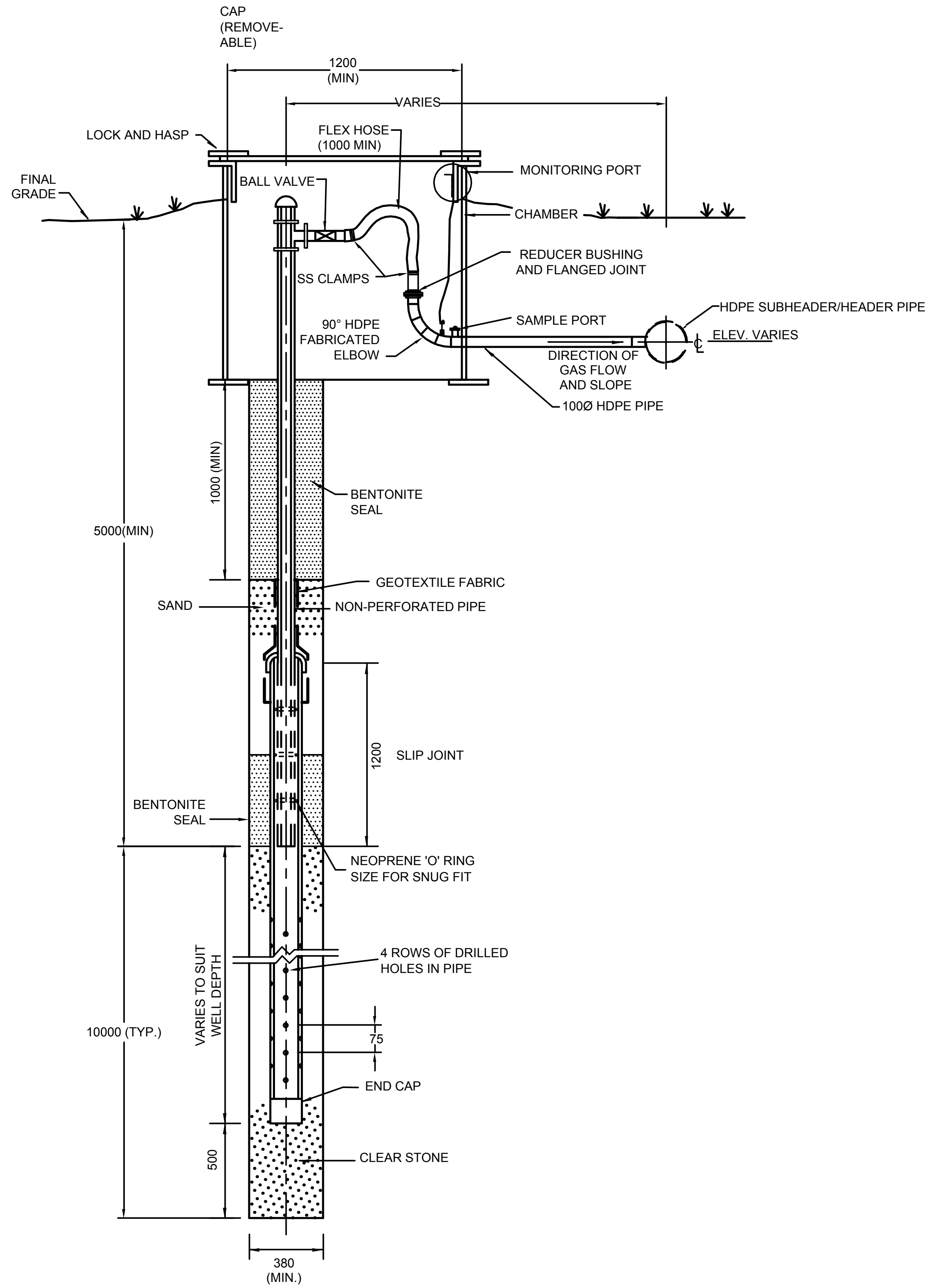
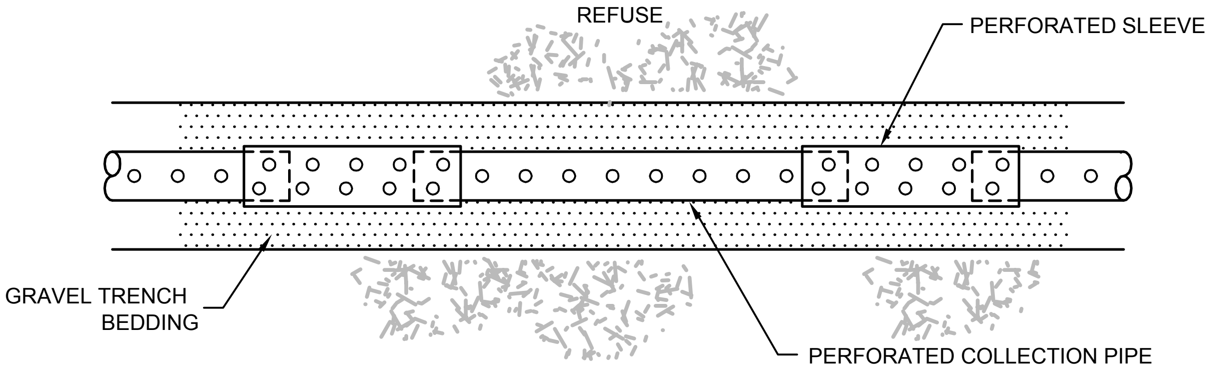


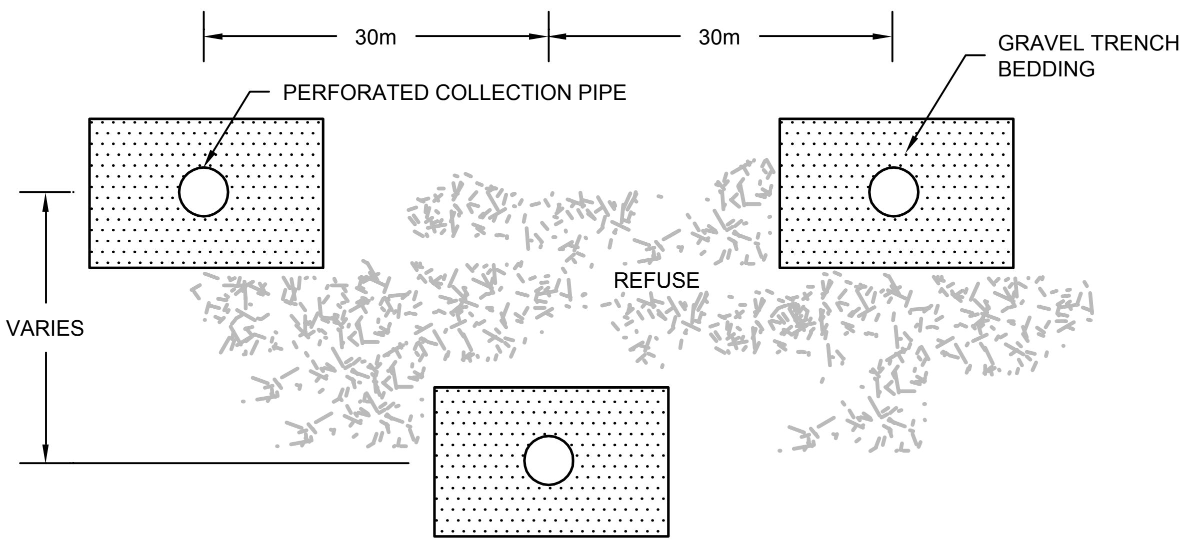
figure 2.5

TYPICAL DETAIL OF A VERTICAL LFG EXTRACTION WELL
HANDBOOK FOR THE PREPARATION OF
LANDFILL GAS TO ENERGY PROJECTS
The World Bank

19399-10(006)GN-WA009 DEC 19/2003



TYPICAL HORIZONTAL COLLECTION TRENCH
PROFILE VIEW



TYPICAL HORIZONTAL COLLECTION TRENCH
CROSS-SECTION

NOT TO SCALE

figure 2.6

TYPICAL DETAIL OF A HORIZONTAL LFG COLLECTION TRENCH
HANDBOOK FOR THE PREPARATION OF
LANDFILL GAS TO ENERGY PROJECTS
The World Bank

- improved areal control of gas emissions;
- well field may be expanded to reflect the changing landfill site conditions; and,
- condensate collection may be minimized.

To maximize collection efficiency, wells should be sited in consideration of the waste depth, age and the physical geometry of the site. If there is a concern regarding subsurface migration of LFG, wells placed close to the outer limits of the waste should be grouped closer together to act as a migration control system.

Some of the general rules for the installation of vertical extraction wells are:

- minimum of 3 to 6 m of landfill depth to be maintained above the extraction well perforations to minimize air entering the LFG collection system;
- the depth from surface to perforations should be increased near side slopes; and
- the ability to install wells along the steeper (4:1) side slopes is limited with conventional drilling equipment.

These conditions may not be absolutely identical at every landfill site, however they serve as a good guideline to ensure proper function of the LFG collection system and minimize the intrusion of air into the flare or LFGTE plant.

Horizontal LFG collection trenches are typically used to collect gas while the site is still active. Following the placement and compaction of a lift of waste, perforated collection pipes are installed and then covered with another layer of waste. This allows for LFG to be collected from waste directly below an area where active filling is taking place. While this technique can control LFG emissions in active areas of the site, horizontal collection trenches are not generally suitable for localized gas control.

In general, the operating principles for vertical wells and horizontal trenches are the same. Both types of collectors should be equipped with telescoping sections of non-perforated pipe to allow for refuse settlement, which occurs over time. It has been found that 10 to 15 inches of water column vacuum at the wellhead or trench represents a reasonable compromise between maximizing zones of influence and minimizing air intrusion into the refuse, while using economical LFG extraction equipment. The radius of the zone of influence with this vacuum ranges from less than 20 m to more 100 m, depending on the waste's heterogeneity and other related characteristics.

The LFG collection system should be used in concert with good leachate management practices. Leachate mounding within the refuse can dramatically impact the rate of LFG recovery because liquid in the extraction wells and collection trenches effectively restricts their ability to collect and convey LFG. In extremely damp sites, the effective LFG fuel recovery may drop to less that 50 percent of the estimated quantity of LFG that may be available.

The costs to install vertical wells can vary dramatically as a function of: local costs for materials such as aggregate, pipe and grout; contractor availability; available equipment types and capacities; and the specific characteristics of the well design. For example the unit cost to install a well to a 30 metre depth in a typical waste mass is higher than for a depth of only 20 metres. Similarly replacement/repair cycles for LFG wells can vary substantively based on the site specific conditions and design. Some typical ranges for LFG installations are as follows:

General Ranges in Vertical Well Costs

Description	Low Range	High Range	Comments
	(US$/vertical metre)	(US$/vertical metre)	
100 to 150 mm diameter wells (<15 metres depth)	$150	$250	
100 to 150 mm diameter wells (>15 metres but less than 30 metres in length	$200	$350	
900 mm diameter wells (any depth)	>$500		These wells are not recommended as cost effective. Refusal to the advancement of a borehole in waste is not an uncommon event that can result in large increases to the cost of deep wells.

LFG Collection Piping

A network of piping is constructed to connect the LFG collection field to the LFG flare or LFGTE plant. A typical LFG collection system includes the following:

- small diameter (minimum 100 mm), short laterals connecting the wells/trenches;
- subheaders which connect the laterals; and
- headers connecting the subheaders to the extraction plant.

There are a several LFG network piping patterns designed to facilitate drainage of liquids and to minimize the length of pipe required for the collection system. Two of the most common layouts are the herringbone and the ring header. The herringbone arrangement has a single main header with subheaders and headers branching from it. This is the most efficient use of piping, and it can be designed to minimize the quantity of condensate, which accumulates in the LFG collection system, by sloping the majority of piping towards the LFG wells.

An on-site ring header may be used when there is no land available for construction of a header system outside the limit of waste. Off-site ring headers reduce some of the problems associated with placement of piping into the refuse. Ring headers should be equipped with valves to allow isolation of portions of the site, and monitoring ports to monitor gas quality and quantity. Dual header systems have been utilized at some large and deep landfill sites that have a long active site life to segregate the methane-rich gas from the deeper portions of the site from the gas collected from near the surface that may be diluted via air intrusion. There are numerous design criteria/constraints related to the piping installations to specify such as minimum and maximum slopes; condensate moisture removal; differential and total settlement stresses; and dead and live load stresses.

The relative costs of the piping systems to collect and transport the LFG to the facility can vary substantively based on site specific conditions and the applicable design basis. For example, above grade piping systems are the least expensive to construct and are often used for temporary systems or for short term repairs but also have successfully been used for full-scale long-term systems. There are advantages and disadvantages to both above and below ground approaches to the installation of the connecting piping systems. The costs for small diameter above grade piping can be less than $30/metre but larger diameter buried piping can cost up to, and more than, $200/metre. The cost is highly influenced by factors such as:

- the nature of the design (e.g., above or below grade);
- the need to remove and relocate any waste;
- the need to add fill or grade areas of the cap and perimeter areas;
- the extent and number of condensate removal traps;
- the cost of petroleum and associated products; and
- the availability and costs for suitable construction contractors.

The specific characteristics of a landfill site will have many direct implications for the design options and related costs of the piping systems. As such, it is highly recommended that these costs be reviewed carefully on a project specific basis. It is also important to note that high density polyethylene (HDPE) piping is highly recommended for most of the LFG piping and its price is largely controlled by the relative cost of petroleum and the proximity to suitable pipe manufacturing facilities.

Blower System and Related Appurtenances

The blower system includes all components that are used to generate and apply the vacuum to collect the LFG and supply it for its subsequent end use. A blower system should be centrally located with sufficient space for expansion, close to the end user (power grid or end user pipelines). The blower system may be enclosed in a building or it may be pad mounted as an exterior installation.

The blower system components include:

- valves and controls as required for safe operation (e.g., a flame arrestor);
- condensate pumping or storage;
- LFG flow metering and recording; and
- blowers or compressors to meet capacity requirements.

The blower system should have the capacity to handle 100 percent of the peak rate of LFG production estimated, plus some allowance for migration control. Some level of backup redundancy is typically recommended for all blower systems that are providing fuel to a revenue-generating LFG utilization system. Depending upon the size and age of a site, a phased approach to LFG control plant construction is often beneficial if gradual increases in LFG production are anticipated.

The costs of the blower systems are a function of many factors and can only be assigned based on the specific requirements for the overall system. Some of the major factors affecting the blower selection are:

- LFG flow range proposed to be collected;
- Piping system design and head loss criteria;
- Available well head vacuum;
- Length of the piping system; and
- Pressure demand for any flare or utilization system being supplied with LFG.

As a simple guideline, the cost for a blower system for a flaring application can range from $25,000 to $50,000 per 1000 m^3/hour of LFG. If the final application is a utilization facility, the cost range for the blower system can increase by a factor from 2 to 5, or more, depending upon the fuel supply requirements.

Condensate drop-out system

LFG is extremely moist and therefore produces a lot of condensate within the LFG collection wells and piping. It is important that all the pipes are designed with minimum slopes so that condensate does not remain within the piping, but flows towards a nearby drain or sump. Improper drainage of the condensate can lead to blockages in the pipe, which can disable large parts of the LFG collection system limiting the amount of LFG that can be collected.

A sump and/or moisture separator may remove condensate. At a minimum, a sump should be constructed in the piping system to drain condensate and to prevent flooding of pipelines. Moisture separators remove droplets of liquid from the flowing LFG therefore reducing the detrimental effects that the corrosive condensate may have on the LFG handling equipment.

BOX 2: IMPORTANCE OF CONDENSATE MANAGEMENT TO LFG COLLECTION SYSTEM PERFORMANCE

One of the most common operational problems for LFG collection systems is liquid blockage in the piping or wells, which has the potential to cripple the operation of the system. Blockage of the laterals or subheaders usually results from a build up of condensate. Condensate removal systems should be installed to collect and remove LFG condensate from the piping systems. The blockage problems caused by inadequately sized piping or piping designed with an inadequate slope, can effectively terminate LFG collection from the affected section of the landfill. Another reason for condensate build-up is the uneven or differential settlement of the waste, which can cause a dip or low point in the piping systems that can then fill with condensate. It is for this reason that LFG collection systems should be designed with a great deal of excess capacity and specific consideration in the design for identifying and addressing settlement issues.

A demonstration of the potentially catastrophic consequences that ineffective condensate management can have is the Kemerburgaz LFGTE project in Turkey. During the startup and commissioning phase, it was found initially that two thirds of the LFG extraction wells had no suction pressure, which meant that there was not enough LFG to supply the engines that were being commissioned. Thankfully, this condition was remedied after a week when it was discovered that a section of pipe had been installed such that condensate was collecting and blocking the pipe, preventing LFG extraction from a significant portion of the site.

The LFGTE project in Krakow, Poland has experienced difficulties with the flooding of their horizontal LFG collection trenches because of leachate mounding within the waste mass. In the future, they are planning to use only vertical LFG extraction wells to combat this problem. The LFGTE project in Olsztyn, Poland has experienced such high leachate levels that all the perforations in the vertical LFG extraction wells are blocked and the wells have been rendered dysfunctional.

At the Waterloo Landfill in Canada, the quantity of LFG recovered has not increased to correspond with the quantity of wells that are presently in-place. Conditions at this site serve to reinforce the importance of understanding the landfill and its operation as well as the physical conditions within the landfill. The Site was found to be very wet, hampering the ability to obtain the gas that is being generated in some portions of the Site. Systems to address the presence of condensate and trace gas impurities in the LFG can requires scrubbers and other treatment systems similar to the equipment shown in the attached picture of a portion of the gas treatment room at the Waterloo Landfill Site.

The importance and benefits associated with effective condensate management to both the short and long-term performance of the LFG management systems can not be overstated. This is a critical item to the success of all LFG management projects that is not always given the consideration that is warranted.

Once separated from LFG, condensate must be disposed of in an environmentally sound manner. Condensate is generally more concentrated than leachate and may be considered a hazardous liquid waste in some jurisdictions.

<u>LFG flare</u>

The LFG collected from a site must be disposed of in an environmentally sound manner such as an enclosed drum flare and/or utilization system. A LFG flare can be used as a backup to the utilization system in case of lengthy downtimes for both scheduled and unscheduled equipment operating and maintenance events. The need for a backup flare and equipment redundancy is optional depending upon the overall systems reliability and the sensitivity to short term loss of LFG extraction and control capability. High temperature flaring of LFG results in conversion of methane components of the LFG to carbon dioxide and water. As well, this high temperature combustion ensures that the trace compounds in LFG are largely destroyed. Most LFG utilization systems provide for destruction efficiencies equal to or better than those achieved in the enclosed drum flares.

As with most of the other system components, the cost of flaring systems is a function of the overall design of the LFG management system and the performance requirements that are expected for the flare. There are 2 basic flare designs; the enclosed drum flare discussed above; and a waste gas flare that simply ignites the methane without any extensive combustion controls. This second type of flare is in common use in many jurisdictions but has not been the focus of this Handbook, primarily because its use is not deemed acceptable if there is any intent to qualify for CERs.

To give a simple cost guideline, a waste gas flare capable of combusting 1000 m^3/hour of LFG would cost in the range between $50,000 and $100,000 depending upon the peripheral controls and safety features required. For relative comparison, an enclosed drum flare with a similar capacity with have a cost range about twice that of the waste gas flare. Some components such as the refractory and control systems can vary substantively in price depending upon the performance requirements.

2.7 Operation of LFG Collection System

Active LFG collection and utilization are highly effective for mitigation of on-site and off-site LFG impacts as well as reduction of GHG emissions to the atmosphere. The LFG capture potential is highly dependent on site design related factors, such as:

- Site configuration (depth of waste, landfill area, depth of water table);
- liner system design;
- cover system design;
- moisture addition/leachate recirculation; and
- operational constraints.

Site configuration has a great impact on the LFG collection potential for a site. Sites that are filled above the natural grade tend to have larger surface areas, therefore increasing the chances of LFG emissions. Sites filled below grade have a greater tendency for off-site LFG migration through the surrounding soils.

A low permeability soil or synthetic liner system combined with a leachate collection system is beneficial in controlling both LFG migration and mounding of leachate within the refuse. The primary purpose for a low permeability liner is to mitigate potential groundwater impacts by allowing leachate recovery from the bottom of the refuse, but it is also recommended for the control of LFG migration.

The permeability of the final cover system is an important factor in LFG management and system performance. Low permeability covers minimize LFG venting to the atmosphere, air intrusion into the waste, as well as moisture infiltration. A low permeability cover can help to improve the performance and areas of influence for vertical extraction wells. However, if the cover system is very tight and allows very little infiltration, it can retard or slow down the rate of decomposition in the upper portion of the landfill that many not be at the optimal moisture content to encourage decomposition. These two competing factors should be considered in the LFG generation assessment.

Moisture addition/rapid waste stabilization is the current trend in LFG recovery, otherwise referred to as landfill bioreactor technology (LBT) systems. This process increases the amount of water contacting the waste, to rapidly stabilize the wastes, significantly increasing the initial quantities of LFG produced with sharply decreased generation rate following waste placement. This increased initial LFG production rate could be beneficial for some LFG utilization projects as it could supply larger, more efficient plants. This approach could shorten the payback period for the project, adversely affecting its financial viability unless a series of cells were developed and operating in sequence were utilized. This rapid stabilization could also potentially increase LFG migration and emissions, and therefore it is best applied at sites with adequate LFG collection capacity as well as a liner and final cover as design elements.

Rapid stabilization must be critically assessed during the conceptual and preliminary site design stages. At a minimum, the following issues have to be considered:

- increased LFG production rates over a shorter timeframe;
- increased LFG collection and handling capacity;
- greater destruction (flaring and/or utilization) capacity requirements;
- increased landfill settlement;
- higher moisture content of the gas, leading to higher condensate volumes;
- leachate mounding within the site;
- leachate collection system capacity; and
- effect on leachate character.

Daily operations have an important influence on the LFG recovery potential. Using permeable daily cover, such as sand, will result in higher rates of moisture infiltration, therefore leading to higher moisture content of the waste and increased rate of LFG production. The filling sequence and method of waste greatly affects the type of collection field selected. Horizontal LFG collection trenches are best used at sites with relatively shallow lifts over large areas. For sites using low permeability daily cover, the layering/stratification of a site is magnified. This may create perched water conditions, which can increase LFG collection costs as well LFG production rates in some areas of the site.

Some special consideration needs to be made for issues associated with condensate collection, removal and disposal from the piping systems and wells installed in the site and also condensate collected and removed in the LFG utilization facility. It is also critical to understand the implications of settlement and differential settlement of the waste. The average amount of settlement at a landfill depends primarily on the specific design and operating characteristics of the site. The total settlement that can be expected from a landfill site can range from 20 to 40 percent of the total depth of the waste following initial placement and compaction. In simple terms, a 30 metre deep landfill could experience total settlement from 6 to 12 metres by the time the process is completed. The rate of settlement is at its peak when the site is still actively receiving waste. Both the load related settlement and decomposition related settlement are typically at their peak during the active site life. More important than total settlement is differential settlement. Settlement in localized areas can be much greater and much more rapid than the average depending on the material landfilled, the amount of compaction it receives, and other factors such as air intrusion or the infiltration of surface water. Features such as vertical gas wells can be localized problem areas if not taken into account during both the design phase and as a key consideration of the operations and maintenance phase of any project.

2.8 Best Management Practices for Operations of LFG Projects to Maximize Energy Recovery Potential

Optimizing LFG collection is directly related to maximizing LFG utilization potential, realizing economic benefits from the sale of LFG energy and reducing GHG emissions. It must always be understood that the landfill operation itself is the primary purpose of the site activities and all other systems or supporting activities, whether beneficial or not, must remain subservient to this activity. One problem area that has been noted throughout the history of the LFG management projects is that improper operation of a LFG collection system to support a utilization system can pose risks of landfill fires and fuel quantity reduction that are both dangerous and counterproductive for both of the systems. Understanding the links and interactions between these two systems is important to developing and sustaining a viable project through the entire term of a 20-year or longer contract term, which can be critical for a LFGTE plant.

LFG COLLECTION FIELD

A well designed, constructed and operated LFG recovery system can collect 75 percent or more of the LFG produced at a site. It is important for a collection system to be designed and operated to match the site's changing LFG generation potential without over or under drawing on the collection field. In addition to the changing LFG generation rate over the life of the landfill, the effective LFG generation rate also varies somewhat over the short term as a function of factors such as; meteorological conditions; differential settlement; equipment efficiencies; and cover system conditions. The collection field must be adjusted to match the changing effective generation rate. The LFG collection field must be periodically monitored and adjusted to optimize the effectiveness of the collection system. The adjustment of valve settings to reduce or increase LFG flows from low or high production areas of the landfill is required to maximize LFG collection without overdrawing from those areas of the site that may be susceptible to air intrusion. One principle that is often misunderstood or ignored, even by those working in the LFG industry, is that the operating basis for an individual well or trench must be based solely on LFG quality at that individual well or trench. Operating a well or trench on the basis of target recovery rates or expected performance yields is counter-productive.

Air intrusion into the landfill must be minimized since it has a negative impact on the natural decomposition of waste. Within a few months following placement, the waste-in-place has typically reached a stable phase of anaerobic (oxygen-free) decomposition. At this point, introducing oxygen will return this environment into aerobic conditions, with the result of: reducing methane generation and an associated decline in potential fuel recovery; increased localized rates of differential settlement; higher subsurface temperatures in the waste; and potentially increased odor problems. This condition may also lead to landfill fires and increases the potential for spreading any fires that are started.

Field monitoring at each of the collection points (wellheads/trenches) should include:

- vacuum;
- differential pressure;
- temperature;
- LFG composition (methane and O_2 content); and
- valve position

Monitoring of each collection point should start with vacuum/pressure measurement to avoid interference with the action of extraction for the LFG sample. The essential monitoring data to collect is the vacuum, LFG composition and valve position. The following indicates readings under ideal operating conditions to maximize energy recovery at each collection point:

- Vacuum maximum 20 inches WC;
- methane 45 to 55 percent by volume;
- O_2 less than 2 percent by volume.

Table 2.1 presents a simple diagnosis tool to highlight some common problems in the operation of the LFG collection and utilization facilities and their probable solutions.

Table 2.1 – Common LFG Collection System and Fuel Recovery Issues

Diagnosis	*Potential results*	*Recommended solution*
$O_2 > 2$ percent v/v	• Diluting LFG fuel therefore reducing energy recovery • Increased rates of differential settlement • High subsurface temperatures • Odor problems • Landfill fires	• Adjust valves and rebalance based on gas quality • Check well head for indications of differential settlement stresses
$CH_4 < 45$ percent v/v	• Same as above	• Adjust valves and rebalance based on gas quality • Check well head for indications of differential settlement stresses
$CH_4 > 55$ percent v/v	• Increased energy content per unit LFG recovered • Odor problems • Vegetation stress • Increased emissions and migration	• Adjust valves and rebalance based on gas quality • If gas quality and quantity are indicative of additional gas in area, add wells to system
Vacuum > 20 " WC with high relative flow rates	• Potential air intrusion • Increased rates of differential settlement • Landfill fires • Odor problems	• Adjust valves and rebalance based on gas quality • If gas quality and quantity are indicative of additional gas in area, add wells to system
Vacuum < 10 " WC with low relative flow rates	• Blockage/breakage of extraction piping • Condensate issues • Odor problems • Vegetation stress Increased emissions migration	• Check well head for indications of differential settlement stresses • Identify and address for blocked piping

As part of the regular monitoring program the well head valves should be adjusted to maximize effectiveness. This adjustment must be made based upon review of historic performance data and within the context of the overall field operation. For instance any great variation of vacuum readings from historical monitoring may indicate defects with the LFG collection piping, such as break or flooding of pipe runs due to excessive settlement. For this reason all the data collected must be looked at as a whole.

At a closed landfill site the LFG generation potential is decreasing with time, therefore some areas of the site may require reduced LFG collection to match this decreased generation. At active landfills LFG generation potential increases until a few years past closure. Therefore, LFG collection system design at active sites must allow for progressive expansion to accommodate the increasing LFG generation.

LFG COLLECTION PLANT

Proper operation and regular maintenance of the LFG collection plant (including condensate drop-out(s), blower(s), flare and associated equipment) enhances collection system efficiency and maximizes equipment life.

Regular inspection should be undertaken at the LFG collection plant to record the gas flow, flare temperature, combustible and oxygen concentrations of LFG, bearing temperatures, motor run times and any other critical parameters. Only personnel familiar with the operation of the LFG collection system should carry out correction of irregularities or adjustment to the system operation.

Minor maintenance procedures, such as greasing bearings, changing belts, and calibrating detectors may be carried out on a monthly cycle. Major system shutdown and equipment overhaul should be undertaken annually as per equipment manufacturer's recommendations.

SYSTEM INTERCONNECTION AND INTERFERENCE ISSUES

Active LFG collection must tie in with other active systems on a site, such as active landfilling operations, leachate collection, base liner and final cover systems. The overall site design must take into considerations all systems in a progressive manner to ensure interconnection of systems and potential progressive site expansion. Some of the interconnection/interference issues with active LFG collection include:

- Connecting the LFG collection system to the leachate collection system. The quantity and quality of LFG that may be collected from the leachate system can be significant. A valve must be installed at the connection point to allow adjustment of flow and pressure applied onto the leachate collection system. The risk of this connection is that if excessive vacuum is applied oxygen may be pulled into both the LFG and leachate collection systems. Oxygen intrusion into both of these systems can be both a safety and operational hazard.

- Ongoing landfilling operations may result in air intrusion into the LFG collection system as well as the landfill itself. At active landfills, care must be taken to protect/cover the LFG collection pipes with adequate waste/interim cover prior to activation to minimize air intrusion. Excessive air intrusion will dilute the LFG collected, reducing its energy content, may cause landfill fires. At open sites another risk is heavy equipment damaging exposed or shallow buried piping.

- Progressive expansion of LFG collection field is beneficial in increasing LFG collection capacity but may interfere with existing liner and final cover systems. Following LFG collection field expansion (installation of wells/trenches and associated laterals) any interruption to the final cover must be replaced to its original condition.

Generally, it is always important to remember that a LFG management system is a supplementary operation to the core business of landfilling on the candidate site. This factor must always be considered when looking at installing and operating LFG collection systems in areas of a site that are still receiving waste and cover materials.

3

Landfill Gas Utilization Technologies

All LFG utilization facilities require a LFG collection system, which is optimized to maximize the recovery of the LFG without causing air intrusion. The collection and flaring of LFG is by itself an effective means of LFG management by reducing odor and migration problems. In addition, flaring LFG in an enclosed drum flare effectively converts the methane in LFG to carbon dioxide, effectively reducing its GHG potential. The implications of this fact, in concert with the development of an international carbon market are discussed further in Section 6. Flaring the LFG does not, however, recover any of the energy from the LFG. This section discusses a number of technologies available to recover some of the energy from the LFG and potentially provide a supplementary source of income to the landfill through the sale of LFG related products.

An effective collection system, associated with a LFG utilization facility, would also protect against odor and other emissions, but as a byproduct of the fuel recovery rather than as the primary objective. In an effectively designed and operated LFG collection system, these two sets of objectives can be made fully compatible.

However, LFG is a wet gas with variable concentrations for a number of trace gases, which must be considered in the design of a LFG utilization system. The high moisture content of LFG guarantees the presence of moisture in the collection system, which may cause problems related to condensate removal/interference with the ability to collect the LFG through the piping system. In addition, some of the trace gases present in combination with moisture may cause corrosion of the equipment. Other operational restrictions such as health hazards such as the danger of explosion from the presence of LFG in confined spaces prevent the use of LFG for household domestic use. The release of contaminants to the atmosphere through air emissions also requires consideration when selecting what type of utilization facility to develop. Depending upon the application, the raw LFG may require some level of gas processing prior to being utilized in order to reduce these concerns.

LFG can be classified into three categories, based on the level of pretreatment/processing prior to utilization. These are:

Low-grade LFG fuel - Utilization of LFG as a low-grade fuel typically requires minimal processing, involving condensate removal chamber(s) as part of the LFG collection system and moisture knockout pots to reduce the amount of moisture in the gas stream.

Medium-grade fuel - Additional gas treatment devices are used to extract more moisture (with contaminants) and finer particulate matter. The process typically involves compression and refrigeration of LFG and/or chemical treatment or scrubbing to remove additional moisture and trace gas compounds such as mercaptans, sulfur compounds, siloxanes, and volatile organic compounds.

High-grade fuel - Utilization of LFG as a high-grade fuel involves extensive gas pretreatment to separate the carbon dioxide and other major constituent gases from the methane and to remove impurities including mercaptans, sulfur compounds, hydrogen sulfide and volatile organic compounds, and gas compression to dehydrate the gas.

Low- and medium-grade fuel produced from LFG has a heating value of approximately 16.8 MJ/m3. This heat value is roughly one-half the heating value of natural gas. LFG that has been further processed and treated to produce high-grade fuel has a higher heating value (37.3 MJ/m3) than low and medium grade fuel, and can be substituted directly for natural gas in pipeline applications (CRA, 1996).

Figure 3.1 provides a visual tool to aid in understanding the following discussion on the various applications for the three grades of fuel that can be produced from raw LFG. It also illustrates the increasing degree of processing that is required to transform the LFG from a low-grade fuel into a more refined fuel source.

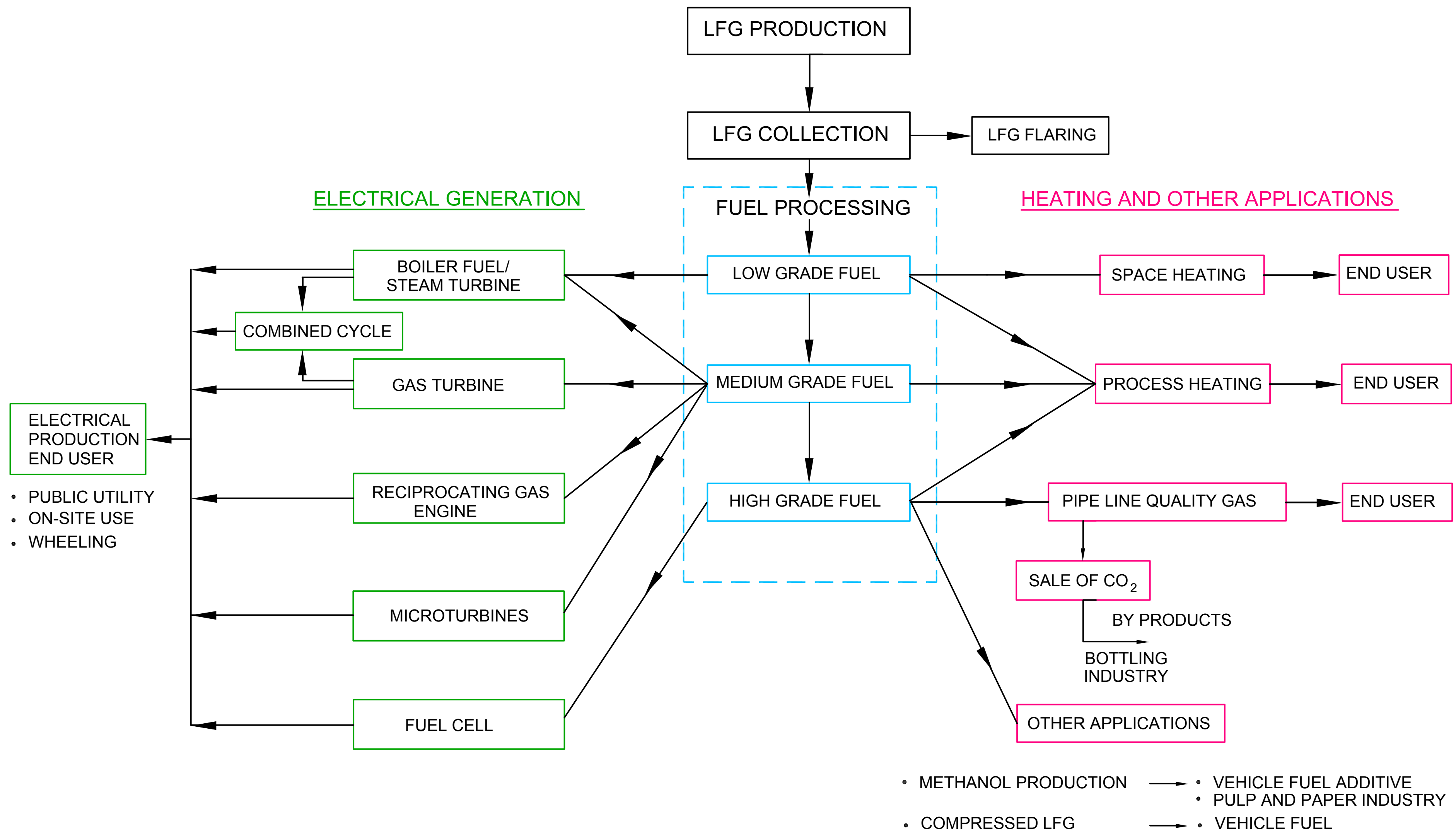


figure 3.1

LFG UTILIZATION OPTIONS
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

19399-10(006)GN-WA008 OCT 16/2003

3.1 Low-Grade Fuel Applications

Heating

LFG can be used with minimal treatment to fuel an on-site or off-site furnace, drying kiln, or boiler. Due to the relatively low heating value, such equipment must be designed to operate on the LFG fuel. The end user must have a constant and adequate demand for the fuel and be within close proximity to the site. The gas is typically transported to a neighboring facility through a dedicated pipeline. It is necessary to design the supply pipeline to avoid condensate accumulation within the pipeline resulting in possible blockage. Raw LFG can also be used for small pilot or demonstration projects, such as heating an on-site greenhouse.

Although direct use of the LFG makes intuitive sense, it is necessary for a suitable user to already exist in close proximity to the site. A "suitable user" means an application that has a base load user profile, which demonstrates an adequate and continuous year round fuel demand exceeding the supply available at the site. It also requires the use of equipment that combusts the fuel with suitable retention time and temperature to ensure adequate destruction efficiency of the numerous trace gas components in the LFG. Criteria for determining the feasibility and suitability of this type of project are further discussed later in this section.

The costs to develop and implement a low grade heating application are minimal if a suitable application exists in close proximity to the site. There will be some costs for the piping to deliver the LFG fuel to the desired location. This cost is a function of the quantity of fuel to be delivered and the distances involved. One practical problem with transmission of low grade fuel is the need for supplementary moisture removal to ensure that there are no fuel transmission issues with condensate dropout and pipe blockage. The fuel delivery requirements may entail some limited gas processing or possibly an upgrade to the supply pressure for the heating systems. There may also be retrofit costs for the fuel gas train to supply LFG to the system. It is typically recommended that any heating system using LFG also be fed with another fuel supply for any periods when the LFG may, for any reason, be unavailable.

Boiler / Steam Turbine

Low-grade LFG can also be used as a fuel for boilers to produce steam for heating or electricity generation. This utilization method requires minimal treatment because the potentially damaging LFG does not contact any moving parts because the gases are contained within the boiler tubes, which are more robust.

The steam produced by the boiler could be used for space heating, process heating, or electricity via a steam turbine. However, steam turbine technology requires additional equipment such as condensers, cooling towers, makeup water treatment, and boiler feed pumps. This technology has the potential for application at very large landfills with potential for electrical generating capacity of more than 10 MW. (CRA, 1996)

As with the discussion for other heating applications noted above, the use of LFG as the fuel supply for a boiler/steam turbine system requires minimal additional preparation except for the fuel supply system to the units and any burner system modifications necessary to use the lower heat content fuel.

Microturbines

Microturbines can use low grade LFG gas with a heating capacity of as little as 350 Btu/scfm. They can typically provide up to 75 kW of electrical power and 85 kW of heat for combined heat and power applications. Microturbine systems contain a compressor, recuperator, combustor, turbine, and permanent magnet generator, but require a very small footprint for operation (Capstone, 2002). The smaller capacity of these units makes them most suitable at older, smaller or remote sites with low LFG production rates (Environment Canada, 2002).

To date, microturbines have not proven the most cost effective option for the larger sized of LFG projects that are generally considered applicable for LAC and the Caribbean. They are adaptable to small installations and may become much more applicable for remote and small applications if the value of electrical power or CERs continues to increase to revenue values that are applicable in Europe. One exception to this may be specific applications in the Caribbean where costs for electrical power are already approaching those seen in Europe. At net revenue values of more than $0.08/kWh, small scale microturbine or reciprocating engine projects may become viable.

3.2 Medium-Grade Fuel Applications

Heating

Medium-grade fuel has a broader range of fuel applications than low-grade fuel because of the reduction in corrosive constituents. It may be used in industrial boilers, dryers, kilns, or gas furnaces. Costs incurred as a result of processing the gas may by offset by a reduction in operation and maintenance costs, and an increased life in the heating equipment. As with low-grade fuel, it is necessary to have a nearby market to which the heat produced can be sold.

As a project moves into the fuel upgrade category, the supplementary costs that must be balanced in the economic assessment are as follows:

- Condensers and chillers;
- Scrubbers and filters;
- Reheating systems;
- Enhanced blower/compressor systems to compensate for head losses; and
- All associated piping, valves, instrumentation and controls.

The costs for these systems will vary as a function of the delivery conditions specified for the LFG. A gas processing system can range in value from $100,000 to $200,000, or more, per 1000 m^3/hour of LFG. As systems increase in size there may be some economies of scale that could be expected. One of the most important cost items associated with gas processing is not the capital cost implications but rather the operating and maintenance cost components. The gas processing systems can be one of the most labor intensive sub-systems of a LFGTE facility and the costs of increased parasitic power and other disposables must be factored into the economics assessment in the feasibility studies on a site and project specific basis.

Reciprocating Gas Engines

Reciprocating engines that use medium grade LFG as a fuel are readily available and may be obtained as modular units or within a complete parallel generator package. They are available in various sizes with electrical outputs ranging from less than 0.5 MW to more than 3.0 MW per unit. They have a comparatively low capital cost per kW and a higher efficiency than most gas turbines and the modular nature of reciprocating engine systems provides flexibility for incremental expansion that may be required due to the uncertain nature of future LFG production. These units can be added in smaller incremental stages than gas turbines. The disadvantages of this technology include higher maintenance costs than for gas turbines and a requirement for skilled maintenance personnel. Exhaust gases may contain some products of incomplete combustion and there is a high lubricating-oil consumption, which includes need for provision of disposal of the waste oil.

Most of the reciprocating engines that have been adapted for LFG applications and proven in use at numerous sites are manufactured in the United States and in Europe. The basic costs of these equipment items are generally well known and well defined. The capital cost of these engine-generator sets is in the range between $600,000 and $800,000 per MW of generating capacity depending upon the size of the facility and the specific engine(s) that is selected for the application. Be careful using these costs because they typically only represent between 40 to 60% of the total facility cost to generate the electrical power and the costs of the LFG collection system is also additional to this cost as well.

Note that import duties and any related taxes may be a significant item and must always be included in any economic assessment as a specific cost item. The time that it may take to import any equipment must also be a key item in any project schedule development. The need and extent of any recommended spare parts must also be specifically discussed and assessed based on the availability of these parts in the specific country, as well as the time that may be required to import the parts. A specific consideration for LAC and the Caribbean that does not exist in most of North America and Europe is that a much more extensive spare parts inventory may be recommended than may be necessary in either of these other jurisdictions.

Gas Turbines

Gas turbines are available as modular and packaged systems. Gas turbines may have some application for sites with higher, more stable LFG production rates. Gas turbines are generally larger than reciprocating engines with electrical outputs ranging from

1 MW to 8 MW for each unit. Gas turbines also offer the flexibility of modular expansion to suit changes in LFG production however, the incremental stages are larger than for reciprocating engines. Gas turbines usually have a higher capital cost associated with initial set up with somewhat lower energy conversion efficiencies compared to reciprocating engines. However, they generally offer superior exhaust emission characteristics, reduced operating and maintenance costs and greater operational flexibility (in the ability to maintain reasonable efficiency despite fluctuations in LFG flow and characteristics) than reciprocating engines. In addition, gas turbines also offer the flexibility to proceed directly to the combined cycle option (as described below) in the future, should LFG production warrant. These positive features of gas turbines have been evaluated by operators in the United States and, in a few cases, have been found to offset the lower capital cost and higher energy conversion efficiency of reciprocating engines.

There are a few gas turbines that have been successfully adapted for LFG applications. However, the compression package that must precede the turbine is the more sensitive piece of equipment for the efficient long-term reliability of the facility. Typically, it is the requirements for the compression stage that will govern the level of LFG processing that will be necessary to ensure reasonable operating and maintenance costs for the facility.

Given the relatively limited number of turbine applications that are expected in the LAC and the Caribbean, it highly recommended that specific pricing be obtained for large sites at the pre-investment stage to ensure that this technology option is given a fair assessment.

Combined Cycle Systems

The combined cycle uses both gas turbine(s) and steam turbine(s) together to produce electricity. This process produces a significant improvement in electrical conversion efficiency to over 40 percent and can be realized by recovering and utilizing the high quality waste heat from the gas turbines in a waste heat boiler. The waste heat is then used to produce steam for the steam turbine. Use of waste heat from the gas turbine(s) reduces the volume of LFG required for the boiler. Combined cycle plants are generally only cost-effective for plants with greater than 10 MW output.

The costs for a combined cycle facility at a suitable large site may have a lower capital cost per installed MW of electrical generating capacity because of the significant energy conversion efficiency gain that can be achieved. Because this technology would only apply to large landfills, it is not recommended that any generic costs be used. For these large sites there may be significant merit in looking for used equipment components to optimize the overall economics for the facility. For example, the large LFG utilization facility in Toronto Canada at the Keele Valley Landfill Site has successfully installed a steam turbine facility using a combination of new and used equipment. The capital cost of that facility is less than $500,000 per MW of electrical generating capacity.

3.3 High-Grade Fuel Applications

Pipeline Quality Gas

Utilization of high quality LFG to produce pipeline quality gas has been undertaken at several landfills in the United States and Europe. The methane component of refined LFG is generally used as a direct substitute for natural gas. The pipeline quality gas is delivered under pressure either to the local utility or directly to a customer(s). Therefore, the markets for this type of product are nearby natural gas utilities or industrial users.

Production of pipeline quality gas involves the removal of carbon dioxide and other gases present in LFG, resulting in gas that is approximately 98 percent methane by volume. The first LFG utilization process developed was LFG upgrading to high Btu gas by "GSF" at Palos Verdes, California in 1975. The revenue from gas product sales did not covered the high capital and operating costs of this system and it has not developed as well as originally expected. In 1992, LFG upgrading installations in North America included Houston, Texas (relocated from Palos Verdes); Calumet City, Illinois; Cincinnati, Ohio; Freshkills, New York; and Pompano Beach, Florida. LFG upgrading is also being practiced in other locations including Wellington, New Zealand.

The capital costs to develop a LFG pipeline grade gas supply is governed by the gas quality standards that must be achieved. This approach must always be developed on a site specific and project specific basis and it is not appropriate to suggest general cost ranges and allowances. There are often some conflicting requirements associated with franchise rights to distribute natural gas that can pose schedule and approval difficulties for a LFGTE project. The LFG must be supplied directly to 1 major fuel user, which does not constitute a distribution network or alternatively, the major utility company agrees to accept the upgraded LFG on a specified quality basis.

Commercial Sale of Carbon Dioxide

Production of carbon dioxide results from the separation of LFG into its major constituents and is considered to be a by-product of the production of high Btu fuel derived from LFG. Carbon dioxide can be removed from LFG by surface adsorption (molecular sieves), membrane separation, or a solvent treatment system. Solvent examples include methyl diethanolamine (MDEA), methyl ethanolamine - diethanolamine adsorption (MEA-DEA), diglycolamine (DGA), hot potassium carbonate, propylene carbonate and selexol. All of these systems utilize liquid solvents that have individual affinities for carbon dioxide and hydrogen sulfide and in some instances, water, but show minimal affinity for methane. This allows the methane to be separated from the other gases to produce pipeline quality gas.

Although technically viable, there are no known existing or planned facilities that sell carbon dioxide derived from LFG. The largest use of carbon dioxide is in the food processing and beverage industries. The use of carbon dioxide from LFG for this use has both perceptual and liability implications that would tend to limit access to this market.

Chemical Products Production

Methane and carbon dioxide, the principal components of LFG, may be used as feedstock for certain chemical products such as methanol, fertilizers, and fuel cells. There are proprietary processes available to produce methanol from LFG. Methanol can be used as an alternative fuel or fuel-additive for gasoline and diesel-powered engines, and as an alternative bleaching agent for the pulp and paper industry. The high capital costs, limited markets for products, and complexity of the process make this option a less favored alternative. Compressed gas storage and subsequent use is also technically viable although the present market conditions do not make it economically viable at the present time.

Fuel Cells

Fuel cells are a new technology that directly converts hydrogen to energy. Use of LFG for fuel cells would require the use of a high-grade fuel processor, including a fuel cell stack power transformer, and a cooling tower for waste heat treatment. A fuel cell based power generation plant would be constructed using a number of individual fuel cells. This would make the system incremental, allowing for expansion to coincide with the fuel resource.

Currently, the price of fuel cells is much higher than other LFG utilization technology because the required fuel cells are not produced in commercial quantities. As the number of cells produced increases, it is expected that the price will drop, increasing the economic viability of a fuel cell based utilization project.

Vehicle Fuel

Compressed LFG (CNG) and Liquefied LFG (LNG), produced through proprietary processes, have been used to fuel vehicles as part of a demonstration project at the Puente Hills Landfill in California. In order to utilize the gas, it must first be treated to remove impurities and boost its fuel value before it is compressed. Advantages of this application include a reduction in fossil fuel consumption and local ozone pollution. However, there are significant costs associated with the retrofitting of vehicles to accept this type of fuel and the cost of building fueling stations. (Pappas, 2002)

These technologies are generally proprietary in nature and project specific costing is necessary to assess the application of this technology to a site.

3.4 LFG Processing

To employ most of the LFG utilization technologies described above, the LFG needs to be processed, at least to some extent. The primary form of treatment of the LFG is to remove some portion of the water vapor from the saturated LFG. Reducing the moisture content of the LFG and the number of trace constituents and particulates reduces the corrosive nature of the LFG, which reduces the maintenance costs for the utilization equipment. The production of high-grade fuel also requires the separation of the methane portion of the LFG from other gases that have no heat value. As with some of the high grade fuel applications, the following technologies are generally proprietary in nature and project specific costing is necessary to assess the application of these technology to a site.

Moisture Removal

The degradation of organic waste is an exothermic process and therefore LFG is warm and essentially saturated with water vapor. High moisture content, in combination with carbon dioxide, hydrogen sulfide, and VOCs, creates a potentially corrosive gas. Moisture reduction techniques that can be applied include moisture separators, mist eliminators, direct cooling, compression followed by cooling, absorption, and adsorption.

Some moisture separators function by swirling gas through a large cylinder, slowing down the gas velocity and allowing moisture in the form of droplets to collect on the walls of the cylinder. Mist eliminators, or coalescing filters, are typically used in conjunction with a moisture separator to collect droplets too small to have been intercepted by the separator. These are typically constructed of a wire mesh screen through which the LFG passes. Mist eliminators also intercept particulate matter entrained within the water droplets.

Cooling and compression of the gas decreases the ability of the LFG to hold water. This process is usually achieved through the use of air/air or air/liquid heat exchangers. Compression following cooling serves to further dehydrate the air. However, it also increases the temperature of the gas, which must be considered with the end utilization of the gas.

Absorption uses a liquid with a high affinity for water. The LFG to be absorbed is either introduced to the bottom of a column of absorbing medium, or the medium is sprayed onto the LFG stream. The water is removed from the gas through a process of physical and chemical reactions with the absorbing medium. The success of this process depends on the specific absorbing medium and the LFG characteristics.

Adsorption techniques use a granular solid material, which has an affinity for water. In this process, the water "sticks" to the granular material as the gas passes. Examples of this media include silica gel, alumina, and silicates known as molecular sieves. This technique is sometimes used in conjunction with absorption in systems such as packed towers, plate columns, spray towers, and venturri scrubbers. Over time, contamination of the specialized media employed in these systems causes reduced efficiency and replacement is required.

Particulate Removal

The solid particles carried within the LFG stream must be removed in applications for use of medium to high-grade fuel to avoid damage to the blower systems and other equipment components. The majority of the fine particulate matter is entrained within the moisture droplets in the gas. Therefore, moisture removal serves the dual purpose of also removing the particulate matter. Particulate filters can also be used to reduce particulate content of the gas but these filters require a high level of maintenance and must be frequently cleaned and/or replaced.

Trace Gas Removal

The trace gases normally removed from LFG are sulfur compounds, non-methane organic compounds (NMOCs), and volatile organic compounds (VOCs). These can be removed through the use of granular activated carbon (GAC), selective solvents, or iron sponge. GAC is the most commonly-used tool to deal with hydrocarbon and VOC treatment. One significant disadvantage of using GAC for LFG polishing applications is its high affinity for moisture. This can be mitigated by the implementation of a good moisture removal process prior to use of the GAC.

Selective solvent processes use various solvents to selectively adsorb trace gases. Iron sponge processes can be used to remove hydrogen sulfide from the LFG. The system uses hydrated iron oxide supported on wood shavings to react and produce iron sulfide.

Carbon Dioxide Stripping

Carbon dioxide has no caloric value, and creates a corrosive liquid when combined with water vapor. By using extraction, adsorption and membrane separation methods, carbon dioxide can be removed from the LFG, increasing the heating value of the gas and collecting the carbon dioxide for other end products. Some proprietary technology exists to remove the carbon dioxide using a solvent, low temperatures and high pressure. Some processes use multiple stages of molecular sieves to adsorb the carbon dioxide. In addition, membranes that are permeable to only the carbon dioxide fraction of the LFG can be used to separate the major LFG fractions. All of these technologies are expensive and tend to limit their application to the LFGTE projects unless there is a very high market value for the fuel products.

3.5 Utilization Selection Factors

As noted above, various technologies exist for the utilization of LFG. The alternative that is best suited for a specific site is dependent upon a number of factors including:

- projected LFG availability;
- presence and location of suitable markets;
- market price for end products;
- environmental and regulatory factors; and
- capital and operating costs of utilization system options, including processing and transporting issues/costs.

The viability of a LFGTE project is largely influenced by the degree to which the LFG is processed and this, in part, is a function of the economics of the specific application.

Electrical Generation Selection Factors

Several factors must be evaluated when considering generating electricity with LFG, whether the technology involves microturbines, reciprocating engines, gas turbines, combined cycle, or steam turbines.

Electrical conversion efficiency, which is an indication of what portion of the energy value of the LFG can be converted into electrical power, varies with each technology. The efficiency can be described in terms of net plant "heat rate" (Btu/kWh) or gross equipment efficiency. This efficiency is equal to the total energy value in the collected LFG divided by the energy value of the power fed to the grid. The net power fed to the grid is equal to the total output from the generator less any plant parasitic losses. These parasitic losses include energy spent on gas compressors, jacket water pumps, lube oil pumps, radiator fans, generator fans, station transformer, and other station auxiliaries.

Other important factors that must be considered when deciding on whether or not to utilize the LFG for electrical generation include availability, installation cost, operation and maintenance costs, and emissions, all of which are site specific. Availability is the actual time of power generation divided by the available hours annually. This is mainly a measure of reliability of power generation equipment and the supply of the fuel to the facility. Cost/kW installed describes the cost per installed kW of a given technology. Operation and maintenance costs include all labor and materials used to produce power, and are expressed as $/kWh for equipment operation. Maintenance charges cover major and minor overhauls. The emissions from exhausts of a LFG flare or a piece of generation equipment must be controlled to within acceptable limits set by governmental agencies. Emissions of concern can include nitrogen oxides, carbon dioxide, carbon monoxide, non-methane hydrocarbons, volatile organic compounds (VOCs), and products of incomplete combustion.

Table 3.1 presents the typical flow ranges required to make the implementation of the following electrical power generation technologies viable. It also shows the typical power ranges associated with the various LFG technologies and flow rates.

Table 3.1 – LFG Utilization Technologies and Typical Flow/Power Ranges

Technology	*Typical Flow Range*	*Preferred Plant Size*	*Electrical Conversion Efficiency (net to grid without waste heat recovery)*
Microturbines	< 100 cfm	< 100 kW	25-30%
Reciprocating engines	>150 to 5,000 cfm	0.5 to 12 MW	32-40%
Gas turbines	>4,000 to 20,000 cfm	3 to 18 MW	26-32%

Steam turbines	>6,000 to >25,000 cfm	10 to 50 MW	24-29%
Combined Cycle Systems	>5,000 to >25,000 cfm	>10 MW	38-45%

Source: Environment Canada, 1996.

BOX 3: APPLICATION OF RECIPROCATING ENGINE TECHNOLOGY

One of the most common LFG utilization technologies for small to relatively large LFGTE projects is the reciprocating engine. This type of technology is well suited for projects from 0.5 MW to 12 MW or more, which is the size of the majority of potential sites in LAC. Reciprocating engines are smaller in size than turbines and can add a smaller increment of capacity with a smaller capital cost as the development of the LFGTE project progresses to mirror the production of LFG at the site.

Reciprocating engine technology is reliable and the costs for operating and maintaining the engines has dropped significantly since their initial adaptation for use with LFG fuel during the 1980's and 1990's. The Waterloo LFGTE project has had an availability of greater than 98 percent since it came on-line in 1999. This is largely attributed to a careful maintenance schedule developed by the reciprocating engine manufacturer that is monitored by a full-time operator with familiarity with all aspects of the engine operations and performance characteristics. The following picture provides an example of a Jenbacher reciprocating engine that has been used to generate electrical power at the Instanbul site in Turkey. Also note that a picture of the Caterpillar engines used at the Waterloo Landfill Site is provided on the cover to the Handbook.

Of the eight case studies provided as annexes to the Handbook, seven of them are using or are planning on using reciprocating engines to produce electricity, which serves to illustrate the importance of this technology to the development of LFGTE projects in LAC and the Caribbean. Some of the LFGTE projects in Latvia and Poland are combined heat and power (CHP) systems that use the waste heat generated by the engines to heat the buildings at the landfill site and contribute heat to a district heating system.

A life-cycle cost/revenue analyses that includes a realistic assessment of on-line plant availability for the specific geographic location should consider the following: access to the required technical expertise; access to the required replacement parts; and the scope and extent of spare parts maintained at the facility. Lost production time can rapidly and dramatically change the economic viability of a project.

Direct Fuel End User Selection Factors

The use of LFG for direct fuel use applications is essentially viable for all size ranges of projects as long as there is a match between the LFG generation profile and the needs of a prospective user that is located relatively near (<10 km) to a candidate site. This option is easy to assess and can be very attractive if there is a market-resource match. Unfortunately, there are typically only a few landfill sites that are located in close proximity to a suitable fuel consumer. Factors to consider in determining suitability of an end user include:

- location of consumer to determine the length and location of a pipeline;
- energy requirements of user in terms of quantity and quality;
- daily and seasonal energy use profile of the prospective market;
- off-gas emission and treatment;
- costs associated with gas treatment, pipeline, and conversion of equipment to utilize LFG;
- operating and maintenance costs; and
- cost of alternative fuels.

Each of these items must be evaluated for the conditions specific to the potential project site to determine the technical feasibility and financial viability of the project. Generally, the end user must consume large volumes of energy on a year round basis and be located in close proximity to the site to achieve an adequate return on investment for this type of LFGTE project development. End users with large daily and/or seasonal fluctuations in fuel demand are less desirable as LFG is produced in the Site at a relatively constant rate and there is little volume for storage of gas within the landfill site.

PART 2 – UNDERSTANDING PERTINENT REGULATIONS, ENERGY MARKETS AND INTERNATIONAL CARBON FINANCE

4

LFG Management and Energy Policies, Legislation, Regulation, and Markets

Energy policies and related legislation control the ability of to market the products of LFG management, such as emissions reductions or energy. The current energy markets are in the process of developing policies with respect to emission reductions that are directly applicable to LFGTE projects and the costs required to produce various energy products and bring them to the marketplace.

Historically, the "business as usual" values assigned to the LFG fuel have not been adequate to encourage the development of LFGTE projects in LAC. One of the changing conditions that can offer additional fiscal support for any LFG management project, including LFGTE projects is the potential supplementary value as an 'emission reduction credit' and how they are treated in the energy policies and legislation of LAC.

An emission reduction credit is defined as one tonne of greenhouse gases, expressed in carbon dioxide equivalents, which would otherwise have been emitted to the atmosphere for an established baseline scenario at a site. Since emissions may consist of a combination of gases (e.g., methane and carbon dioxide), the tonnages of individual gases are expressed as a carbon dioxide equivalent (eCO_2) in terms of global warming potential. This is accomplished by multiplying the tonnes of individual gases by technical coefficients based on scientific principles reflecting the impact on the global warming impact. For example, one tonne of methane is equal to 21 tonnes of carbon dioxide. (E.g., 1 tonne methane = 21 tonnes eCO_2)

Emission reduction credits must be real, quantifiable, additional, verifiable, and unique. Some of the current methods for proving these criteria are discussed further in Section 6. These credits can be created both directly or as a result of fuel offsetting. LFGTE projects may generate supplementary offset credits that represent the emissions avoided through the use of the LFG fuel in lieu of other fuel sources. For example, the offset fuel could be natural gas or coal.

While the technical coefficients to employ in the calculation of emission reduction credits have been established and periodically reviewed, the economic value of CERs have not yet been fully established. While transactions involving sale and purchase of emission reduction credits have occurred on international markets, it remains for a larger number of buyers and sellers with transactions occurring, to establish market prices. A significant part of the problem exists because most of the trading activities have involved 'voluntary early actions' as opposed to enforcement of cutbacks, which will require significant action. As ratification of the Kyoto Protocol comes closer in time, it is expected that there will be significant numbers of transactions occurring in the near-term future, with the result that the value of the emission reduction credits will firm up quickly.

The economic value of a CER is expected to increase if, and when, local legislation requires cutbacks and the less expensive emission reduction options are taken up. LFGTE projects are considered less expensive than many of the other options for emission reductions and, as a consequence, it is considered that the LFGTE projects will be rapidly purchased by major international corporations, as a means of obtaining least cost emission reduction credits for their required CERs.

An important reason that LFGTE is one of the least expensive emission reduction opportunities is because LFG combustion transforms the methane to carbon dioxide. Hence, emission reduction credits are a natural outcome of LFG collection and flaring or utilization, because as the methane combustion occurs, the carbon dioxide equivalent emissions are decreased. The addition of the economic value of the emission reduction credits to the LFG management project thus provides: a positive incentive for improving the design and operation of the landfill; a positive influence towards improving the overall waste management system; and could potentially contribute to the financial feasibility of a LFGTE project, with the result that projects may be developed that would otherwise not have been considered financially viable.

Whether the CERs for LFG projects are recognized and can be sold depends upon whether local landfill regulations specifically require collection and treatment of the LFG. For example, if the landfill regulations in a specific jurisdiction require abatement of emissions (e.g., for odor or health reasons) through prescriptive measures such as the use of LFG collection and combustion systems, the site and any associated emission reductions may be considered to be 'regulated' and thus be precluded from recognition as

CERs. As a consequence, the wording of any legislation is a key factor that must be considered when analyzing a potential LFG management project. The net result is that it is very important to establish whether landfill regulations require specific abatement of air emissions, since this will influence whether the emission reductions can be certified and sold. Simply stated the landfill industry can abide by, and should be governed by, any regulatory requirements applicable to health and safety or that are applicable to all air emissions sources within a country. However, specific regulations that identify the waste management industry apply a higher standard than is applicable to industry and governments as a whole may unfairly remove the LFG CERs as an available asset or commodity. As future control of GHG emissions develops and becomes more stringent, the opportunities to generate CERs will be reduced. The current "window of opportunity" for LFG management projects results because of the gap between the global realization that GHG emissions must be controlled (as illustrated by the Kyoto Protocol) and the current status of emission control legislation in most parts of the world. Because of the importance of issues such as those indicated above, this section of the Handbook examines elements of policies, legislation, regulations, and markets as they influence the potential for LFGTE projects. Elements of consideration will include how modifications to policies, legislation and regulations can be developed or changed to encourage LFGTE projects.

The energy sector of LAC, primarily Venezuela and Mexico, is a net exporter of energy resources, mainly oil, and this is expected to continue over the next 25 years. As far as electricity is concerned, the predominant source is hydroelectric-based energy. The International Energy Agency (May 03) IEA energy projections for Latin America suggest that the region's energy demand will double between 2000 and 2020 and consequently there is extensive demand foreseen for electricity in the future. This appears to create an incentive for LFG management projects that include LFGTE operations in LAC.

4.1 Background

The legislation existing in an LAC country will greatly influence the potential development of an LFGTE project by influencing the investment opportunity and economic returns to investors for project developments. In many countries in LAC, policies, legislation, and regulations of the energy market are in their infancy and subject to change. Therefore, this section discusses these issues with the intent to provide guidance on how the regulations might be changed/improved with guidance, in order to encourage the development of LFGTE projects, which can have a positive influence on both the energy sector and the entire integrated waste management system.

Countries in LAC are adapting their legal and institutional frameworks to encourage sustainable development, with the intent of reversing trends of environmental degradation. As well, governments are looking for greater efficiencies in electricity production through increased competitiveness (e.g., privatization) and the raising of capital from sources outside government. As a consequence, national environmental laws and institutions are being strengthened in response to international demands to protect against further environmental deterioration. Such laws however, face a variety of challenges including jurisdictional questions between federal and state authorities.

The development of energy market policies, legislation, taxation, and regulation that reflect positively on the development of LFGTE policies will encourage these projects and will influence their financial viability.

Energy regulations differ between countries and therefore it is not feasible to review all of the policies for LAC. In addition, most of these countries, with few exceptions, are only beginning to establish regulations focusing on the energy sector and therefore are currently in a state of flux. Therefore, rather than focussing on the specific energy regulations, the Handbook takes a "checklist approach".

Table 4.1 is structured to outline the type of regulatory or policy issue that might be encountered, the rationale for this type of regulation or policy issue, and an example of the potential type of regulation or policy issue currently in place. Table 4.1 has an additional column to allow persons considering a specific site to use the table as a worksheet where they can make notes about the information applying specifically to the site of interest.

TABLE 4.1

CHECKLIST FOR APPLICABLE ENERGY POLICIES, LEGISLATION, REGULATION, AND MARKETS
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

	Regulatory or Policy Issue	Discussion & Rationale for application of Regulatory or Policy Issue to LFG-to-Energy Projects	Special Concerns	Potential Project - Specific Inputs
	Electrical Power			
1	Regulatory Authority over electrical power generation for location of candidate project or site	• It is critical to identify the level of government and hierarchy of authority over electrical power generation (e.g. federal, provincial, regional or other) • Is the administration of the regulation under the same level of government authority (e.g. some jurisdictions may pass administration of a regulation to a different level of government or government-controlled corporation or utility. • Are there any legislative mechanisms, which will create demand for alternative electricity generation?	• Article 27 of the Constitution of Mexico provides exclusive rights to the state for electric power generation. For any other generators, the electricity must be for self-use. • Green logo may be mandated by governmental initiative (ECP 79 in Canada) which allows certified generators of "green power" to be identified	
2	Regulatory Authority over electrical power distribution for location of candidate project or site	• It is critical to identify the level of government and hierarchy of authority over electrical power distribution (e.g. federal, provincial, regional or other). Note that this may or may not be the same regulation and authority as for the generation noted above. • Is the administration of the regulation under the same level of government authority (e.g. some jurisdictions may pass administration of a regulation to a different level of government or government-controlled corporation or utility. • Who is responsible for building and maintaining the transmission lines to connect the landfill to the grid? • What is the current distribution market	• Monopoly situations may make it difficult/impossible for transmission of electricity. Negotiations for lineage fees are possible in Brazil	

TABLE 4.1

CHECKLIST FOR APPLICABLE ENERGY POLICIES, LEGISLATION, REGULATION, AND MARKETS
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

	Regulatory or Policy Issue	Discussion & Rationale for application of Regulatory or Policy Issue to LFG-to-Energy Projects	Special Concerns	Potential Project - Specific Inputs
		structure (deregulation, publicly-owned, etc.)?		
3	Authority to Issue Contracts to Independent Power Producers (IPPs)	• Does the regulation allow for independent power producers to have access to the distribution grid and to the markets. • Are independent power producers welcomed or tolerated in the specific country or region?	• The deregulated electricity market in Argentina provides the mechanism for IPPs to sell to the electrical system • In Mexico, Article 27 provides exclusive right to the state for generation, transmission and distribution, for public service. The Comision Regulador de Energia is the entity that provides the required permits to private investors to install or import electric power.	
4	Price-Setting for Wholesale Power generated by IPP's	• Who sets the price for power? • How does the price for power change over time? • Are there time limits on contracts that may jeopardize the prices if project delays occur?	• Getlini's (Latvia) contract lapsed as a result of project delays and caused significant problems	
5	Wheeling of Power and Access Charges	• Is "wheeling" (use of transmission lines to carry the generated electricity) permitted? • If yes, who regulates this? • Who sets the price for access to, and wheeling through, the transmission distribution grid? • Are there any tariffs associated with the	• If a monopoly situation exists, the costs of transmission may be substantial.	

TABLE 4.1

CHECKLIST FOR APPLICABLE ENERGY POLICIES, LEGISLATION, REGULATION, AND MARKETS
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

	Regulatory or Policy Issue	Discussion & Rationale for application of Regulatory or Policy Issue to LFG-to-Energy Projects	Special Concerns	Potential Project - Specific Inputs
		private generation and access for sale of electricity? • Who is responsible for design of the interconnect system?		
6	Permits and Approvals • Building permits • Air emissions permits • Operations permits	• Who issues them? • What are the timelines and costs associated with this issue?	• Typically this is a government-controlled mandate	
7	Emission Reductions	• Are carbon offsets regulated and therefore not able to be sold? Are there any regulations or policy statements regarding the existence of carbon offsets? • Do the regulations place any restrictions on the ownership, transfer, or validation of emission reductions?	• Regulations mandating that LFG collection is required would effect value of carbon credit value • Projects could not represent “additionality” concept under those regulations	
8	Green Power or Renewable Energy Category	• Is the concept of renewable energy or green power embodied in any energy policies or regulations? • Will identification of energy as ”green” allow increased pricing? • Are there any specific certification requirements or policies embodied in any energy policies or regulations? • Does legislation automatically assign renewable energy credits to the generators or the utilities or the direct consumers?	• In some situations, the price of green energy includes transfer of emission reduction credits to the utilities	
8	Power Sales Contracts	• Do any standard power sales contracts exist that are applicable to the potential project?	• The potential may exist for the pricing structure for electricity to change, with	

TABLE 4.1

CHECKLIST FOR APPLICABLE ENERGY POLICIES, LEGISLATION, REGULATION, AND MARKETS
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

	Regulatory or Policy Issue	Discussion & Rationale for application of Regulatory or Policy Issue to LFG-to-Energy Projects	Special Concerns	Potential Project - Specific Inputs
		• Do customer rate caps on electricity prices exist?	onset of electricity system deregulation (e.g. in Mexico)	
9	Emissions Testing	• Is there any specific testing embodied in any energy policies or regulations? This can be a relatively expensive line item and affects the financing phase of any project development. Also refer to Table 5.1 for related Environmental regulations and policy issues. • Do the costs for testing and certifying a source of energy as green fall onto the certifying agency (or government) or the electricity producer?	• The normal situation is that the costs for testing and certifying fall on the generating entity	
10	Pending Regulations or Policies	• It is critical to know if there are any pending regulations or policies in the areas pertinent to LFG-to-Energy projects because of the direct implications associated with emissions reductions revenue streams and the ownership of any emission reductions that may be generated by a project.	• Questions may exist as to who owns the waste? e.g. is it the municipality in which the wastes are generated, or the entity in which the landfill resides. Resolution of this question is very important	
11	Taxation and Duties	• Do any federal, state or municipal sales taxes apply to the project? • Do import duties or other related charges apply to renewable energy projects?		
12	Tax Treatment/Incentives/Credits	• Do any tax incentives or credits apply to qualifying projects and for cleaner electrical generation technologies? • What are the applicable taxation and depreciation rates for this type of project?	• The availability of tax credits in the US was a primary initiator to get LFGTE projects implemented • In Canada, there are R&D tax credits available	

TABLE 4.1

CHECKLIST FOR APPLICABLE ENERGY POLICIES, LEGISLATION, REGULATION, AND MARKETS
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

	Regulatory or Policy Issue	**Discussion & Rationale for application of Regulatory or Policy Issue to LFG-to-Energy Projects**	**Special Concerns**	**Potential Project - Specific Inputs**
		Is there potential to influence the promulgation of legislation? • Are there tax incentives for R&D work for green power generation?		
13	Sustainable Energy Projects	• Is there legislation to support sustainable energy project development initiatives?		
14	Interconnection Approvals and Charges	• The interconnection approvals and charges can be a significant item with respect to the cost and timetable for a potential project to develop. What are the requirements and costs to obtain this market access? • What are the technical requirements/restrictions to connect into the grid (voltage, current, etc.)?		
	<u>Direct Fuel Use (Pipeline or as Fuel)</u>			
15	Regulatory Authority over natural gas fuel transmission and sale for location of candidate project or site	• It is critical to identify the level of government and hierarchy of authority over electrical power generation (e.g. federal, provincial, regional or other) • Is the administration of the regulation under the same level of government authority (e.g. some jurisdictions may pass administration of a regulatory to a different level of government or government controlled corporation of utility. • Are there any other legislative mechanisms in place to create demand for alternative		

TABLE 4.1

CHECKLIST FOR APPLICABLE ENERGY POLICIES, LEGISLATION, REGULATION, AND MARKETS
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

	Regulatory or Policy Issue	Discussion & Rationale for application of Regulatory or Policy Issue to LFG-to-Energy Projects	Special Concerns	Potential Project - Specific Inputs
		electricity generation?		
16	Authority to Issue Contracts to Independent Fuel Producers	• Does the regulation allow for independent fuel producers to have access to the distribution pipelines and to the markets? • Are independent fuel producers welcomed or tolerated in the specific country or Region. • What franchise limitations on the transport of LFG through a pipeline are applicable?	• In some locations, franchise stipulations preclude (other than the franchise owner) the transporting of 'manufactured' gases. LFG may be considered a manufactured gas.	
17	Market Access	• What obligations exist for the major natural gas utility to consider accepting a renewable energy source of fuel? • How and by whom is the price for the fuel established or is this dependent on what is negotiated? • Can direct consumers choose to use LFG, or are there restrictions on access?		
18	Fuel Quality	• What are the gas quality requirements to gain access to the distribution pipeline? • Who establishes and approves the quality criteria?		
19	Permits and Approvals	• Who issues them? • What are the timelines and costs associated with this issue?		
20	Emission Reductions	• Are there any regulation or policy statements regarding the existence of carbon offsets (carbon credit value for 'carbon fuels not burned') for direct fuel use? • Do any regulations place any restrictions on the ownership, transfer or validation of	• Recognition of an "offset" credit for fuels not combusted is allowed in Canada	

TABLE 4.1

CHECKLIST FOR APPLICABLE ENERGY POLICIES, LEGISLATION, REGULATION, AND MARKETS
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

	Regulatory or Policy Issue	Discussion & Rationale for application of Regulatory or Policy Issue to LFG-to-Energy Projects	Special Concerns	Potential Project - Specific Inputs
		emission reductions?		
21	Fuel Sales Contracts	• Do any standard fuel sales contracts exist that are applicable to the potential project? • Do customer rate caps on charge rates exist?		
22	Pending Regulations or Policies	• It is critical to know if there are any pending regulations or policies in the areas pertinent to LFG-to-Energy projects. There may be direct implications associated with emissions reduction revenue streams and the ownership of any emission reductions generated by a project.		
23	Taxation and Duties	• Do any federal or state sales taxes apply to the project?		
24	Tax Treatment/Incentives/Credits	• Do any tax incentives or credits apply to qualifying projects and for cleaner burning biogas fuel technologies? • What are the applicable taxation and depreciation rates for this type of project? • Are there tax incentives for R&D work for renewable energy projects?		
25	Sustainable Energy Projects	• Is there legislation to support sustainable energy project development initiatives?		

TABLE 4.1

CHECKLIST FOR APPLICABLE ENERGY POLICIES, LEGISLATION, REGULATION, AND MARKETS
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

	Regulatory or Policy Issue	Discussion & Rationale for application of Regulatory or Policy Issue to LFG-to-Energy Projects	Special Concerns	Potential Project - Specific Inputs
	Other Market, Issues			
1	Ownership restrictions on projects	• Are there limitations on who may retain ownership of projects?	• Mexican legislation currently has ownership restrictions	
2	CDM country office requirements	• The Kyoto Protocol stipulates that the country office of the CDM participate in any international transfer of emission reduction credits. • What levels of fees are involved? • What approvals are required?		

4.2 Green Power Designations, GHG Compliance and Accelerated Tax WriteOffs

Domestic legislation is underway to establish GHG compliance markets in numerous countries, including UK, Denmark, The Netherlands, Canada, France, Australia, and New Zealand. For example, Canada has recently enacted legislation entitled ECP-79, which is intended to improve the investment potential in renewable low-impact electricity projects, including LFG projects. The legislation specifies the types of projects which will be allowed to use an EcoLogo certification, which is intended to allow the energy to be labelled as 'green' and hence be marketed at a higher price to electricity consumers. A copy of ECP-79 is provided as a reference document in Appendix B, and the legislation is discussed further in Section 5.2.

Recognition of LFG-generated energy as 'green' may provide the opportunity to charge consumers an increased price, assuming there is willingness and ability to pay increased prices by the consumers.

A very different strategy is being used in Brazil, where distributors for alternative electrical generation sources are negotiating different prices. Specifically, the normative prices are listed in Table 4.2 and demonstrate the relative prices for electricity produced using different generation mechanisms. This is an alternative (to relying upon consumers' willingness to pay) strategy to encourage specific generation mechanisms for electricity.

Table 4.2 - Energy Prices Paid by Distributors to Generators of Electricity in Brazil

Generation Mechanism	*US $/MWh*	*Price Ratio Relative to Hydro (large plant)*
Hydro (large plant)	25.4	1.00
Coal	26.3	1.04
Small Hydro Plant	27.8	1.09
Biomass	31.5	1.24
Wind	39.3	1.55
Solar	92.6	3.65

The Federal Government in Brazil has created PROINFA, which was structured to encourage green energy generation. Under this program, ELETROBRAS, a consortium of large generators in Brazil, is guaranteeing to buy the electricity from small, green producers for up to 15 years duration.

Further, interconnection fees to the electrical network are being reduced for green energy, which includes LFGTE projects, to approximately 50 percent of those charged for traditional forms of energy. These measures are positive, but the offered price for LFG projects would likely be treated as Biomass projects. The revenue price specified in Table 4.2 is likely inadequate by itself to encourage LFGTE projects without some other form of revenue supplement such as CER's. With future deregulation, it is likely that the above noted structure may change.

4.3 Legislation

Legislation that allows improved economics may be extremely important in enhancing the environment to encourage development of LFGTE projects. Governments may significantly influence project development by developing the taxation structure to encourage innovation and project development. As a specific example, the existence of a favorable taxation structure was the genesis of the LFG industry in California. Much of the taxation structure was initiated by accelerated tax writeoffs as a means of assisting the maturing of the LFG utilization industry.

Examples of current legislation and regulations that govern LFG as a potential energy resource are reviewed in the sections that follow.

The key to legislation insofar as it impacts LFGTE facilities is whether it encourages the development or not. There are profound changes in governmental regulations ongoing in the electrical sectors through such venues as privatization and increased competition in many countries. Of interest in this section is how regulations are changing and/or does the potential exist to influence legislation, to improve the opportunities for LFGTE facilities. The following sections review the current situation, and the ongoing changes, and summarise what it means in terms of potential for adjusting legislation to improve opportunities for LFGTE projects. Ensuring access to electrical transmission systems, or 'wheeling', is a key to project viability. If the owner of the transmission system maintains or has a monopoly, there are considerably greater problems ensuring access to the transmission system and hence this is a question of major importance in assessing the feasibility of a LFG project.

<u>LEGISLATION IN BRAZIL AND IMPLICATIONS TO LFGTE PROJECTS</u>

Brazil has enormous energy potential and rapidly increasing demand for electricity. Brazil's fossil fuel reserves are relatively low but hydroelectric sources are numerous and huge potential exists with respect to solar and biomass energy. However, to date, only two energy sources, namely hydroelectric and petroleum-based, have been extensively used for developing electrical energy in Brazil, with approximately 90 percent coming from hydroelectric facilities. The combination of increasing demand, lack of expansion capabilities in the traditional sectors, and financial, socio-economic and environmental constraints, all indicate the future of energy supply in Brazil will increasingly depend on alternative energy sources, which bodes well for LFGTE facilities if energy policies and related legislation allow for these new 'green' energy projects at market prices that will encourage their development.

Given the above situation, a number of issues are highly relevant to the potential for LFGTE utilization projects:

1) The Brazilian electric sector is currently undergoing a restructuring process with profound modifications in its institutional, financial, and regulatory aspects. The changes involve privatization of most state and federal-owned distributors, the creation of the "Agencia Nacional de Energia" (National Agency of Electric Energy) and the creation of the "Operador Nacional do Sistema Electrico", as well as the restructuring of ELECTROBRAS.

2) Brazil's Federal Government's tasks are now focused primarily on formulating new policies for the electricity sector and in changing regulations governing its activities. The sector's decentralization and the introduction of free competition with regard to generation and commercialization of electricity have facilitated private investments, the reduction of costs, as well as an overall increase in efficiencies within the system. The "birth" of this open market is based on the creation of the "Mercado Atacadista de Energia" (or MAE), an environment where the commercial transactions of electricity are not covered by bilateral contracts between generators and distributors of electricity but the entities are free to negotiate with whomever.

3) The ramifications of these changes in market strategy, from the monopolist, state-controlled market, to an open free-competing market are currently in a transition phase. Until 2001, all contracts concerning electricity generation and distribution had to be entirely fulfilled, including the demand and growth forecasts made at the time of their signature. In this system, electricity was sold as a whole, including the costs for the electricity itself, the generation, and the distribution, and the prices were fully regulated by the Ministry of Mines and Energy. On top of that, the distributors of the electricity could only buy from one producer.

   Starting in 2002, the additional demand increments had to be freely negotiated, according to the rules stipulated by the MAE. With this new structure, the price has been segmented into three components, electricity itself (cost per Mwh to buy), generation (cost per MWh to produce) and the transmission/distribution price. Distributors now may purchase from any producer. From 2003 on, the contracts will have their amounts of commercialized, free negotiated energy gradually increased by 25 percent per year. It is intended that the market will be totally open to free competition in 2006. This bodes well for the potential for LFGTE projects since the generators will have a free market to sign agreements with distributors.

The price to use the electric lines in Brazil depends on how much power will be produced, the quality (reliability), and the source. Hence, the price that is paid to "wheel" the electricity across the electricity transmission corridor is negotiable. An example of the pricing structure is .50 $ US + 25 percent sales tax/kW/month. Consequently, for a 1 MW facility, the wheeling cost to distribute the electricity using the available transmission system would be approximately 625 $/month. This pricing structure would amount to only .08 cents/kWh for lineage fees.

4) The current retail price of electricity in Brazil is 18.62 $/MWh in the northeast. It is noted that this value represents a very significant challenge to the viability of LFGTE facilities due to its low price.

LEGISLATION IN MEXICO

The economic growth of the Mexican economy during the last decade resulted in a 5.2 percent average annual growth in annual electricity demand. Total installed capacity in Mexico in 1999 was 35,000 MW and future demand is expected to grow at 5.8 percent per year until 2010. Access to electricity in the country is high, with 95 percent of Mexicans having electrical services.

Power Sector Regulations in Mexico

Article 27 of the Constitution of Mexico provides exclusive rights to the state for electric power generation, transmission, and distribution for public service. Until 1992, the state-owned Comision Federal de Electricidad (CFE) and Compania de Luz y Therza del Centro (CLFC) were the only players in the power sector. This situation changed in 1992 when the Ley del Servicio Publico de Energia Electrica (the Electricity Law) was modified to allow participation of private investors in power generation. Since then, private parties can: i) generate power for self-consumption e.g., for co-generation for small industries; ii) generate power as independent power producers for exclusive sale to CFE; iii) generate power for emergencies in the case of the failure of the public service system; and iv) import power for self consumption.

The Comision Reguladora de Energia (CRE) created in 1995, is the entity that provides the required permits to private investors to install or import electric power. It was agreed at negotiations that SIMEPRODESO would apply and receive from CRE a permit for the co-generation of electricity and thereafter maintain the permit throughout project implementation.

The Future of Mexico's Power Sector and Impact on LF-to-Energy Opportunities

The tremendous investments required to support the growth in the power sector can no longer be financed by the state-owned companies in Mexico alone and therefore, there is growing pressure to restructure and open the power sector to private investors. It is expected that, in addition to bringing to the power sector the required capital, restructuring the sector would promote efficiency and competition in the electric power market, which should benefit the users. The changes proposed by the outgoing administration, which Congress decided to postpone for future consideration, are focused on the vertical and horizontal unbundling of the existing companies (CFE and CLFC) and the subsequent formation of several generation and distribution companies and a national transmission company. A national power market, to which all qualified players would have access, would be created.

One of the concerns regarding viability of LFGTE projects is the existing regulations on electricity generation in Mexico which restrict electricity generation to 'auto-use', or self-use. The regulations about selling energy are strict in Mexico, but the Federal government is encouraging private generation of energy for auto-use (e.g., a Municipality might use the electricity within the Municipality for streetlights). This type of use is acceptable within the existing regulations and is beneficial in that it avoids the retail costs of purchasing electricity. The savings may be substantial, as demonstrated in the example below. In Mexico, CFE buys electricity from independent power generators for the following prices:

From coal:	45 $/Mwh
From fuel oil:	50 $/Mwh
From geotechnical:	55 $/Mwh
From combined sources:	30 $/Mwh

However, Municipal governments are purchasing electricity at 120 $/Mwh for streetlighting, which means the cost-avoided, is substantial. It is noted that the current Mexican CFE law requires that a buyer of a minimum of 80 percent of the electricity has to be available, with the remaining 20 percent that can be sold to CFE. It is also relevant to indicate that it is expected that direct sale to industry will be allowed soon within the governmental regulations. Access to the CFE distribution system can be made at the cost of 1.0 to 1.5 $/MWh.

The only LFG utilization facility currently in operation in Mexico is that in Monterrey where a public-private partnership at a landfill has been developed and is operating in Salinas Victoria. There remains an issue of the technical and institutional experience specific to the identification, design, and implementation of LFG capture and utilization projects. Regulations targeting LFG management at landfills have yet to be issued in Mexico.

Example of Innovative Legislation in Canada

An additional important dimension to encourage is legislation that supports the potential for LFGTE projects. For example, in Canada the Environmental Choice Program (or ECP-79) specifies applicable criteria, verification requirements and subsequent authority to label qualifying electricity with ECP's EcoLogo. The ECP maintains verification protocols that clearly define the terminology and associated criteria limits that allow 'biogas-fuelled' electricity which means electricity generated from a system in which biogases are captured for combustion and conversion to electricity (e.g., landfill sites, sewage treatment plants and anaerobic digestion organic waste processing facilities). To meet the requirements of ECP-79, biogas-fuelled electricity must be generated in such a manner that the total of air emissions of carbon monoxide, particulate matter, nitrogen oxides, and sulphur oxides does not exceed a specific magnitude (for details, see Environmental Choice Program Certification Criteria Document, CCD-003, January 9, 2003)

This legislation is also a clear example of the importance of CER ownership with respect to LFGTE projects. This is discussed in Section 5, along with other resource ownership issues.

Offset or displacement credits could be a significant item as a function of which type of energy generation is displaced (e.g., coal-fired thermal plants).

Considerable interest exists in developing a consumer tax credit for purchasers of electricity from sources such as wind, solar and biomass fuels. This would represent a broader investment tax-credit system for green power research and development and could be very important in encouraging alternative power generation opportunities. A perceived lack of consumer demand is considered to be the reason that green energy products aren't being developed and used as alternatives to fossil fuels in Canada. To create that demand, the potential exists to introduce the consumer tax credit.

Tax credits for research and development of green power technologies could also help to provide supplementary incentives and the Government is currently considering these.

BOX 4: ACCESS TO, AND CONFIRMATION OF, "GREEN" POWER PRICING PREMIUMS

The independent developer for the Waterloo LFGTE Project, Toromont Energy, experienced a great deal of difficulty in obtaining a contract to sell electrical power. The contract to design, build, own and operate the LFG utilization facility was awarded in 1995, but Toromont did not sign the contract until 1999 because of these market access difficulties. The initial signing delay of several years could have been fatal to the project if the landfill had been approaching its site closure. The following picture provides an aerial view of the LFGTE plant in Istanbul, Turkey. The electrical substation and overhead power lines to connect the facility can be seen both in the foreground and in the background.

The revenue stream associated with the sale of electrical power needed to come from Ontario Hydro, as it was essentially a monopoly. Initially Ontario Hydro showed little interest in the project because its policies did not encourage non-utility power generation projects. Low valuations were assigned to the wholesale power making it not economically viable to develop new generating capacity at small private facilities.

A change in the provincial government in the mid 90's brought the disassembling of Ontario Hydro in anticipation of a transition from a regulated electricity market to an open or deregulated market. In preparation for competition, the new provincial power company, OPG, began investing in renewable energy projects so that they could provide consumers with "green power" in an open market. In addition, the provincial government established a pilot emission reductions trading program that created an added incentive for OPG in the form of emission reduction credits (ERC) and allowed Toromont to sell the power they generated at a premium "green power" rate that made the project financially viable.

It is crucial that market access for energy products from LFGTE projects be made available, whether it be general access or specific access for qualifying renewable energy projects. Further, this access must be at rates to make the projects economically viable and/or be flexible enough to allow supplementary revenue to be realized from the emission reduction benefits of a project.

4.4 Markets for Electricity

Competitive access to the energy market and consumers is an important factor in having a successful LFGTE project. Some countries in LAC, such as Argentina, have an extremely competitive energy market with ongoing privatization. Opportunity for consumers to choose green power, and monetary incentives to purchase this power, add to the financial incentives produced by LFGTE projects.

Some Applicable Market Considerations

- LFG systems generally operate at base load steady state operating mode. Peaking isn't generally feasible with LFG.
- Energy markets in a highly competitive, decentralized system such as in Argentina can be very complex. Simplified access for small qualifying 'green power' projects would be a major asset, ideally with standard form contracts that are simple to negotiate and finalize.
- Consider adoption of Ecologo certification, or its equivalent, for new and existing projects in terms of 'green electricity'.
- The market access for sale of electrical power is often controlled by a local electrical utility. The sale of electrical power is subject to the policies of the utility. In some regions, purchase of power from non-utility generators has been frozen or cut back due to a surplus of power or a lack of interest in accepting small non-utility generators. Some special consideration for small 'green' non-utility generators would help to facilitate LFGTE projects in many areas of LAC.
- It is very important that developer/investor confidence be improved for qualifying 'green' energy projects. Uncertainty about future markets and regulations is one of the largest impediments to project development if legislation isn't conducive or is unclear.

<u>Market Access Considerations in Brazil include:</u>

- There is a small facilities recognition (<30 MW) that would encompass likely most of the LFGTE facilities. This recognition is a positive measure that should be considered in all jurisdictions within LAC.
- There is a minimum discount of 50 percent in the fees charged for access and use of the transmission and distribution grids. This is a very key consideration and it should be considered for all jurisdictions within LAC.
- Utilization of the resources as defined by the Fuel Consumption Account (FCA) has been encouraged in Brazil. This is a special subsidy from the Federal Government related to electricity generation initiatives that utilize fossil fuels, especially diesel. Due to environmental concerns regarding the production of GHGs, and to promote the use of sustainable and renewable energy sources, Brazil has extended the subsidies to initiatives that replace the use of such fossil fuels by sustainable and

renewable energy sources such as LFG. This is a positive measure that should be considered for all jurisdictions within LAC.

- Independent Power Producers can freely sell the electricity they produce. Law in Brazil guarantees access to the main distribution grid. This is an important milestone, with the objective to make a smooth transition from the regulated electricity markets that operated on fixed tariffs, to a deregulated market (e.g., with tariffs being freely negotiated between generators and distributors) law No. 964 of March 27, 1998 was passed in the Brazilian Congress). This law defined "initial contracts" between the generators and distributors and lays the foundations for the market transition, which is based on the so-called "initial contracts". The transition is starting off by deregulating tariffs by 25 percent per year commencing in 2002 until its completion in 2006. Any exceeding amounts of electricity, which had been previously established in an initial contract, can be negotiated between generators and distributors, based on the above-mentioned law.

<u>Other Market Access Issues</u>

- The potential for self-insurance could be an asset for the LFGTE industry. It appears certain that in most markets, the supplementary revenue and benefits associated with GHG emission reductions will be necessary to encourage project developments. Uncertainty in the marketplace over the validation and existence of certified emission reductions (CERs) is an impediment to the market development. Some type of fund or internal reserve of carbon credits, which will be set aside to compensate for any reductions in expected carbon credit outputs from a project that may be caused by unexpected events, would help to reduce project risks and encourage more developments.
- Tariff levels for electricity have been relatively low due to a centralized pricing structure fixed by governments. The ability to capture tariff increases is uncertain due to the onset of free electricity markets such as will exist in Brazil.

5

Environmental and Waste Management Policies, Legislation, and Regulation

It is of great importance for governments in LAC to outline the policies and procedures that help to mitigate environmental and social problems resulting from existing solid waste management practices and to implement a system that minimizes the potential for future problems. Solid waste management planning is critical for LAC to protect human health and the environment, to specify measures encouraging the conservation and recovery of resources, and to establish integrated governmental policies for the management of solid wastes.

Currently there are very few regulations that specify detail requirements for control and combustion of the LFG. If these regulations develop, as result of global or national pressure for limiting GHG emissions, there will be no economic value for the CERs, as they will no longer be considered 'voluntary'. The current potential monetary incentive for LFG management projects for sale of CERs results from a gap between the global recognition that GHG emissions must be controlled (e.g., the Kyoto Protocol) and the current status of regulations controlling GHG emissions in all aspects of the respective of industrial and commercial activities in all developed and developing countries.

It is crucial that legislators understand that legislation that specifically targets air emissions from the waste management sector rather than national air emissions for all industrial/commercial sectors, may negate the potential for the CER value. Focussed legislation would in fact be counterproductive to the goal of encouraging LFG management projects in LAC and elsewhere in both the developed and developing countries. The waste management sector can accept and meet standards that are fully protective of health and safety and it should be governed by all air emission regulations that are applicable to the industry and governments in the applicable jurisdiction.

The Kyoto Protocol calls for the creation of GHG reduction credits only in instances where the act is voluntary. Therefore, when assessing a potential LFG management project it is crucial that one is aware of all current and upcoming environmental regulations that could potentially affect the viability of the project as a voluntary act. The development of stronger environmental regulations could eliminate the potential for GHG emission reduction credit creation and sale if they are not carefully considered.

Table 5.1 is structured in a similar manner to Table 4.1, and outlines the potential regulatory or policy issues, a discussion of the application of the regulatory or policy issue with regard to LFG management projects, and an example of such a regulatory or policy issue. In addition, there is a fourth column to allow for persons evaluating a potential project to use the table as a worksheet.

TABLE 5.1

CHECKLIST FOR APPLICABLE ENVIRONMENTAL AND WASTE MANAGEMENT POLICIES, LEGISLATION, AND REGULATIONS
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

	Regulatory or Policy Issue	Discussion & Rationale for application of Regulatory or Policy Issues to LFG-to-Energy Projects	Special Concerns	Potential Project-Specific Inputs
	Waste Management			
1	Regulatory Authority over Waste Management for location of candidate project or site	• Which levels of government have jurisdiction over solid waste management?	Brazil • The requirement for an environmental assessment and the operating license are under national control • The facility approval is controlled by state regulations Argentina • The Federal Environmental Pact (COFEMA) defines the regulations • Specific municipal and provincial rules are backed by national regulations	
2	Permits and Approvals	• Who issues them/ • What are the timelines and costs to obtain them?	Canada • Provincially regulated permits USA • USEPA, subtitle D outlines landfill controls and state governments issue permits Brazil • National regulations • Approvals and permits issued by State environmental agency • Takes approx. 4 months Argentina	

TABLE 5.1

CHECKLIST FOR APPLICABLE ENVIRONMENTAL AND WASTE MANAGEMENT POLICIES, LEGISLATION, AND REGULATIONS
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

	Regulatory or Policy Issue	Discussion & Rationale for application of Regulatory or Policy Issues to LFG-to-Energy Projects	Special Concerns	Potential Project-Specific Inputs
			• Provincial Health Systems (SIPROSA) created by Law 5652, Sept. 26, 1984	
3	Public Consultation Requirements	• Is public consultation or related involvement required to satisfy the environmental review process? If it is, the time and cost implications need to be identified.	Canada • Provincially regulated permits	
4	Landfill Site Ownership	• Who owns the prospective site and therefore the LFG resource?	Brazil • Can be the generating municipality or the municipality where the landfill is located	
5	Landfill Design and Operating Standards and Requirements	• What are the design requirements for landfills that can influence the LFG generation and resource characteristics? • For example, the nature of cover systems affects both the rate of gas generation and influences the ability to effectively collect the LFG. • Will the LFG utilization project interfere with the landfill site rehabilitation and intended final use?	Brazil • EIA requirement CONAMA resolution No. 001 Jan. 23, 1986 Argentina • Law 5652, Sept. 26, 1984 • Law 7076, Sept. 26, 2000	
6	Waste Disposal Requirements	• Are there constraints on the type of wastes that can go into the landfill such as specific organic or inorganic materials?	Brazil • State environmental agency regs. Argentina • Law 7076, Sept. 26, 2000	

TABLE 5.1

CHECKLIST FOR APPLICABLE ENVIRONMENTAL AND WASTE MANAGEMENT POLICIES, LEGISLATION, AND REGULATIONS
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

	Regulatory or Policy Issue	Discussion & Rationale for application of Regulatory or Policy Issues to LFG-to-Energy Projects	Special Concerns	Potential Project-Specific Inputs
7	Pending Regulations or Policies	• Are there foreseeable legislative or policy changes that will drastically change the incoming waste composition? This item may be critical with respect to the valuation of any potential emission reductions for the potential project.		
	Air Quality			
7	Emissions Testing	• Are there any specific emission testing requirements in any environmental regulations? • What is the frequency of sampling required? • What are the required sampling conditions and sampling methods to be used for testing air impacts?	Brazil • CONAMA resolution No. 005, June 5th, 1989 • Law No. 6938, Aug. 31, 1981 • IBAMA enforced • Each state has specific regulations under PRONAR umbrella Ex. State of San Paulo (CETESB) uses CONAMA resolution No. 003, June 28, 1990 • Frequency is State based	
8	Air Permits and Approvals	• Identify what, if any, air permits or approvals may be required. • Identify applicable discharge criteria. • What level of pretreatment of the LFG, if any, is required to meet applicable regulations?	Brazil • State regulations and approvals based on PRONAR's standards (national reg.) • Discharge criteria resolution No.008 Dec. 6, 1990 and State	

TABLE 5.1

CHECKLIST FOR APPLICABLE ENVIRONMENTAL AND WASTE MANAGEMENT POLICIES, LEGISLATION, AND REGULATIONS
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

	Regulatory or Policy Issue	Discussion & Rationale for application of Regulatory or Policy Issues to LFG-to-Energy Projects	Special Concerns	Potential Project-Specific Inputs
		• Identify any post-commissioning monitoring and reporting requirements.	Environmental Agency regulations • EU Landfill Directive requires operators to control accumulation and migration of LFG and to flare or utilize LFG	
	Water Quality			
9	Regulatory Authority over Water and Surface Water	• LFG projects generate condensate, which is similar to leachate but with higher concentrations of some VOCs. What restrictions govern the handling and disposal of condensate and are any approvals associated with this item.		
10	Stormwater Management and Site Grading Plans	• The nature of the stormwater management and grading plans can have a significant influence on the layout of the LFG collection system and the nature of any condensate controls. There may be permit issues that should be addressed for the stormwater and grading.	Argentina • Law 7076, Sept. 26, 2000	

5.1 Regulatory Bodies and Approvals Requirements

It is important to understand what regulatory body or bodies have jurisdiction over a site. In some cases, such as in Brazil, the landfill may be owned and operated at the municipal level, while state or national legislation governs permits and approvals for the landfill. It is important to be aware of all the regulatory authorities, which may have legislation that affects the operation of the landfill and could potentially affect the success of any LFG management project being considered. It is also important to be aware of all the permits and approvals required for the landfill and who it is that issues them, and at what level of government (or what private company).

The timeline required to obtain permits and approvals must also be known. LFG management projects are time-sensitive because of the decline that occurs in the LFG generation rates following closure of the site. Organic waste materials in LAC represent a significant portion of the refuse stream (more so than in North America, for example) and these wastes typically degrade relatively quickly with a high LFG yield. Hence the LFG recovery system needs to be in place quickly to ensure the capture of the majority of biogases generated.

BOX 5: IMPORTANCE OF PERMITTING IN PROJECT DEVELOPMENT

Permits and approvals are expected constraints to the project schedule and overall project viability. An excellent example of the potential implications for permits and approvals is the case study for South Africa. The major outstanding permit requirement for the project being undertaken in the eThekwini Municipality in South Africa is the environmental impact assessment (EIA). This assessment is required in terms of national South African legislation, but is administered at a provincial level by the KwaZulu Natal Department of Agriculture and Environmental Affairs. Initially, mandated in terms of the Environmental Conservation Act, and now required by the National Environmental Management Act, the impact assessment process requires extensive stakeholder and public consultation, as well as technical assessment, before being reviewed by the relevant authorities. The required tasks for this specific process are extensive as outlined in the following:

- Appointing an independent environmental specialist to conduct the public consultation and manage specialist studies;
- Submitting an application for the project with the KwaZulu Natal Department;
- Develop an initial report and plan of study for public consultation, to be approved by the relevant authority;
- Consult stakeholders, authorities and interested parties extensively regarding the development, and formulate and define the necessary specialist studies required;
- Submit the scoping report and plan of study for assessment to the authorities;
- Conduct the necessary specialist studies, and formulate an environmental impact assessment report to be submitted to the authorities;

- Receive a record of decision either permitting or declining the development plans based on the impact report; and
- Go through the appeals process where any involved party may appeal the decision of the authorities.

The Project Team underestimated the extent and rigor of the EIA requirements in the original project schedule. At the current time, it is expected that the engineering aspects of the project will be unable to commence until June 2004 at the earliest. These types of delays can increase the risk and likelihood of success for a LFGTE project. It is also not often that a private sector developer will be willing or able to develop a project of the size and type envisaged over an extended review period unless there is an unusually attractive profit incentive.

Obtaining permits and approvals can be a significant item on the critical path schedule for a potential project. Since timing is a key element in the project feasibility and economics assessment, this can sometimes be a "make or break" item for a candidate project, and it must be considered a key element in every project assessment.

Public consultation may be required as part of the process to receive permits or approvals for a LFG management project. This requirement is important to identify because of the time and cost involved in undertaking a public consultation process.

5.2 Resource Ownership

Determining ownership of the landfill and subsequently, the LFG resource is of crucial importance when assessing a potential LFG management project. This has implication towards contracts binding the sale of the LFG resource and any potential CERs generated by the project. Clear title to the LFG resource and any associated emission reductions must be identified and tracked throughout the process from identification to eventual status as a CER. There should not be any federal or state policies that imply or restrict ownership of emission reductions in any way.

BOX 6: EMISSION REDUCTION CREDIT OWNERSHIP

It is important that the ownership of any potential emission reduction credits is clearly assigned and that there is no cloud of uncertainty regarding the validity of the credits.

In the case of the Waterloo Landfill in Canada, all rights for any emission reductions associated with the generation of the electrical power were transferred with the sale of power to the utility. The facility obtained and has retained an EcoLogo certification as a green power supplier. In this particular contractual arrangement, the buyer did not ask for or require specific quantification and certification of the emission reductions. In most future projects, this will be a requirement.

An example of a large enclosed drum flare system that is presently in operation at the Keele Valley Landfill Site near Toronto, Canada is provided in the following picture.

This flare system has the capacity to combust more than the equivalent of 2,000,000 tonnes of eCO_2 annually.

Validation and certification of emission reductions have very important implications. It is critical to ensure that regulations do not have the effect of an expropriation of the emission reduction credits. In other words, certified renewable energy will, in most cases, be sold to utilities for distribution to consumers or directly to industrial consumers. The utility companies and industrial consumers will negotiate prices for the purchase of electricity, but may or may not pay a premium to acquire emission reduction credits if they are automatically assigned with the electricity to maintain the certification. If this is adhered to, the right of the generator to sell the CERs independently will be foregone and the generator will thus be deprived of this supplementary economic value.

5.3 Landfill Design and Operating Standards and Requirements

It is critical to have a clear understanding of the current and future design and operating standards for the landfill because these could have negative effects on a potential LFG management project in many ways.

Legislation dictating the daily operations of the landfill has the capacity to effect the generation of LFG if there are requirements for the construction or operations of the landfill. For example, there could be a requirement for the use of a low permeable daily cover, which would impede the ability to collect LFG. There may also be impediments to the use of techniques, such as moisture addition to the waste, as is used in bioreactor landfills to increase the initial rate of LFG generation.

In addition, legislation affecting what type of waste is permitted in a landfill can have negative effects on a LFG management project if there is an emphasis on removing organic material from the waste stream. This is because LFG is generated by the organic fraction of the decomposing waste. The future projections of waste filling are a significant component of the LFG generation projections and are therefore tied directly to the value of the resource and the economic justification necessary to support a project.

It is important to not only have a good understanding of the current regulations and policies governing the design and operations of the landfill, but to also be aware of any upcoming legislation that could affect the viability of a LFG management project. The general life of these projects (10 to 20+ years), especially LFGTE projects, makes them vulnerable to the introduction of future legislation especially with respect to establishing voluntary GHG emissions reductions.

5.4 Air Quality Policies, Legislation, and Regulations

In most jurisdictions within LAC, air quality policies and regulations are in their infancy and still being developed. One important principle that seems to be missed or ignored with respect to LFG projects is that it is the net total emissions before, and after, a project that should be considered in evaluating the merits of a specific project or candidate site. For example, there have been some conflicts in meeting emission reduction targets at some jurisdictions in North America as a result of combustion products other than methane (for example volatile organic compounds, NOx and SOx). It is recommended that the net impact and benefits of all emission reductions be considered together when assessing the merits and benefits of a prospective project. With most LFG management there is a dramatic benefit in CERs. There is also a very significant benefit in reducing the emissions of volatile organic compounds, as they are both green house gas contributors and toxic gas emissions. There is typically a slight increase in NOx and SOx emissions from LFG management projects but the overall air quality benefits far exceed the implications of these minor increases.

5.5 Water Quality Policies, Legislation, and Regulations

One of the most important factors that must always be recognized with LFG management projects is that they are associated with a landfill site. This means that the performance of some of the aspects of landfill design, operations and maintenance other than the LFG management itself can be relevant to the stable long-term performance of a LFG system. LFG gas systems generate condensate as a waste liquid that must be collected and disposed of. The quantities are generally quite small relative to the volumes of leachate that are generated in a landfill. Care should be taken to not impose any restrictions on condensate management and disposal that would be cost prohibitive. Condensate should be allowed to be treated in a similar manner to the leachate generated in the landfill.

5.6 LFG Management Projects as Part of an Integrated Waste Management System

In many countries in LAC, they are still developing waste management policies, regulations and systems. Environmentally healthy management of solid wastes should eventually go beyond simple deposit of the waste in an approved facility and should pursue modifying the overall process stream in an attempt to change non-sustainable production of waste and non-conservative consumption standards. The concept of an integrated life cycle waste management approach presents the unique opportunity of coordinating and reconciling development of a sustainable waste management system that integrates and addresses all of the environmental considerations and constraints in a proactive rather than reactive manner. There are numerous tools and program outlines available to aid in policy and planning for an integrated waste management system, such as the World Bank's Planning Guide CD-ROM, "Strategic Planning Guide for Solid Waste Management". LFG management projects are part of an integrated waste management system and they have great potential to become both an incentive for improvement and to provide additional financial resources that can lead directly to improving the overall waste management system.

There are some key elements fundamental to developing a sound integrated waste management approach that are discussed briefly in the following.

<u>Waste Reduction</u>

Reducing the quantity and nature of the waste that is being generated is fundamental to a successful plan. Waste reduction can only be truly successful if all elements of the society adopt and accept the basic tenets of the program. The nature of products that are produced, how they and handled, packaged and transported must all be considered. The consumer or end-user whether it is industry, government or the general population must all modify current practices to achieve an optimized waste reduction goal.

<u>Maximize Waste Reuse and Recycling</u>

It is important to make a fundamental change in the approach and handling of our "waste" materials. The first concept that is key is that, to the extent practical, materials must be removed from the waste stream through programmed recovery and reuse of materials or through recycling the materials. To do this, it is necessary to develop an entire infrastructure and markets to handle, process, sell and use the recovered materials. All aspects of this sub-industry must be developed in concert. It is not productive or useful to recover materials for which there is no market or demand. Each of the specific materials that could fall into this category will have different practical and economic constraints. The size of the applicable market and the quantity of recoverable or reusable materials will affect the viability of any program. It is expected that movement towards the ideal objectives will be step wise, through the various product streams. It is also likely that because of critical mass considerations, some materials and some residual quantity of waste materials will always be generated and need to be disposed of or treated.

Residual Waste Disposal and Treatment

As noted above, there will be residual waste materials that will need to be handled and processed. LFG management projects are fully compatible with progressive movement towards a sustainable integrated waste management policy. Recognizing that a large portion of the LFG that will be generated over the next 20 or more years is a result of waste that is already deposited in landfill sites, validates that LFG management projects should be a key element of any strategy. Although important to collect LFG, it is a secondary function beyond the disposal of waste at a site. Hence, the need exists to integrate the gas collection system into the landfilling activities.

Also recognizing that, irrespective of the ideal goals and objectives for an integrated waste management approach, the movement towards this type of system will be progressive and not instantaneous, the benefits of LFG management projects can be realized over the foreseeable future. By introducing a financial incentive mechanism into the waste management system, it can aid in improving the overall performance of the system and help to financially support the development of an integrated system approach.

Sustainability

The self-sustainability of the institutional solid waste management must be based on adequate economic instruments and incentives with feasible and sustainable short and medium term implementation. It will be necessary to provide financial support to encourage municipalities to reach economic self-sustainability of municipal waste collection systems through the creation and implementation of collection and excise mechanisms compatible with the people's payment capacity.

Governments need to achieve sustainable development that is based on ecologically efficient use of natural, social, and economic resources and integrate environmental, economic, and social factors.

Other Applicable Considerations

In LAC, the concept and framework for an integrated waste management system represent ideals for policy development. In the near term, one of the first steps is to ensure that waste management collection and disposal services are made available throughout all of the respective countries and regions. It is also necessary to ensure that the wastes are disposed in sites that are selected for their natural protection characteristics and prepared with consideration for current landfill design practices and engineered controls. The respective populations need to integrate the concepts of solid waste management into the day-to-day life of the people to make them a part of the solution.

6

International Carbon Finance

6.1 The Kyoto Protocol and the Carbon Market

The Kyoto Protocol was signed in 1997, following the 1992 United Nations Framework Convention on Climate Change (UNFCCC). The Protocol established greenhouse gas (GHG) emission-reduction targets for developed countries and transition economies, the so-called Annex B countries; a greenhouse gas emission-trading program; and the need for future meetings to establish penalties for failure to meet targets and the rules and regulations of the new emission trading program (Markarenko, 2002). Non-Annex B countries, including all countries in LAC region, have no quantitative commitment under the Protocol. Overall, the Kyoto Protocol states that emissions of six GHGs in Annex B countries must be 5.2 percent below their 1990 levels, on average, between 2008 to 2012. On top of domestic actions, the Protocol allows countries to meet their commitments through three 'flexibility mechanisms':

- International Emissions Trading (ET) – trading of emission permits between industrialized countries.
- Joint Implementation (JI) – creating emission offsets resulting from projects implemented in industrialized countries.
- Clean Development Mechanism (CDM) – crediting of emission offsets resulting from projects in non-Annex B countries. Once credited, the offsets are called Certified Emission Reductions (CERs).

Global carbon markets have started to form as a result of the growing recognition that the future will include a globally-based carbon-constrained environmental system(s), and therefore political and economic institutions must modify and/or reduce their dependency on fossil fuels. Since the inception of the Kyoto Protocol, several international carbon funds have been established to assist in the development of projects that reduce anthropogenic carbon emissions.

The Kyoto Protocol reflects these constraints and acts to encourage effected governments, corporations and international bodies to take measures ahead of possible regulatory measures. (Pronove, 2002) The Protocol results in what is generally referred to as a "cap and trade" system, where the committed country is given a level at which it must "cap" its emissions. As these countries place regulatory requirements on their domestic companies to meet target emission reductions, regulatory pressure on private companies to meet domestic caps are expected to create a demand for carbon offset credits offshore where it is presumed to be less expensive.

An example of a few of the many carbon funds established in the wake of the Kyoto Protocol include three funds established by the World Bank, the Prototype Carbon Fund (PCF, *prototypecarbonfund.org*), the Community Development Carbon Fund (CDCF, *communitycarbonfund.org*), and the BioCarbon Fund (*biocarbonfund.org*). The United Nations and Earth Council Institute have implemented the UNCTAD/Earth Council Institute Geneva (ECIG) Carbon Market Programme (*r0.unctad.org/ghg/*). In addition, the government of The Netherlands has established Carboncredits.nl (*carboncredits.nl*), while the United Kingdom has established The Carbon Trust *(www.thecarbontrust.co.uk)* to act like a venture capitalist group funding British-based carbon reduction technology. In the United States, the Chicago Climate Exchange (CCX) (*www.chicagoclimatex.com*) is being developed as a self-regulatory, multi-national, multi-sector marketplace for GHG emission reductions. Each of the carbon funds or potential CER buyers is focused on somewhat different objectives and each has different qualification requirements for the type of projects that are eligible for funding. These funds and buyers also have different procedures for establishing which projects qualify and the way emissions are calculated, reviewed and certified. However, each of these funds relies on the activation of the Kyoto Protocol and the CDM and JI process criteria to make the emission reductions achieved "real".

The CDM of the Protocol, which allows for the creation, issuance, and sale of CERs for projects undertaken in developing countries, increases the financial incentive for agencies or companies interested in pursuing the transfer of clean technologies. The addition of CER sales to a project cash flow may increase the financial internal rates of return (IRR) for a project. This is especially true for solid waste projects related to the collection and destruction or utilization of LFG. Over a 100-year time horizon, in comparison with carbon dioxide, methane has a global warming potential (GWP) 21 times more efficient at trapping heat within the atmosphere. Therefore, the destruction of methane generates substantively more emission reductions per volume of gas than does carbon dioxide. Recently there have been studies that suggest the GWP of methane should be increased from 21 to 23 (UNFCCC Third Assessment Report), but this has yet to gain global acceptance. If this did occur, it would only serve to improve the economics of LFG management projects. On average, the IRR increase for solid waste projects involving the destruction/utilization of methane is greater than five percent (Fernandez-Asin, 2002).

BOX 7: IMPLICATIONS OF EMISSION REDUCTION CREDITS TO VIABILITY OF LFGTE PROJECTS

The advent of the carbon market is encouraging a review of candidate projects in LAC and the Caribbean. The carbon market is still in its infancy and it is currently difficult to predict what final form the market will take. What is a certainty is that the addition of revenue from the sale of emission reductions would make LFG management projects a lot more attractive to develop for candidate landfill sites that would otherwise not be provided with LFG control systems, or which would have much reduced control systems.

It is not possible to overstate the importance of the consideration of emission reductions to the viability of a LFG project. For example, the eThekwini LFGTE project in South Africa has been under consideration since 1995, but the project was catalyzed by the intervention of the World Bank, the Prototype Carbon Fund (PCF), and the World Summit on Sustainable Development. The project involves three landfills and a combined total of approximately 12.5 million tonnes of waste. Prior to PCF involvement in the project, the collection and destruction of LFG at the sites were largely limited by budgetary constraints. The introduction of funds from the sale of emission reductions will allow an expansion of the existing LFG collection infrastructure at the site and allow for investment in a LFGTE project. The project is still in the development phase, due in large part to a very lengthy environmental approvals process discussed in Box 5, but the initial economic analysis shows that revenue from the sale of CERs would help recover the capital costs for further development of the LFG collection system. It would also supplement the cost of energy production so that it could be sold for 90 percent of the current rate that is being offered to the Electricity Department by the South Africa's sole energy utility, which uses produces primarily coal-generated power.

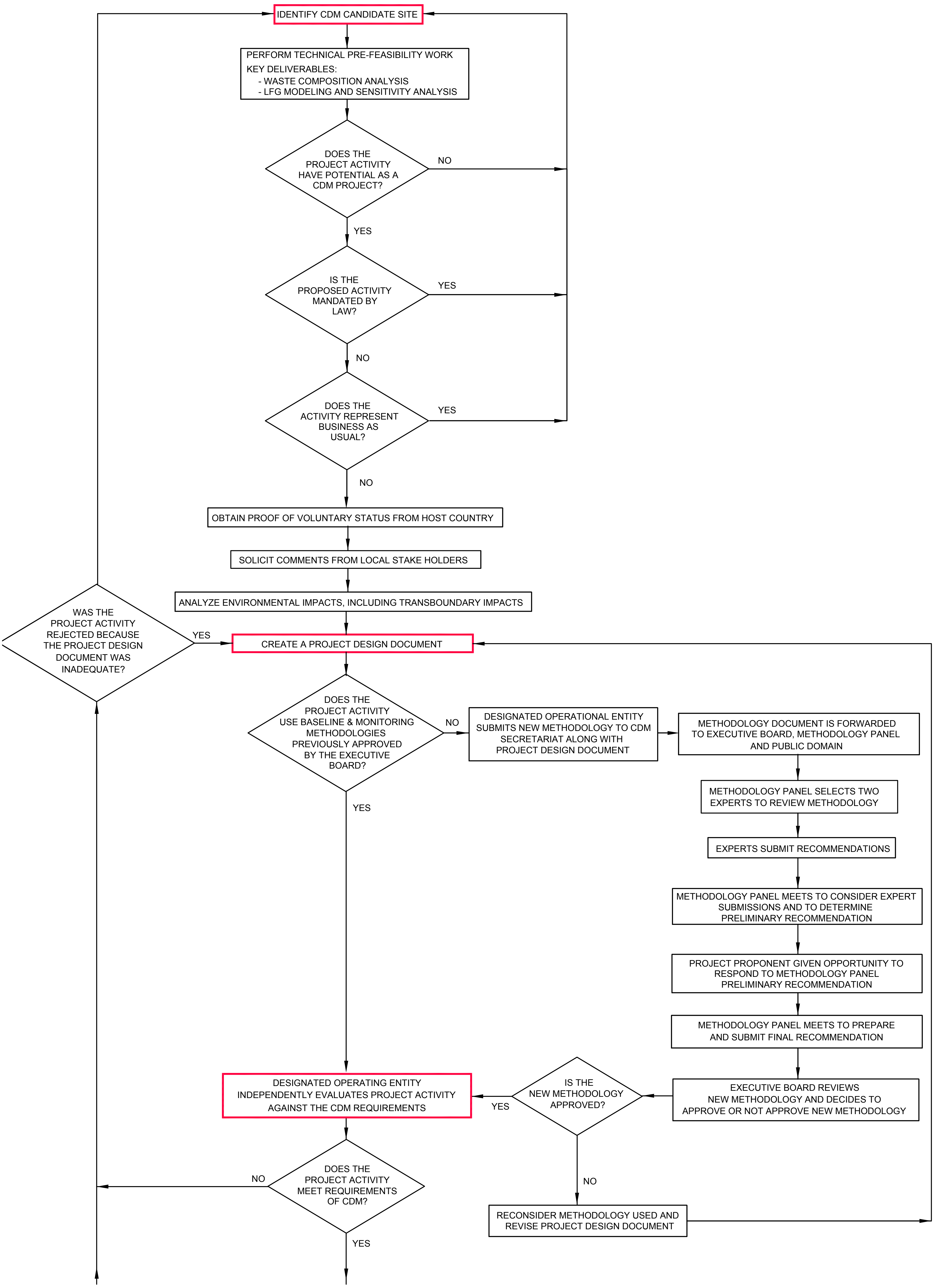
Similar testimonials to the need for consideration of emission reductions can be made for the European, Canadian and Mexican case studies. All of the successful case studies have utilized and leveraged the environmental benefits associated with emission reductions to make them viable and to obtain the public and regulatory support necessary to develop the projects.

Other Annex B entities, even those outside the Kyoto umbrella, might be interested in buying emission credits. For example, State-level legislation in some U.S. States requires power plants to limit their carbon dioxide emissions, and allow the purchase of offshore emission credits to meet these requirements (e.g., Oregon). Individual firms might also be interested in investing in such projects out of the Kyoto umbrella, for good public relations even if there may be no regulatory requirement to do so.

Detailed requirements may vary depending on the legal regime under which the buyer wants the emission offsets to be validated. However, the core concepts and components of any carbon finance project are likely to be very similar. The following material is based on the requirements for the Clean Development Mechanism (CDM) of the Kyoto Protocol and is considered typical of current carbon emission credit and carbon financing activities.

6.2 The CDM Project Cycle

In order to create CERs, all CDM projects must follow a specified procedure (the CDM Project Cycle) outlined by the UNFCCC on their website (*www.unfccc.int*). The following section briefly describes this procedure. Figure 6.1 provides a visual tool to illustrate this process. Parties interested in the details of the CDM Project Cycle should refer to the UNFCCC website.



MILESTONE

figure 6.1a

FLOWCHART OF LFG PROJECT ACTIVITY CYCLE
PRE-INVESTMENT PHASE

HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

19399-10(006)GN-WA001 FEB 02/2004

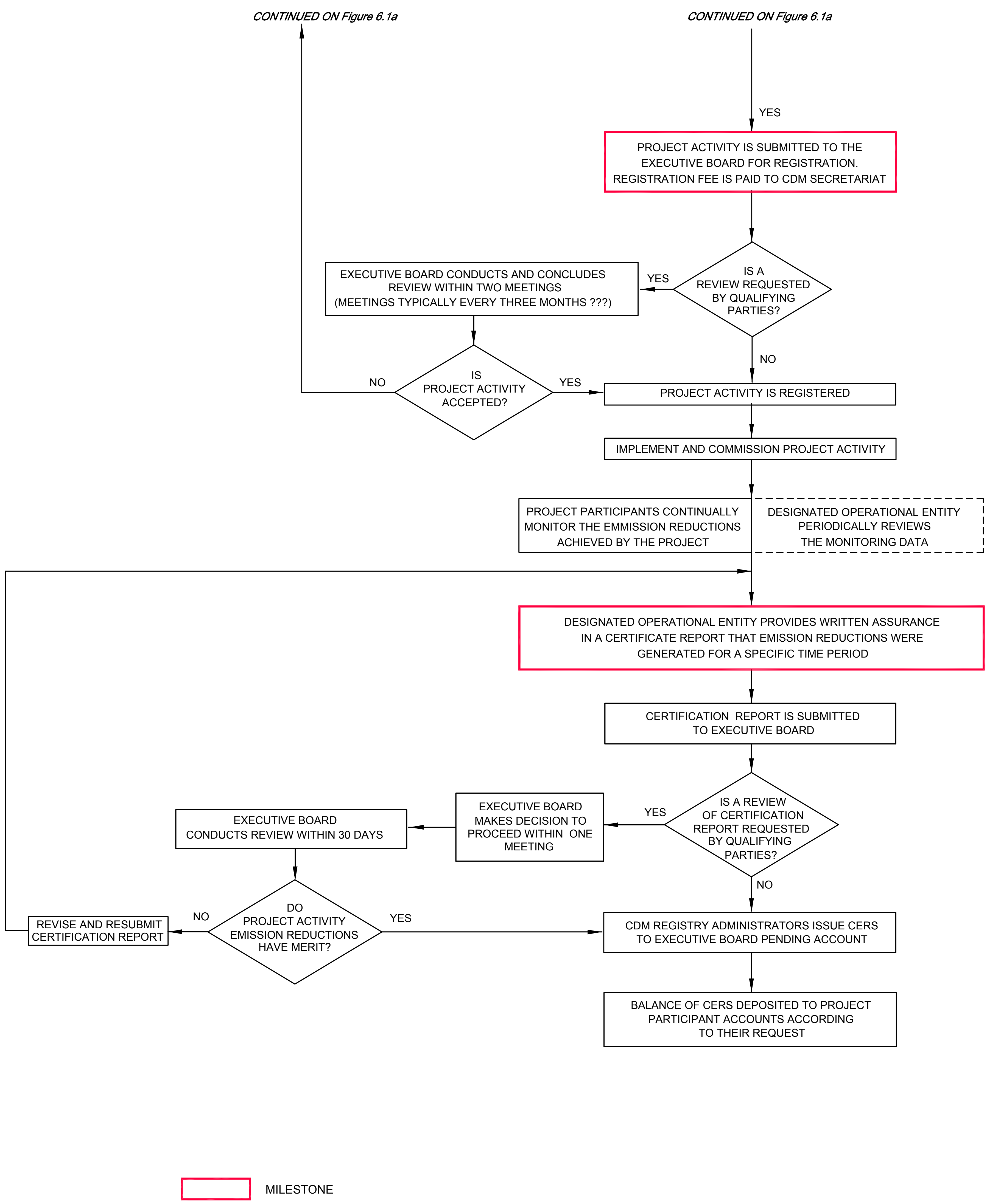


figure 6.1b

FLOW CHART OF LFG PROJECT ACTIVITY CYCLE
PROJECT IMPLEMENTATION PHASE
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

19399-10(006)GN-WA002 FEB 02/2004

6.2.1 Participating Entities

The CDM Project Cycle requires the involvement of a number of different entities. The following outlines the names and functions of the various entities participating in the CDM cycle.

Conference of Parties/Meeting of Parties (COP/MOP) – This body has authority over, and provides guidance to, the CDM. The COP/MOP makes the final decision on all recommendations made by the EB regarding DOEs and accreditation standards. The COP/MOP is also responsible to review the annual reports of the EB, and the regional distribution of both DOEs and CDM projects. In addition, the COP/MOP is to assist in the arrangement of CDM funds.

Executive Board (EB) - The Executive Board is comprised of ten members, five representing each of the UN Regional Groups, two representing Annex B countries (countries that have committed to emission reduction targets through the Kyoto Protocol), two representing non-Annex B countries (countries that have not committed to emission reduction targets through the Kyoto Protocol) and one representing small island developing states. The EB is fully accountable to the COP/MOP. It is responsible for supervising the CDM including making recommendations to the COP/MOP on procedures, accreditation of DOEs, and regional distribution of projects and accredited DOEs. In addition, the EB publicizes information as part of the CDM and acts as a record keeper for CDM projects.

Project Participants (PP) – Private and/or public entities interested in participating in the CDM process are obligated to ensure that the project is consistent with the submitted documentation. They are responsible for choosing an accredited DOE to validate and verify their project activity as part of the CDM project cycle. At the registration of the project, a PP will sign a document indicating the methods of communication to be used with the EB and the allocation of CERs.

Designated Operational Entity (DOE) – These entities are accountable to the COP/MOP through the EB and must comply with the procedures set out by the EB. They are selected by the PP, certified by the EB, and are responsible for validating proposed CDM project activities and verifying and certifying anthropogenic GHG emission reductions. They are responsible for disclosing any possible conflict of interest arising from a CDM project, as well as maintaining a record of each project for which they have carried out validation, verification, and certification.

Applicant Entity (AE) – This entity is permitted to submit a new methodology for review by the EB. This is permitted assuming that a CDM assessment team has been assigned by the EB to the AE, and that the AE maintains documentation of the new methodology submitted to the EB.

Designated National Authority (DNA) - All PP are required to select a DNA for the CDM process (the CDM office). The CDM Secretariat posts this authority publicly. The PP is required to obtain written proof from the DNA that the project activity being submitted to the CDM process is voluntary and is consistent with the sustainable development in the host country.

CDM Secretariat – The Secretariat is responsible for providing technical and secretarial services to the EB, as well as other CDM sub-committees. This includes the dissemination of information submitted to the EB, such as the project design document or the approved methodology descriptions, through the CDM website and keeping a record of these documents throughout the project life. They also identify promising projects, provide advice and promote projects to outside investors.

6.2.2 CDM Project Activity Cycle Procedures

The procedure to be followed in applying for a CDM project is continually being refined as the modalities of the Kyoto Protocol evolve; however, the basic premise of each milestone has been defined and is presented below. Refer to Figure 6.1 for a visual outline of the milestones incorporating the CDM Project Cycle in the form of a flowchart.

Design A project activity is proposed by submitting a Project Design Document (CDM-PDD) to the DOE. The CDM-PDD includes a general description of the project, a description of the baseline methodology, the duration of the project/crediting period, the monitoring methodology and plan, calculations of the GHG emissions, environmental impacts and stakeholder comments. The format for the CDM-PDD is outlined in Annex B of Decision 17/CP.7 (*cdm.unfccc.int/Reference/Documents/cdmmp*). In addition, the PP is required to obtain written proof from the Host country, through the DNA, that the project is a voluntary action.

If the proposed project activity utilizes a baseline or monitoring methodology that has not previously been approved by the EB, then that methodology is to be submitted to the EB through a DOE or AE by completing the relevant documentation for inclusion in the CDM-PDD.

New Methodology — The process for evaluating a new methodology takes approximately four months. The proposed methodology is forwarded to both the EB and a methodology panel. In addition, the methodology is made available for public review. The methodology panel chooses two experts to evaluate the proposed methodology and submit recommendations to the EB. The methodology panel reviews these recommendations and formulates their own recommendation, which is then considered by the EB. The EB then either approves or rejects the new methodology.

Validation — The DOE independently evaluates the project activity on the basis of the CDM-PDD against the requirements of the CDM. These requirements include written proof from the Host country that the voluntary undertaking of the project beyond all regulations from the host country or other regulatory body with jurisdiction over the site of the CDM project activity. It is also required that the host

	country is a non-Annex B country. The PP must include in their CDM-PDD and supporting documentation, evidence that they have solicited comments from local stakeholders regarding the project activity, analyzed the environmental impact of the project including transboundary impacts, that the ERs resulting from the project are additional, within the project boundary, and can be reasonably attributed to the project activity. It must also be confirmed that the methodologies used to monitor the ERs is either a methodology previously approved by the EB, or that a submission has been made to the EB for review and approval of the new methodology. The DOE is also responsible, as part of the validation process, for soliciting and receiving comments from Parties, stakeholders and UNFCCC accredited non-governmental organizations (NGOs).
Registration	The project activity is submitted for registration once the DOE has determined that the project is considered valid. This validation is conveyed to the EB through the submission of a validation report, a request for registration and an explanation of how comments were received during the validation process. Registration of the project by the EB will be complete within eight weeks of receiving the request for registration and the registration fee, unless one of the Parties or three members of the EB request a review. If a review is requested, it must be dealt within two meetings of the COP/MOP (approximately six months).
Verification	The DOE will periodically monitor the project activity to verify the emission reductions achieved by the project. This may include site visits, a review of performance records, interviews with project participants and local stakeholders, collection of measurements, observation of established practices, and testing of the accuracy of monitoring equipment to ensure the validity of the emission reductions and the methodologies carried out to calculate them. The results of the verification will be made available to both the public and the EB in the form of a verification report.
Certification	The DOE issues a written report, based on its verification report, stating that the project activity has achieved a certain amount of ERs in a specified time period. This document is to be made available to the PP, Parties, EB, and the public. This report also constitutes a request for the issuance of CERs.
Issuance	The issuance of CERs will be considered final after 15 days, unless a Party of the PP or at least three members of the EB request a review. If a review is requested, it shall be conducted within 30

days of the decision to have a review and the decision shall be made known to the PP and the public.

Under the instruction of the EB, the CDM registry administrator will issue the specified quantity of CERs into the pending account of the EB in the CDM registry. The number of CERs required to cover the costs of expenses and to assist in meeting costs of adaptation will be placed in the appropriate CDM management accounts. The balance of the CERs will be placed into the accounts of the PP according to their request.

6.3 The Additionality Concept and Emission Reduction Calculations

The CDM definition of the additionality concept as defined in UNFCCC Decision 17/CP.7, #43 states:

> *"A CDM project activity is additional if anthropogenic emissions of greenhouse gases by sources are reduced below those that would have occurred in the absence of the registered CDM project activity."*

The Kyoto Protocol states, in Article 12.C, that "Emission reductions resulting from each project activity shall be certified by operational entities … on the basis of: … reductions in emissions that are ***additional*** to any that would occur in the absence of the certified project activity". This concept of additionality is understood to mean the difference between "business as usual" and the proposed project activity. This concept of additionality as applied to LFG management has two aspects: the emission reductions from the combustion of LFG and the emission reductions associated with the use of LFG fuel to offset other fuel uses. The additional emission reductions (ERs) can be calculated as the positive difference between the baseline emissions, or emissions resulting from operations under a business as usual scenario, and the emissions resulting after the undertaking of the proposed project. This concept provides the necessity to establish a baseline scenario of emissions that would occur if the project did not take place and careful monitoring of emissions throughout the project activity to quantify and to verify the ERs resulting from the project.

As stated in the previous section, the methodology used for establishing the baseline scenario and emissions reductions resulting from the project activity must be approved by the EB prior to the registration of the project with the CDM Secretariat.

6.4 Validation/Verification Processes

The Project Design Document (PDD) describes in detail the project activity to be undertaken by the project participants. The information that should be included in this document is listed in Annex B of UNFCCC Decision 17/CP.7, Modalities and procedures for a clean development mechanism as defined in Article 12 of the Kyoto Protocol *(available at cdm.unfccc.int/Reference/Documents/cdmmp)***.**

Validation is the independent evaluation by a DOE of the project activity, based on the PDD, against the requirements of the CDM as listed in UNFCCC Decision 17/CP.7. The criteria for validation are listed in UNFCCC Decision 17/CP.7, #37. This step is critical because validation of the project activity and subsequent monitoring methodologies is a pre-requisite for registration of the project activity with the CDM. Additional clarification on the requirements for validation to be checked by the DOE are outlined in the UNFCCC Report on the Eighth Meeting of the Executive Board, Appendix 3, Clarifications of Validation Requirements to be Checked by a Designated Operational Entity.

The CDM EB evaluates and designates both domestic legal bodies and international organizations capable of validating potential CDM project activities as DOEs. This designation is made on a provisional basis pending confirmation by the COP/MOP.

Once a project is validated and registered with the CDM, it must then be verified that the monitoring procedures set out in the PDD are followed accurately and the data collected from these procedures is accurate. The real data collected must also be cross-referenced with the assumptions made to calculate the expected ERs resulting from the project activity to test their accuracy and adjust any assumptions that prove incorrect. This process is carried out by the DOEs and takes place periodically over the life of the project.

The verification process is completed with the preparation of a verification report, in which the DOE certifies in writing that the project activity resulted in the reduction of anthropogenic GHG emissions during the discrete time period over which the project activity took place.

6.5 LFG Utilization Projects and Important Validation/Verification Issues

Validation and verification for CERs generated as a result of LFG management projects are primarily concerned with assessment of the project baseline, additionality, and measuring and monitoring issues. LFG management have one very significant advantage over many projects or actions that may tend to yield emission reductions, that being that they are readily and easily verifiable using actual recorded data for both the measured flows and characterization of the LFG fuel that has been used. There will also be recorded data demonstrating the performance of the equipment that uses the fuel. Essentially this means that verification process is simple and utilizes direct reading instrumentation with straight-line calculations to present the emission reductions associated with the combustion of the LFG. The potential for calculating any potential supplementary CERs for offset or displacement recognition is similarly simple and straight forward, which is based on recorded data.

Although as noted above, verification is quite simple for LFG management projects, the validation process still must satisfy all of the requirements to achieve CER or similar status recognition. To establish baseline and additionality of emission reductions for each potential project, understanding the LFG resource is critical. It is important that parties interested in undertaking an emissions reduction project carefully assess the prospective landfill site and understand the sensitivities of the site and how this will affect the ultimate success of the project. With respect to Methane emissions, safety and social concerns should be examined, and potential benefits of project assessed from this perspective. It also important to consider how a LFG management project will affect the waste filling operations, as this is the primary objective of the landfill's existence.

The Scholl Canyon Model, explained in Section 2.2, can be used to develop methane production estimates and sensitivity analyses over the life of the landfill as shown in Section 8.0. The methane produced by the landfill over time from the beginning of landfilling activities to the time when there is no longer sufficient LFG to collect would be proposed to represent the "business as usual" or baseline condition for a potential emission reduction project. Project baseline conditions for emission reduction calculation purposes may be influenced by pre-existing LFG control measures at the landfill or by the requirements on any operating permits that may relate specifically to LFG control.

In creating and offering carbon credits on an international market, it is important to understand that there are a number of factors that should be accounted for in setting the price for any credits offered. There are a number of information needs that may arise in order to establish the validity of the emission reductions. Initial estimates for the baseline study, as part of the feasibility study for the project, estimate a time frame of 10-14 weeks and a cost of about US $25,000 - US $50,000, and proceeding through the full CDM Cycle will likely total around US $150,000- US $250,000.

In projects where there are a number of parties contributing to the project (e.g., wastes are produced in one municipality while the landfill is located in another), it is important to establish the undeniable ownership of credits, as they represent a saleable commodity. Other concerns with the establishment of emission reductions that influence the validation process are the evolving status of the CDM cycle process and Host country regulatory criteria development.

In summary, LFG management should be straightforward to verify. The more critical aspect is the validation of qualifying emission reductions. These must be handled on a site specific and jurisdiction specific basis.

6.6 Carbon Market Development

The carbon market development and associated terminology of the reduction in carbon-based emissions is complicated. Before parties interested in undertaking potential GHG reductions purchase, or sale, it is helpful to understand that the "market" is currently in transition and evolving with every annual Conference of Parties (COP) that seeks to clarify the terms, conditions and methodologies required to implement the Kyoto Protocol. As such, the "real" value of these emission reductions is still largely speculative in nature even though some monies and rights have changed hands. Most of the 'deals' that have been enacted have been those of voluntary early action.

Preliminary test markets for carbon credits and information sources for further information are as follows:

- The Prototype Carbon Fund, *prototypecarbonfund.org*;
- The Community Development Carbon Fund, *communitycarbonfund.org*;
- The BioCarbon Fund, *biocarbonfund.org*;
- The UNCTAD/Earth Council Institute Geneva (ECIG) Carbon Market Program, *r0.unctad.org/ghg/*;
- Carboncredits.nl, *carboncredits.nl*;
- The Carbon Trust, *www.thecarbontrust.co.uk*; and
- The Chicago Climate Exchange (CCX), *www.chicagoclimatex.com*.

6.7 Carbon Sales Contracting Approaches

The refinement of legal documents pertinent to the sale and transfer of carbon credits is constantly changing with subsequent meetings of the Conference of Parties (COP), with each meeting serving to further clarify the details of the Kyoto Protocol.

The legal instruments used in the establishment of a project activity will vary depending on whether the project is receiving funding through a carbon fund, or whether they are participating directly in the CDM or JI project cycle.

Contracts are required to establish agreements between all parties participating in the project. As part of engaging in any type carbon trading activities, contracts need to be established between:

- all parties involved in carrying out the emission reducing project;
- the carbon fund or any other entity providing funds to finance the project and the project participants;
- the DOE selected to evaluate, validate and verify the emission reductions produced by the project and the project participants; and
- the CDM funding entity and the project participants (upon registration of the funding).

The details of these agreements should be established in project contracts as discussed in section 9.0 of this Handbook.

The World Bank's PCF is one potential source of funding for projects adhering to the CDM project criteria They have implemented a series of five contracts as part of their project process. These contracts are discussed below as an example of one carbon fund's system of contract documentation. The various carbon funds, in addition to other funding sources, will have similar objectives and content but different documentation associated with them. The five legal documents currently used by the PCF in its emission reduction purchase transactions are:

- Letter of Project Endorsement or No Objection (LoE);
- Letter of Intent (LoI);
- Letter of Approval (LoA);
- Emission Reductions Purchase Agreement (ERPA); and
- Host Country Agreement (HCA) – note that this is only required for Joint Implementation (JI) projects.

The LoE is written from the project's host country (Host Country) to the World Bank acting as Trustee for the PCF (Trustee). The LoE is a unilateral endorsement by the Host Country of the Project and is usually sought by the PCF once a potentially viable project has been identified. The purpose of the LoE is to minimize the risk to the PCF that a Host Country may later determine that the project is not in line with its sustainability criteria and (or for other reasons) refuse to issue a LoA. In circumstances where a LoA has already been granted, or will be available within a very short period of time, the Trustee may waive the requirement for the LoE.

The LoI is the first written document signed between the Project Entity and the Trustee. The LoI is primarily a letter of exclusivity, which provides the PCF the exclusive rights to negotiate the terms of purchase of emission reductions from the Project Entity. If the Project Entity unilaterally withdraws from the negotiations, the LoI requires it to repay a capped amount of project preparation costs.

The LoA is a formal letter from the Host Country in which the Host Country grants formal approval of the project for the purpose of Article 12 of the Kyoto Protocol. One of the key requirements of the LoA is the confirmation that the project contributes towards the Host Country's sustainable development. The LoA is required by the Kyoto Protocol and is therefore critical in the acceptance of the project by the UNFCCC.

The ERPA is the principal legal document governing the purchase and sale of emission reductions by the PCF. Under the ERPA, the project entity agrees to sell all rights, title and interests in and to all, or a specified part of, the greenhouse gas reductions generated by the project. The group of rights, title and interests is defined as the "Emission Reductions" (or ERs). The Trustee agrees to pay the specified purchase price on delivery of the verification report verifying the number of greenhouse gas emission reductions produced. In addition to the key purchase and sale provisions within the ERPA are a number of sections relating to various obligations, representations and warrantees as well as conditions precedent the disbursement of funds which cover activities such as the successful implementation of the project and management of identified project risks.

The HCA is required for JI projects only, and is entered into between the Host Country and the Trustee. Within the HCA, the Host Country agrees to transfer the amount of emission reduction units (ERUs) equivalent to the quantity of ERs generated by the project into the accounts of the PCF project participants. Note that the actual transfer is not scheduled to occur until the beginning of the first commitment period of the Kyoto Protocol.

6.8 Risk Issues in Carbon Financing

There are a number of risk factors related to LFG management projects and carbon finance. These risk factors can focus on either the generator of the emission reduction credits or the purchaser of the credits.

Some potential sources of risk may include:

- time issues related to both obtaining contracts and validation of the emission reductions;
- term length of contracts insufficient for project to be economical;
- value of emission reductions over time;
- potential liabilities for projects not achieving sufficient emission reductions;
- dependency of project "voluntary status" on host country legislation; and
- scientific accuracy of project selection, monitoring and controlling.

The priority of the buyer of CERs will essentially be to get the lowest possible cost for the emissions credits being purchased. Emphasis on minimal transaction complexity is preferred. The following list provides some consideration for purchasers (and sellers understanding) to minimise potential carbon financing risks as follows:

- packaged credits for ease of negotiating agreements;
- seller guarantees, insures the validity of reductions;
- low credit risk and low counter-party performance risks;
- greater demand for simple transactions rather than investments. Very important that the seller create an effective selling package; and
- ownership of reductions must be clearly established by contract. A third party company must be engaged for quantification, monitoring and verification.

The priority of the seller of CERs on the other hand, will desire the highest possible price for the emission credit being purchased. Some consideration for an offering that will assist in minimizing risk and enhance potential marketing effort of the emission reductions should include:

- quantity and price;
- year the action was taken;
- year the reduction was generated;

- location and method of reduction;
- baseline year to measure the incremental change; and
- liability accepted by seller.

Although the preceding discussion presents a brief outline to the topic of international carbon finance, and the UNFCCC CDM project activity cycle, a more comprehensive collection of reference materials is available from the UNFCCC CDM website at *www.unfccc.int/cdm*. Persons interested in potentially developing a project should consult this website for detailed information relating to the CDM process, updates that may occur, document requirements, and appropriate templates.

PART 3 – ASSESSING AND DEVELOPING LFG MANAGEMENT PROJECTS

7

Risk Factors Related to Environmental, Financial and Resource Management Aspects of LFG Management Projects

Increasing development of LFGTE projects in North America and Europe over the past decade has increased investor confidence in LFGTE projects. However, energy recovery from LFG is still not considered a mature industry, and it often operates at the margins of economic viability and engineering knowledge with non-economic incentives driving some of the project developments. Therefore the risks associated with LFGTE projects must be well understood and conveyed, as these factors will lead potential developers, end users, and/or financiers to perceive them as high-risk projects.

In the context of the Handbook, risk is being used to refer to all aspects of a project that cannot reasonably be known prior to commencing a project and making the required financial and time commitments necessary to implement a LFGTE project. This includes risks or uncertainties that relate to:

- the generation rate and availability of the LFG;
- the technology used to collect and utilize the LFG; and
- the potential source(s) of project revenue.

LFGTE technology is proven and has real potential for sites at which the LFG generation, market, legislative and investment conditions are conducive to a site-specific development. However, the regulations and policies regarding LFG utilization are still developing throughout LAC, and although these policies and regulations have the potential to be shaped in favor of developing such projects, their present uncertain status represents a risk and a concern to prospective developers and financing institutions. With the potential future development of the international carbon market, there is also an opportunity to further improve the return of investment of LFGTE projects to increase the likelihood that they will become a reality in LAC.

7.1 LFG Availability Risks

The mechanisms for LFG generation and the factors, which affect the ultimate quantities and generation rate of the LFG, are discussed in Section 2.0. A shortfall in the amount of LFG available will have serious impact on the success of any LFG management project that relies on LFG as a direct or indirect source of revenue. There are three areas where LFG availability risk are found: the quantity of waste that may be available to produce the LFG fuel; the characteristics of the waste that produce the LFG fuel; and the in-situ environment that controls the process of anaerobic decomposition that to produce the LFG fuel.

The first area of risk is the real quantity of waste available. Risk is introduced if there is uncertainty about the amount of waste already at the site, or if there is doubt with regards to the future quantities of waste to be accepted and disposed of at a candidate site. The second source of risk is uncertainty about the percentage of the waste that is organic, both presently in a candidate landfill and in future waste streams, and therefore will contribute to the future LFG fuel resource. In the Scholl Canyon Model, a range of L_o values represents this uncertainty. The third source of risk is uncertainty about the conditions under which the waste is decomposing. This is represented in the Scholl Canyon Model by a range of k values, based on the conditions at the site.

Some of the risk or uncertainty can be alleviated by pumping test data used in conjunction with the LFG modeling to demonstrate current LFG quality and quantities and help refine the parameters input to the model. However, this does not alleviate all the risk as pumping tests can only indicate the resource for the period of the field test and cannot provide any indication of future gas resource. Typically, in order to obtain financing for a utilization project, a private company will require a reasonable level of assurance that LFG production and collection rate models are representative of actual conditions.

The availability risk can be reduced and managed in a number of ways:

- by applying a conservative (low) multiplier against the modeled LFG recovery curve to protect against any shortfall in available LFG fuel:

- by undertaking to construct and operate the LFG collection system for some minimum agreed period to verify the presence and quantity of the LFG resource;
- by staging the development in Phases to minimize that capital risks associated with over-sizing the LFG utilization system, which is the major cost component of a project; and
- by utilizing any or all of the above in some combination.

Quantifying this risk factor, or any of those to follow, is difficult and there is no simple answer or formula that can be used. The basic principle that the higher the LFG recovery percentage that is assumed, the higher are the inherent project risks is somewhat self evident but no easier to quantity and must be done on a project-specific basis.

BOX 8: IMPORTANCE OF DUE DILIGENCE REVIEW OF LFG RESOURCE POTENTIAL

A pumping test of the LFG resource potential can help to reduce some of the uncertainty in predicting the amount of LFG available at a site and it can provide some added confidence to financing partners to the project.

The case study for the Kemerburgaz Landfill in Turkey provides a clear example of why the LFG resource analysis, including the pumping trial, should be the responsibility of parties that have a stake in the results to provide incentive for properly completing and interpreting the test results. At this site, the pumping trial appeared to indicate that there was sufficient LFG available at the site to support the generation of 4 – 6 MW of electricity. The pumping trial was undertaken by a Contractor unfamiliar with the nature and importance of the pumping test and without any vested interest or liabilities associated with the results of the testing. Subsequent to the field test, the first stage of the plant was built with the capacity to generate 4 MW of electricity. The site has, to date, been unable to support the first phase of the LFGTE development. At this point, it is unclear whether there are LFG resource issues or system performance issues that are the cause of the fuel shortfall. This case study example reinforces that the most critical factor for every LFGTE project is to know and understand both the site and the fuel resource to the extent practical, and to ensure that there is flexibility in the design basis and performance expectations for the facility. There is a great deal of financial risk incurred if the LFG fuel resource is improperly evaluated. Parties with proven experience with LFG projects should undertake the assessment, which then should be carefully reviewed by parties with a stake in the success of the contract. The subsequent picture reinforces and illustrates some of the key elements of monitoring the LFG resource to ensure that there is a sound understanding of the fuel potential and that high reliability of the fuel supply can be sustained.

7.2 LFG Technology Risks

Another source of risk with LFGTE projects is the equipment used to collect and manage the LFG and the operation thereof. The technologies to collect and utilize the LFG fuel are generally well developed and are reliable. It is not the technologies or equipment that poses any project risk but rather, it is the site-specific conditions that may limit the application and/or effectiveness of the proven technologies.

All the LFG that is being generated within the refuse cannot be collected. A well designed and operated LFG collection system can typically collect 75 percent or more of the total quantity of LFG that is generated. In the previous subsection, it was noted that the quantity of LFG that is generated is only estimated and the estimate is only as good as the available data and application of the LFG modeling assessment.

Additional risk associated with LFG collection rate is associated with O&M of the LFG collection systems. Poor or improper operation and maintenance (O&M) may result in deterioration of the LFG collection system and reduced LFG quantity and quality. This can significantly impact the economics of utilization and may be of considerable concern to the owner of the utilization facility. Understanding the responsibility and obligations of all parties is critical. A landfill site operates under dynamic conditions and it is crucial that the O&M program be proactive and able to adapt and change with time. There will, of necessity, be an ongoing program of well field repair, replacement, and expansion required to address the changing conditions on an evolving landfill site.

There are potentially serious implications (e.g., landfill fires) related to improper operation of the gas recovery system or overdrawing on a system. Over-pumping from an LFG extraction well can have serious safety implications but it also can negatively affect the fuel supply by diluting and reducing the available LFG quantity, therefore reducing its heating value (ideally the collected LFG is approximately 50 percent by volume methane). It must always be remembered that a well designed and operated LFG extraction well system can still have widely varying collection rates from individual wells because of the extreme heterogeneity of the waste mass.

In order to offset the risks, it important that every project utilize a life-cycle cost analyses approach with sensitivity assessment related to all of the areas of uncertainty in the analyses. Contracts may wish to stipulate minimum LFG collection rates and/or guarantees with penalties for non-compliance but this is generally unacceptable to landfill owners in the public domain as it places undue financial risk on the landfill owner. The risks can often be satisfactorily mitigated be providing assurances as to the level of effort, schedules, and procedures associated with O&M activities. Adopting an official policy such as implementing an environmental management system such as ISO-14000 at the landfill can make further assurances.

Expanding and maintaining the LFG collection well field to collect the gas is an ongoing responsibility that must be clearly defined to protect and secure the revenue streams to any LFGTE project. Most LFGTE projects will have a potential service life well in excess of twenty years and preserving this long-term asset can help to ensure the financial viability/opportunity to yield an appropriate return on investment.

LFG is a wet and potentially corrosive gas that may require some degree of pre-treatment prior to utilization. This item is primarily a financial issue that relates to the lifecycle costing for the project and is not a technology risk since the technologies are generally well developed and proven.

Another area of risk is the potential for conflict between the operating landfill, and the LFG collection and utilization system. In most cases, the best sites for LFG management projects are those which use LFG from an active site. To have this work, the design and operation of the LFG system must not interfere with the primary site purpose; the landfilling of wastes. This includes resolving conflicts between both the operations and systems (i.e., leachate collection system) of the working landfill.

In both cases, having well-trained operational staff who understand the nature of the LFG resource and the basic operations of the landfill can mitigate the risk.

7.3 REGULATORY AND APPROVAL RISKS

The future implementation of regulations that require the collection of LFG may provide a hindrance to the development of several LFG management projects because the creation of emission reduction credits can only be achieved through voluntary action. Therefore, policy makers must be aware of all the potential implications of legislation created to deal with LFG collection and utilization.

The coordination of permits and approvals for active waste disposal sites that remain operational concurrently with the LFG management project is crucial for the viability of the project. Any conflicts between the requirements and objectives of each operation must be resolved and agreed upon through proper integration and cooperation, so the viability of the project is not hindered.

The timeline required to obtain permits and approvals is also a risk. LFG management projects are time-sensitive because of the sharp decline that occurs in the LFG generation rates following closure of the site, and particularly in LAC regions where both the organic content of the waste and the degradation rates are higher than in North America and Europe.

7.4 Market/Revenue Risk Factors

The marginal nature of most LFG management projects, especially LFGTE projects, means that they often rely on more than one source of revenue to make them viable. Various aspects of these revenue streams are external to the project, but can have a major impact on the project economics. These factors include uncertainty regarding the future price of electricity or fuel supplies. There is also risk incurred with uncertainty regarding the future value of emission reductions.

The competitiveness of LFGTE projects will depend on the market price of competing energy sources. The economics of LFG use are typically tied to the price of fossil fuel, unless cost or price incentives are in place. On the open market, customers would probably discount sales of LFG because of perceived risks of using a non-conventional fuel source. It follows that, on the open market, LFG projects will more likely be financially viable in countries with higher energy costs.

The number of parties claiming ownership of the LFG can sometimes complicate the use of LFG as a resource and access to the supplementary revenue associated with CER's. Issues of ownership and rights depend on the nature of a waste disposal industry in the specific jurisdiction of LAC.

Section 4.0 outlines in detail some of the implications that changes in the energy market can have on LFGTE projects. Section 5.0 outlines in detail some of the implications that changes in governmental regulations can have on LFG management projects. Section 6.0 outlines in detail the current development of the carbon finance market.

In all cases, it is important to recognize the potential sources of risk to the project so that they may be correctly calculated and managed. As part of the economic evaluation of the project, a sensitivity analysis should be conducted to quantify the impact that changes in the various revenue streams may have on the project.

The simplest and most effective way to eliminate market risk is simply through negotiation and execution of long-term contracts for the sale of energy products and CER's that supports an adequate ROI to allow a candidate project to proceed. It is often possible to get performance and availability guarantees to offset any equipment performance risks. It may be possible to obtain insurance for projects against currency and some of the other market risks. Ideally the regulatory framework in the various countries in LAC could implement policies and regulations that could help to ensure that the energy values for "green energy" projects are protected in some manner, at least for projects that are negotiated and implemented on the basis of revenue supplements.

BOX 9: NEGOTIATING ENERGY SALES CONTRACT CONDITIONS

Obtaining guaranteed "green" power premiums can be a difficult thing to do, especially while energy companies are only beginning to consider power from renewable sources seriously. Once a plant has been constructed, the LFGTE project team is at a disadvantage in negotiations, especially in a regulated energy market. The Getlini LFGTE Project provides an example of these difficulties.

The project team for the Getlini LFGTE project in Riga, Latvia determined that the most profitable action for the plant was the production of electricity for sale to the grid. Initially, a two-year contract was negotiated with the electrical power utility company. This contract included a premium price for "green" power, which raised the sale price of the electricity from approximately $40 USD/MWh to $52 USD/MWh. However, the project ran into some delays and the contract expired requiring renewed negotiations. This time, the electrical power utility company elected not to offer the premium price for the power produced at the site. Negotiations are currently on-going for this project, but the 30% premium in the power sales revenue has obvious direct and severe implications for the financial viability of the project.

The following picture is looking at the entrance to the LFGTE facility at the Keele Valley Landfill Site in Toronto, Canada. This is a 35 MW electrical generating plant that has been operating for almost 10 years, with a service life of at least another 15 years that was constructed for a capital cost of approximately $500,000 (US$) per MW of installed generating capacity.

Since the construction of the Getlini LFGTE plant, the Latvian government has brought in legislation that obliges power companies to buy energy produced from renewable sources at a set premium. Under the new legislation, it usually takes 2 – 3 months to negotiate and approve a contract. Unfortunately this legislation is not retroactive and therefore, it does not help the Getlini power negotiations.

8

Pre-investment Studies

Sections 8 and 9 are designed to use the generic information and background materials provided in Part 1 and Part 2 of the Handbook to illustrate how to take a candidate project through the various steps necessary to assess and then to implement a successful LFG management project. Figure 8.1 presents a flowchart through the various steps in these two sections to assist with the text explanations that are provided.

Developing candidate projects is a complex exercise but the potential benefits are significant environmentally and can be significant economically if certain market conditions and energy product values exist. The development of a LFG management project can provide incentive to improve the overall design and operation of the landfill through monetary support to the waste management system, in addition to the reduction in GHG emissions.

In Section 8, the Handbook will attempt to give the reader the ability to assess whether or not a candidate project may potentially be viable. It is expected that it will be necessary to take a "team approach" to fully assess the pre-investment phase for a candidate LFG management project but it is expected that a user of the Handbook can undertake a first screening of the likelihood that a candidate project may be developed. The Handbook should also provide the basis for a reader to formulate and ask the correct questions to assess the viability of a candidate project in those areas that may be outside the experience and expertise of the reader. It is recognized that the experience and skill sets required to fully assess a project will likely require a team approach. The Handbook can be used to formulate the basis for assembling a project team that has the requisite experience and resources to move a project forward.

There are some very basic principles and questions that must always be asked and addressed in the pre-investment phase leading to a successful LFG management project. At the end of the pre-investment phase, the following must be clearly understood and quantified:

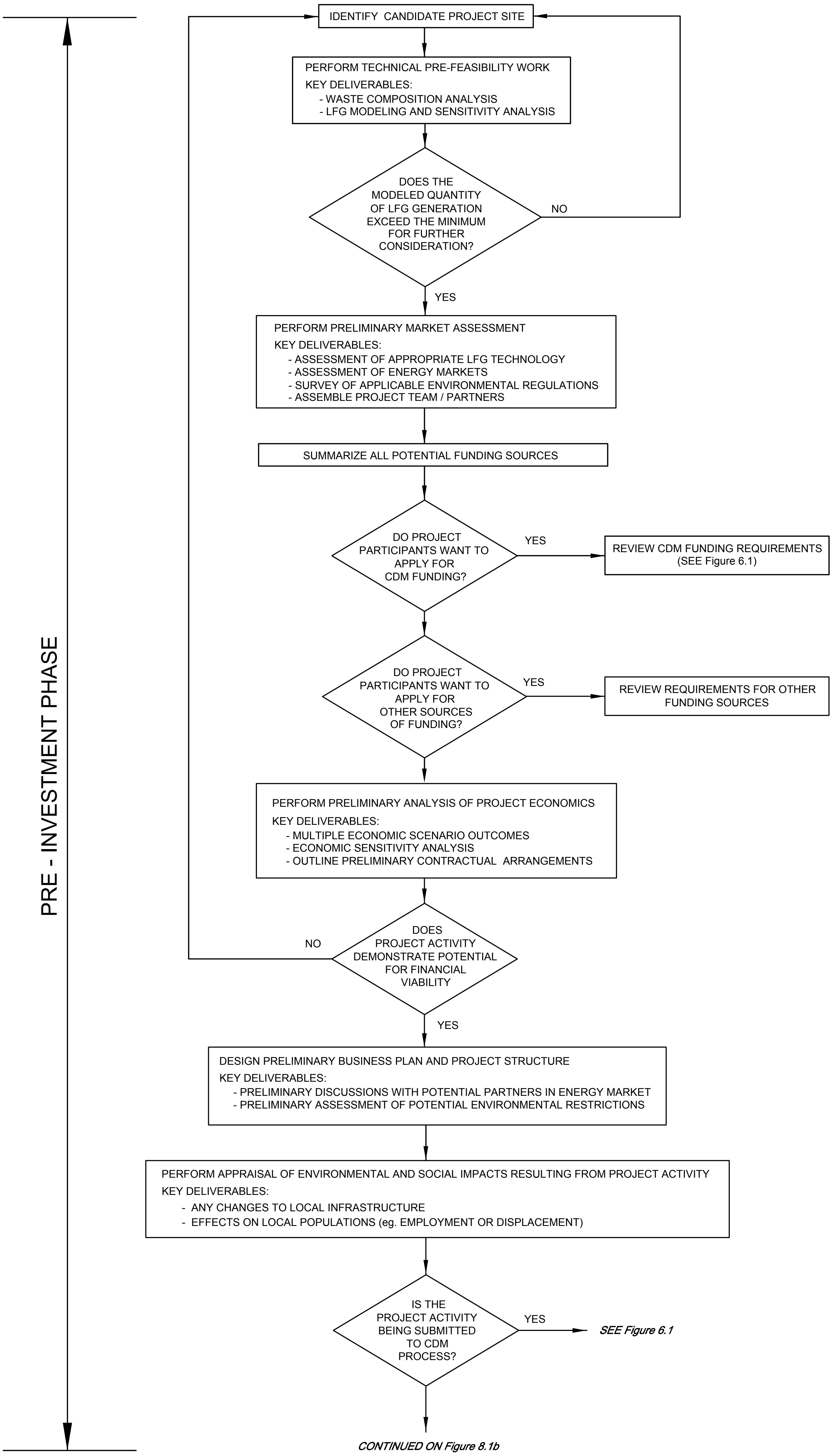


figure 8.1a

NOTE: THERE ARE SPECIFIC MILESTONES AND REQUIREMENTS IN THE CDM PROCESS THAT MUST BE COORDINATED WITH THE OVERALL PROJECT DEVELOPEMENTS.

FLOWCHART OF LFG PROJECT ACTIVITY CYCLE
PRE INVESTMENT PHASE
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

19399-10(006)GN-WA003 FEB 02/2004

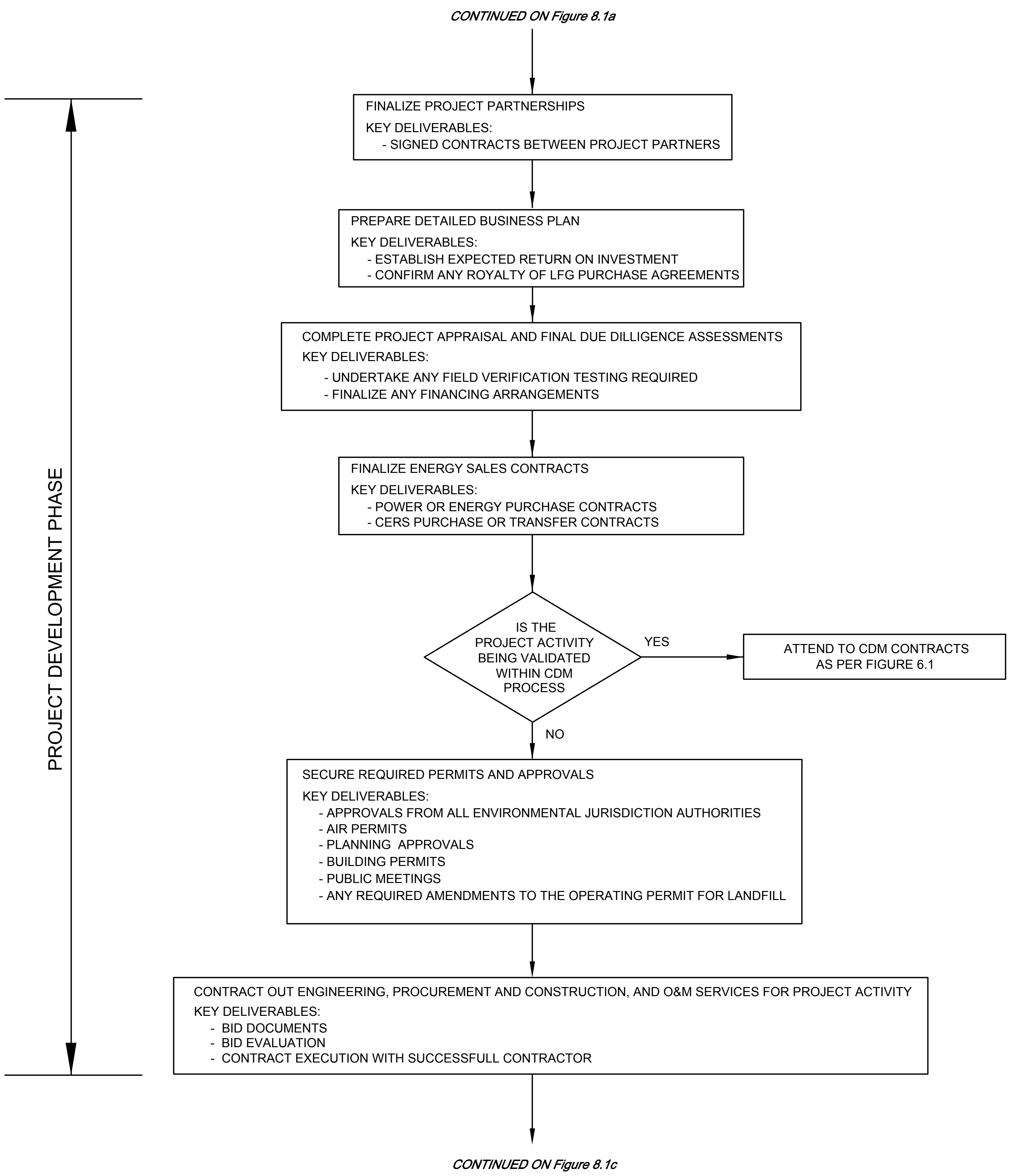


figure 8.1b

FLOWCHART OF LFG PROJECT ACTIVITY CYCLE
PROJECT DEVELOMENT PHASE
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

19399-10(006)GN-WA004 FEB 02/2004

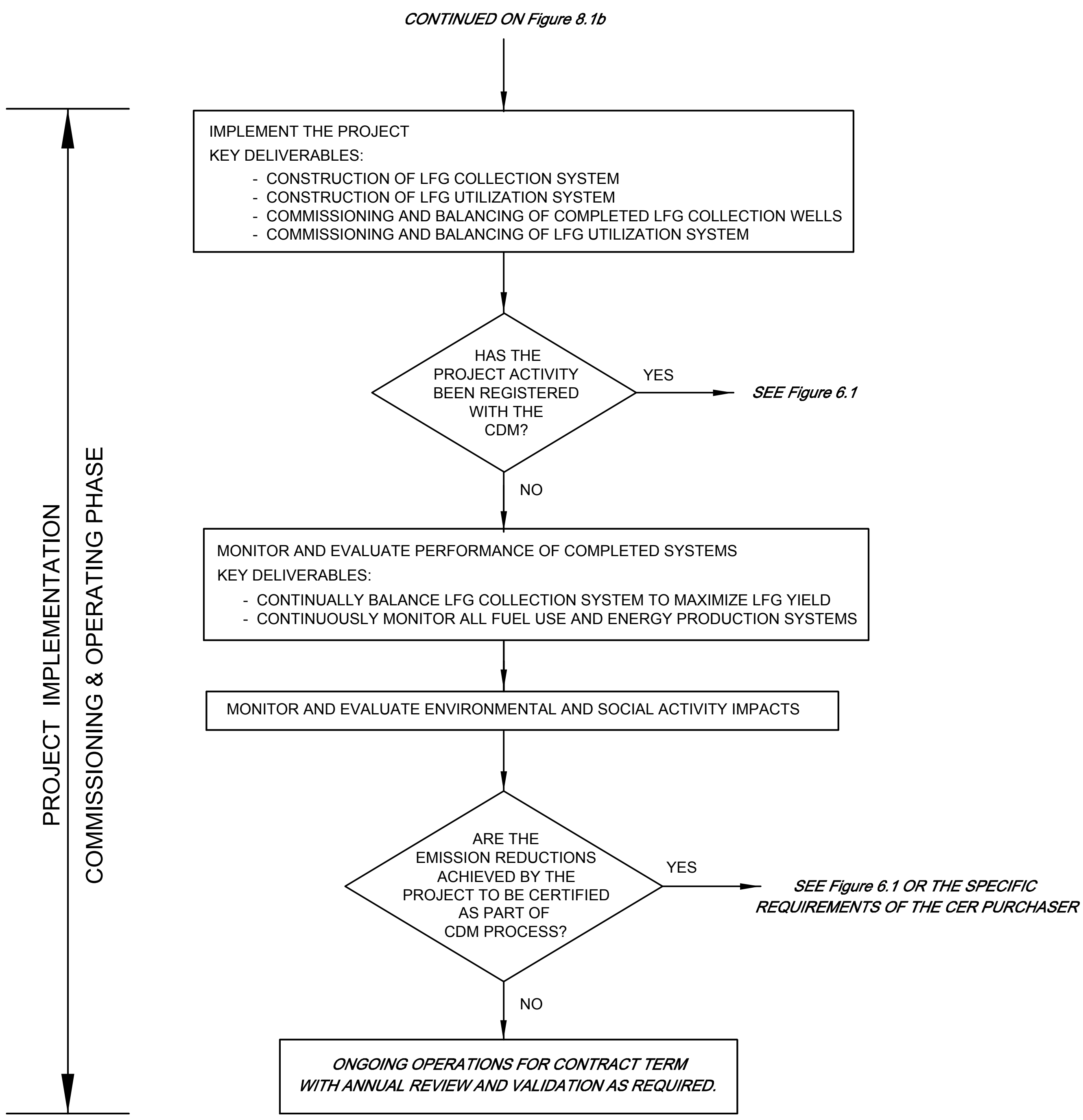


figure 8.1c

FLOWCHART OF LFG PROJECT ACTIVITY CYCLE
PROJECT IMPLEMENTATION, COMMISSIONING AND OPERATING PHASE
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

(i) The LFG resource must be estimated and sensitivity analyses completed for the present and future gas quantities that may be generated and recoverable from the candidate site. This includes quantifying any risk or uncertainties that may affect the recoverable gas quantities;

(ii) The markets for the energy products and emission reduction benefits of the project must be known and quantified, together with clear understanding of the ownership and control of the LFG and any potential CERs;

(iii) The project team must be established with full understanding of areas of responsibility and accountability;

(iv) The conceptual design must be completed to a level that will allow adequate cost estimations for both capital and operating costs to support negotiations for financing and revenue streams; and

(v) There must be an understanding of how the LFG management project will integrate into the overall waste management facility and system that generates the LFG resource including a clear understanding of any regulations, approvals or policies that may affect the candidate project.

These basic principles and objectives should be reviewed at the end of Pre-Investment phase to ensure that they are fully addressed before moving into the detailed project development phase.

BOX 10: PRE-FEASIBILITY STUDIES FOR A DEMONSTRATION PROJECT IN MEXICO

There are a number of conditions that should be looked at when considering a potential LFGTE project. In cases where there are a number of sites that have the potential to be developed, there are key issues that must be examined in order to choose the best candidate site or sites to invest in.

How a site is constructed and operated is important to understanding the development potential of a candidate site. The following picture is of a large site in Salvador, Brazil that has large completed cells and newly developing areas. A site that is still open receiving wastes can help to given assurance of the sustainability of the LFG fuel resource.

The World Bank undertook a pre-feasibility study to select a candidate site to host a demonstration LFGTE project in Mexico. The original study looked at 33 landfill sites that met the initial criteria: greater than 500,000 inhabitants; a minimum precipitation of 200 mm; and an annual temperature between 15°C and 30°C. The 33 initial sites were then assessed for technical, financial, and institutional compatibility with a LFGTE project. This assessment included:

- Technical issues at a regional and municipal level;
- Economic conditions; and
- Financial, social, political, and legal considerations.

This led to a short listing of seven municipalities with a total of ten landfill sites, which were each sent a questionnaire requesting technical, institutional and social information about the sites.

The end uses for the LFG that were considered included:

- Power generation for sale to CFE (for use on the grid) or the municipality;
- Direct LFG supply to nearby industry;
- Supply of compressed methane to industry pipeline for domestic use; and

- Purifying the LFG to be used as methane gas for use as vehicle fuel

Financial, technical and market access analysis of these options led to the conclusion that the best option was for the sale of electricity to the host municipality.

Social considerations included a comparative study of the number of scavengers at the site and the distance to residential establishments, in addition to the position of the local unions and authorities.

When the comparisons had been completed, the Salinas Victoria Landfill in Monterrey, Mexico was selected as the site for the demonstration project. Following the selection of this site, a detailed technical and financial feasibility study, further refining the previous information, was carried out prior to the final commitment to the project and the commencement of construction.

8.1 Technical Pre-Feasibility

To assess the viability of any project it is first important to understand the specific nature and characteristics of the fuel resource that will become the basis for the project. For LFG projects, the fuel resource is actually a by-product of the waste management system that places decomposable organic materials into a landfill site. Recognition of this factor is critical to understanding the links that the prospective project must have to the waste management system that generates the fuel resource. This also means that some pre-knowledge and understanding of the overall waste management system is a prerequisite for developing a successful LFG management facility at a candidate site and managing the economic risks of the project. It is important for all project participants to be aware of the nature of the LFG resource and waste management system, even in those cases where other parties may retain responsibility to supply the LFG fuel resource. A LFG resource should not be viewed as simply another utility service such as a natural gas fuel supply. It is important for all participants to understand this factor when determining their respective risks/rewards in a candidate project.

Table 8.1 presents an overview fact sheet for the waste management system that should be filled out to the extent practical, as the basis for developing the initial LFG generation estimate and assessing the confidence limits in the generation estimate. The primary objectives in filling out Table 8.1 are to obtain the best possible basis for estimating the mass of organic matter that would be available in the candidate site to generate LFG, and to obtain a basic understanding of the overall site conditions to assist in making an estimate of the recoverability of the LFG. This exercise to understand the fuel resource is applicable to all candidate projects, including responsibility for the collection of supply of the LFG fuel resource. In the latter case, due diligence in gaining an understanding of the fuel resource is still necessary to review and negotiate the terms and conditions for any contractual arrangements between the parties.

TABLE 8.1

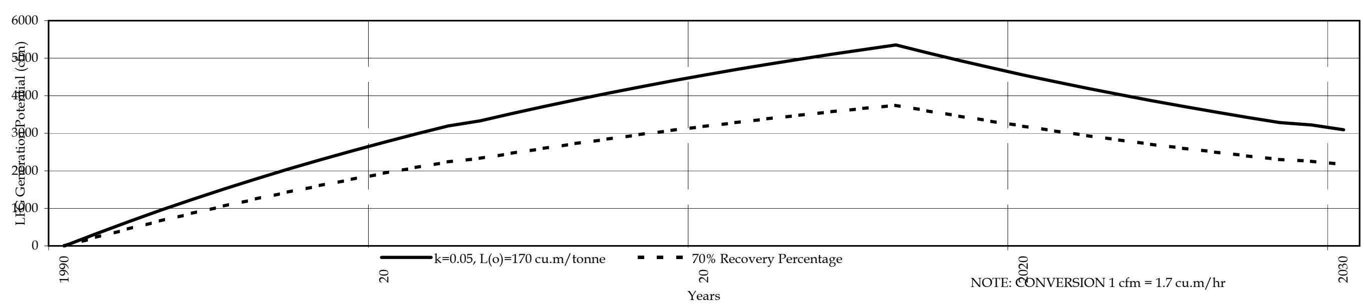
CANDIDATE SITE FACT SHEET - POTENTIAL LFG DEVELOPMENT PROJECT
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

Site Name:	Site Location:

SITE DESCRIPTION SUMMARY

Landfill Owner: Contact Name: Address: Tel.No.: Fax No.: Email:	**Utilization System Owner:** Contact Name: Address: Tel.No.: Fax No.: Email:
Background:	
Year Open: Year Close: Filling Rate (tonnes/year): Waste in Place (tonnes): Site Capacity (tonnes): Average Depth of Waste (m): Type of Waste:	Landfill Area (ha): Description of Liner: Description of Capping: Description of Leachate Collection: Description of Local Fuel Demand : Description of Site Setting:
Meterology:	
Annual Total Precipitation: Average Annual Temperature:	Average Seasonal Precipitation (Wet/Dry): Average Seasonal Temperature (Winter/Summer):
Migration Monitoring:	
Number of Monitoring Locations: Methane Concentration (%v/v):	Migration Control System: Yes ☐ No ☐ System Description:
Existing LFG Capture and Flaring: Yes ☐ No ☐	**LFG Generation Potential (@ 50% CH_4 Content):**
Current LFG Flow Rate (cfm): Methane Concentration (%v/v): Average CO_2 Equivalent (tonnes/year): Description of LFG Collection System:	Average Production in 2005 (cfm): Average Production in 2015 (cfm):
Existing LFG Utilization: Yes ☐ No ☐	
LFG End Use: LFG Utilized (cfm):	Btu of LFG (Btu/cf): Financial Arrangement:

LFG GENERATION POTENTIAL



COST-BENEFIT ANALYSIS

Additional LFG Capture and Flaring Potential (based on 70% curve):	
Potential to Install/Upgrade Existing System: Yes ☐ No ☐ Average CO_2 Equivalent (tonnes/year): Potential Increase in CO_2 Equivalent (tonnes):	Capital Cost Allowance for LFG Capture and Flaring: Annual O&M Cost Allowance for Capture and Flaring: Value of Additional GHG Credits:
Additional LFG Utilization Background Information:	
Potential Electrical Generation Potential (MW): Potential Unit Revenue: a) Net Wholesale Electrical Power ($/kW): b) Green Power Premium ($/kW): c) Value of Natural Gas (MMBtu):	Capital Cost Allowance for LFG Utilization: Annual O&M Cost Allowance for Utilization:

At this stage in the process, the technical pre-feasibility studies will be entirely a desktop study and site inspection with no intrusive investigations being required. In many cases, it may be difficult to obtain all of the information suggested in Table 8.1. This does not prevent the assessment from being completed, but it will affect the approach in developing a sensitivity envelope of the expected generation and recoverable LFG. Please refer back to Section 2 for a review of the model equations and guidelines for the selection of appropriate input parameters suitable for the specific site being evaluated.

Using all of the information assembled in Table 8.1, it is then possible to assign model parameters and generate a preliminary gas generation estimate. A sensitivity envelope of gas generation potential should then be prepared using a conservative range of input parameters that would be based on the site-specific knowledge for the site. Additionally, the site-specific geometry (e.g., depth or waste and area of filling) and the meteorology (rainfall and temperature conditions) will be used to help develop the sensitivity envelope of the gas generation.

One of the factors that warrant special mention in the case of LFG generation assessment is the forward-looking estimate. LFG is generated by waste that has already been placed into a landfill, but it is also a function of the waste that is projected to be placed into the site in the coming years. The gas generation estimate takes into account both of these elements but there needs to be a secondary review of the forward-looking waste quantity projections to see how changes in the waste input to the site may affect a potential project.

It is then necessary to apply an efficiency or collection factor to the above-noted LFG generation estimates to assign a recoverable quantity of LFG. Essentially, this factor recognizes that not all of the LFG that is being generated can be collected. As discussed in Section 2.6, there are economic tradeoffs between cost of collection and efficiency of collection. A well-designed gas collection system can typically collect 75 percent or more of the total quantity of gas that is generated. The level of certainty and the inherent financial risk can be effectively managed, assuming that the appropriate input parameters are assigned to the modeling, and there is a sound understanding of the specific waste management systems for the site.

To facilitate the initial screening process, a simple spreadsheet model has been provided to assist in the initial resource assessment phase. This spreadsheet is based on the Scholl Canyon Model described in Section 2.2. Table 8.2 is a data input table that can be used to prepare the waste quantity information for use in the LFG generation modeling. The table requires estimates of waste quantities in metric tonnes for each of the years that the landfill site has been open and for the future projections of waste filling. For some sites this may be a simple exercise but for others that have limited data, this may require some effort and assumptions to develop the necessary input field. For sites with little or no data, the waste quantity estimation can be difficult. Typically, the year that the site was open is known, but frequently the annual waste disposal quantities are not available for part or all of the site history. Assuming that there is a valid site plan and defined waste disposal limits, it may be possible to estimate the volume of waste in place based on

TABLE 8.2

CANDIDATE SITE DATA INPUT TABLE - POTENTIAL LFG DEVELOPMENT PROJECT
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

Model Parameters

Landfill gas production rate, k =	**0.05**	$year^{-1}$
CH4 Production potential, Lo =	**170**	
Gas Production potential, Lo =	**340**	m^3/tonnes
lag time before start of gas production, lag =	**1**	years
year landfill opened	**1990**	
year landfill closed	**2015**	
number of production years after closure	**50**	
methane (by volume)	**50%**	
adjustment factor for known inert waste quantit	**0%**	
Assumed recovery factor	**70%**	

Fill in shaded cells ONLY.

Gas Facts

CH_4 density (STP	0.72	kg/m^3
CO_2 density (STP	1.97	kg/m^3
Energy Value	18.63	MJ/m^3
	500	Btu/ft^3

Year	Year Number	**Annual Tonnage (tonnes)**	Annual Decomposible Tonnage (tonnes)	Theoretical Annual Gas Production (m^3/year)	Factored Annual Gas Production (m^3/year)	Theoretical Annual Gas Production (cfm)	Factored Annual Gas Production (cfm)	Factored Annual Gas Production (m^3/hour)	Factored Annual CH_4 Production (tonnes/year)	Factored Annual Energy Value (MJ/day)	Factored Gross Annual CH_4 as eCO_2 (tonnes/year)
1990	1	**500,000**	500,000	0	0	0	0	0	0	0	0
1991	2	**500,000**	500,000	8,500,000	5,950,000	571	400	679	3,060	303,670	64,260
1992	3	**500,000**	500,000	16,585,450	11,609,815	1,114	780	1,325	5,971	592,530	125,386
1993	4	**500,000**	500,000	24,276,568	16,993,598	1,631	1,142	1,940	8,740	867,301	183,531
1994	5	**500,000**	500,000	31,592,586	22,114,810	2,122	1,486	2,525	11,373	1,128,672	238,840
1995	6	**500,000**	500,000	38,551,800	26,986,260	2,590	1,813	3,081	13,879	1,377,296	291,452
1996	7	**500,000**	500,000	45,171,604	31,620,123	3,035	2,124	3,610	16,262	1,613,795	341,497
1997	8	**500,000**	500,000	51,468,560	36,027,992	3,458	2,420	4,113	18,529	1,838,759	389,102
1998	9	**500,000**	500,000	57,458,408	40,220,886	3,860	2,702	4,591	20,685	2,052,751	434,386
1999	10	**500,000**	500,000	63,156,128	44,209,290	4,243	2,970	5,047	22,736	2,256,307	477,460
2000	11	**500,000**	500,000	68,575,968	48,003,178	4,607	3,225	5,480	24,687	2,449,936	518,434
2001	12	**500,000**	500,000	73,731,480	51,612,036	4,953	3,467	5,892	26,543	2,634,121	557,410
2002	13	**500,000**	500,000	78,635,552	55,044,886	5,283	3,698	6,284	28,309	2,809,323	594,485
2003	14	**500,000**	500,000	83,300,456	58,310,319	5,596	3,917	6,656	29,988	2,975,981	629,751
2004	15	**500,000**	500,000	87,737,840	61,416,488	5,894	4,126	7,011	31,586	3,134,510	663,298
2005	16	**500,000**	500,000	91,958,816	64,371,171	6,178	4,324	7,348	33,105	3,285,308	695,209
2006	17	**500,000**	500,000	95,973,936	67,181,755	6,448	4,513	7,669	34,551	3,428,752	725,563

historical and current survey data to determine the airspace volume that has been filled with waste. It is then necessary to convert this volume into an approximate waste density based on an understanding of the landfilling equipment and practices being employed. The waste densities in a landfill site can range from less than 500 kg/m^3 to more than 1000 kg/ m^3 and should be assigned based on knowledge of the site-specific conditions including the geometry of the disposal site. Often it is a good practice to cross-check the estimated quantity against industry estimates for waste generation per capita for the geographic area where the site is located. The risk factor for LFG generation quantity projections depends upon the confidence in the estimated waste disposal masses. Assigning the available and projected waste quantities is a critical step as it is these quantities that represent the resource potential. Any sensitivity analyses should be developed with knowledge of the potential range in decomposable organic matter that could be contained within the candidate site.

If there is a portion of the site, which is known to have waste that is inorganic and therefore non-decomposing (non-contributing to gas generation such as brick rubble or concrete), one can apply a reduction factor to the waste quantities input to Table 8.2 for the percentage of inorganic waste present. It is only recommended to make a direct reduction for inorganic wastes if there are clear records that document these quantities. It should be recognized that the modeling exercise being applied is empirical in nature. If correctly assigned, the model parameters are intended to recognize that only a portion of the total quantity of wastes is decomposable organic waste. The L_o parameter takes this factor into account. The L_o parameter is typically set in the range of 170 m^3/tonne of waste, assuming an average waste moisture content of 25 percent. In fact this is an averaged value because pure inorganic non-decomposable matter would generate no LFG and a tonne of fully decomposable organic matter would have a L_o approaching 400 m^3/tonne.

It is important that any pre-feasibility analysis for a prospective project pay strict attention to the LFG resource assessment. All subsequent calculations, quantity takeoffs, and financial projections will rely heavily on this estimate and it deserves close attention and understanding.

After the waste quantity input table has been completed, the LFG generation modeling can then utilize the data to generate site-specific gas generation curves. Table 8.2 utilizes the assembled data and calculates the annual LFG generation rates for each year through the generating life of the candidate site. Figure 8.2 presents the LFG generation data in a graphical format for ease of interpretation and to assist in the sizing for the LFG collection and utilization facility. Figure 8.2 presents an envelope of potential sensitivity band of LFG generation that can then be used to assign project design parameters and LFG collection targets. Figure 8.3 utilizes the curves produced in Figure 8.2 and assigns a potentially recoverable quantity of LFG on a figure that also shows the approximate flow of typical LFG that is needed to generate electrical power (in 1 MW increments).

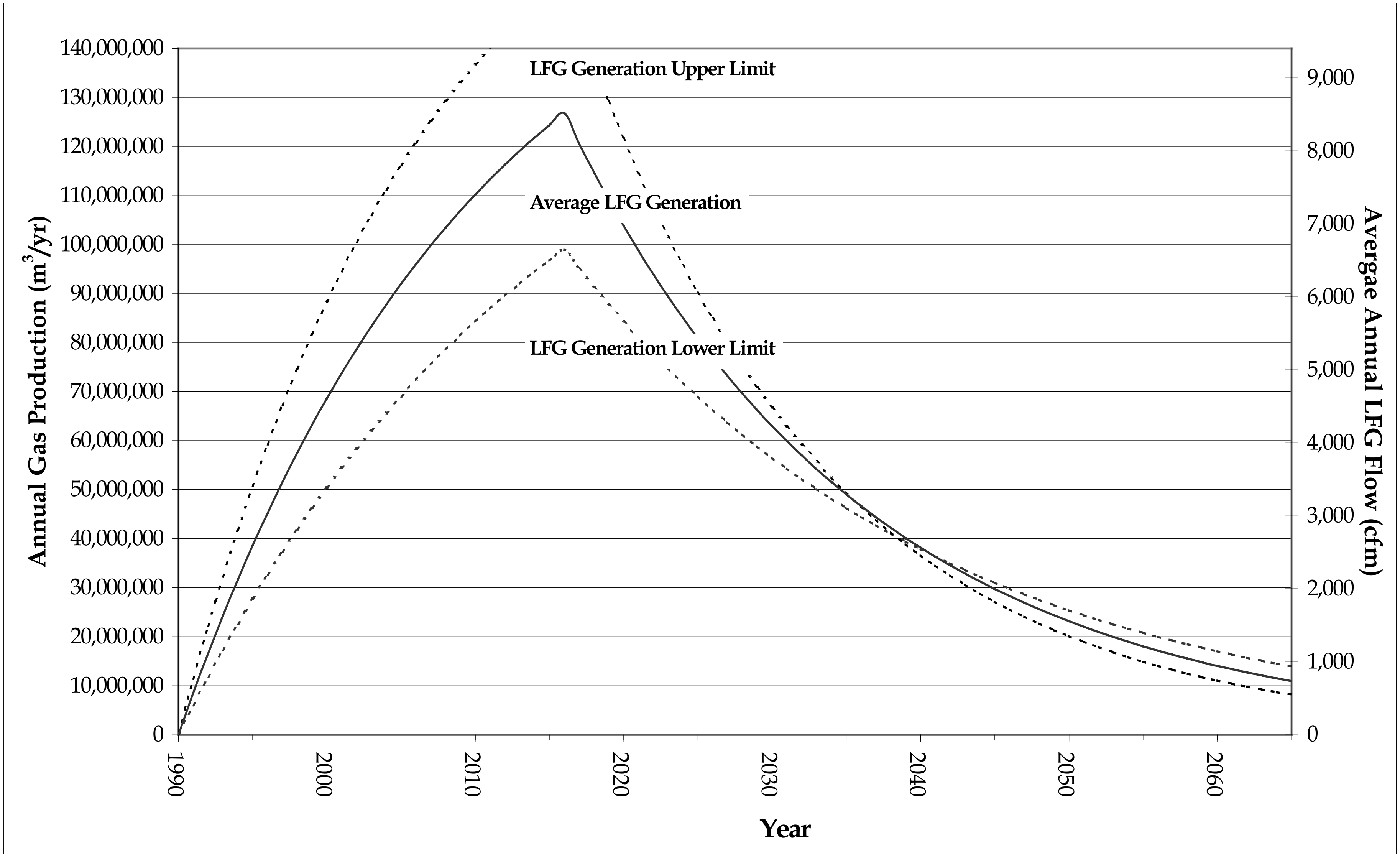


figure 8.2

LANDFILL GAS GENERATION ENVELOPE
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

The selection of the site-specific k constant and L_o parameter for the computer modeling requires some understanding of the site and the waste characteristics. In the specific example provided, the following have been assumed:

- k value of 0.04 and 0.06 have been used since the site is assumed to be in a warm climate with more than 30 inches of rainfall annually;
- the annual waste quantity has been set at 500,000 tonnes/year. It is assumed for purposes of this example that there is no specific waste characterization information available that would allow this quantity to be adjusted. The L_o range is set at a level from 150 to 190 m^3/tonne of waste, given the wastes are assumed to be a relatively typical mix of municipal, industrial, commercial and institutional non-hazardous solid wastes; and
- a sensitivity analysis should use both lower and upper L_o and k values to develop an envelope of potential LFG generation.

The LFG curve generated will be used as the basis for all subsequent discussions of the pre-feasibility and detailed development phases. The curves used in Figure 8.3 for the subsequent analyses are based on the averaged gas flows from the sensitivity band and an assumed 75 percent LFG recovery rate.

Using the LFG generation curve, it is now necessary to assign the design basis for a LFG collection system. Typically, a safe maximum flow rate is used for the preliminary sizing and costing for the LFG collection system. It is good practice to use the peak LFG generation of the upper level curve to size these design elements. The collection system element of the overall cost of a complete system is the smaller portion of the total costs. However, it is also the limiting factor for the capacity of a utilization system. It is strongly recommended that the collection system be sized for the maximum quantity of gas that could potentially be collected based on the modeling analyses. The cost of larger diameter piping is a relatively minor element of the costs, but could be a stumbling block to future developments if undersized. The other dominant factor in developing both a conceptual design and costs for the collection system is driven by the waste disposal area or footprint of the site. It is also necessary to know the depth of waste to establish an appropriate density of extraction wells or trenches to extract the LFG from the site. General rules for conceptual design of the LFG system include:

- allow for a ring header system around the disposal cell;
- set up the initial well grid at 60-75 m on centre. At the pre-feasibility stage, it can be simply using the available waste disposal area divided by an assumed influence area for each well;
- positive slopes of all piping to allow the condensate generated by the LFG to drain from the pipes to prevent the liquid from blocking LFG flow in the pipe;
- available applied vacuum for individual gas wells or trenches should not exceed 20 inches of water column; and

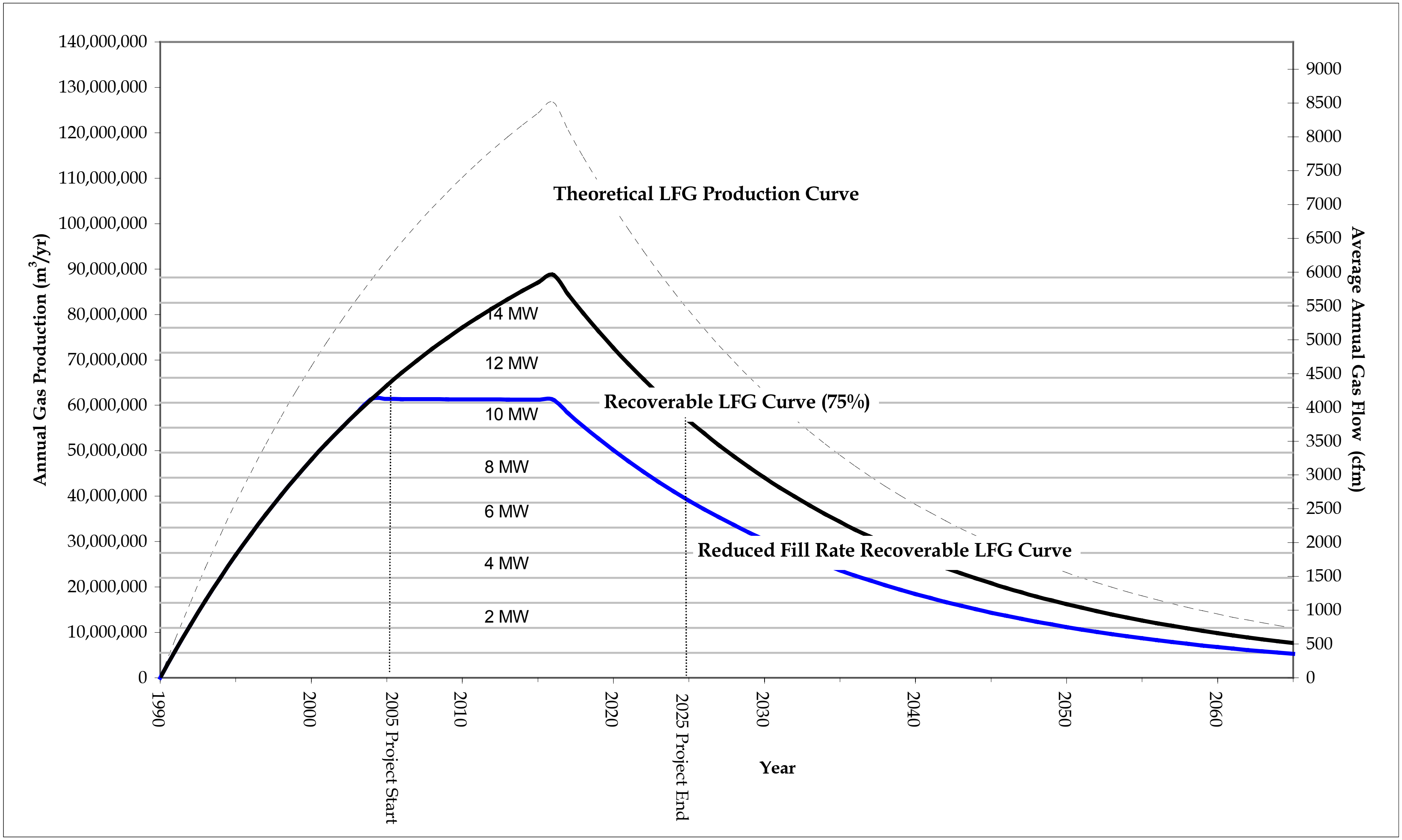


figure 8.3

LANDFILL GAS GENERATION ENVELOPE - PRE-INVESTMENT PHASE
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

- piping systems should be selected for high flow, low velocity and minimizing the friction losses in the system.

It is difficult to provide standard rules for costing gas collection systems because the specific nature of candidate sites can vary widely. For example, the cost per unit volume to collect LFG from a large shallow site is significantly higher than the cost to collect gas from a larger, deeper site with a smaller disposal area footprint. A conceptual design and preliminary cost estimate for developing the LFG collection system must then be developed as one of the inputs for the subsequent economic analysis in the pre-investment studies. Table 8.3 presents a checklist table for all of the key elements that should be considered in the capital and operating cost allowances for a LFG collection system. All of the functional elements of LFG collection systems are identified in Table 8.3. The required elements and quantities can be inserted into the table to develop a preliminary estimate. As a crude preliminary screening tool, the costs could be assigned on a per hectare basis. The costs to install a typical gas collection system that satisfies good practice and conforms to the guidelines noted herein can range from less than \$25,000 to more than \$50,000 per hectare, depending upon the specific site conditions and the scope of the overall design and services that may be required. For a simple first pre-screening step, an initial high end estimate could be used but it is recommended that a conceptual design basis be established and used to provide quantities for use in the preliminary estimate format provided in Table 8.3.

At this point in the pre-investment phase for a candidate site, the assessment would have reached the first decision point as outlined in the flowchart presented as Figure 8.1a. Typically, there would need to be projections of LFG generation at threshold levels of more than 750 m^3/hr (approximately 450 cfm) for a minimum of 10 years before active LFG collection would be given any serious consideration. The threshold value for considering LFG utilization is a function of the LFG recovery potential for the candidate site and the energy value for the specific geographic market location. Generally a LFG flow of greater than 1000 m^3/hr (approximately 600 cfm) for a future period 20 years or more is the threshold level required for consideration of a LFGTE project if the energy value (including consideration for CER's) is worth at least \$0.065/kWh or its equivalent. If the equivalent energy value is higher than this level, it may lower the threshold for consideration of smaller LFGTE projects. If these thresholds have not been met, further assessment of the candidate site is not likely warranted unless there are other non-economic motivations for a project, which require further investigation.

The other major capital cost element of the candidate LFGTE project is the equipment and facilities to use the LFG as an energy resource. For illustrative purposes, the Handbook will use, as an example, the conversion of LFG into electrical power for sale to the power grid. The principles for other uses of the LFG are almost identical.

First, the potential range for the LFG use must be understood. Figure 8.3 has been created using a generic waste profile. To assist in assessing potential options, horizontal lines have been added to the figure at the approximate LFG quantities necessary to

TABLE 8.3

CHECKLIST AND PRELIMINARY COST ALLOWANCES
LFG COLLECTION SYSTEM FOR CANDIDATE SITES
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

Item	Description	Unit	Quantity	Unit Price ($US)	Sub-total
A.	**Project Development and Management**				
1	Project management/administration	L.S			
2	Pre-Investment Studies and Assessments	L.S			
3	Project Developments and Due Diligence Reviews	L.S			
4	CER or Equivalent Application Costs/Fees	L.S			
5	Permits and Approvals	L.S			
6	Mobilization and Project Startup	L.S			
7	Bonds	L.S			
8	Insurance	L.S			
9	Health and Safety Plan	L.S			
B.	**LFG Collection System**				
1	Drilling and Well Installation	m			
2	Excavation and Trenching	m^3			
3	Vertical LFG Extraction Well Connections and Chambers	EA.			
	Well Head c/w valve, orifice, piping, fittings, vault w/ cover				
	Drilling				
4	Horizontal LFG Extraction Trenches	l.m.			
	Excavation				
5	Valve chambers (c/w piping and appurtenances)	EA			
6	a) Header c/w 450mm dia. pipe, fittings, valves	l.m.			
	b) Header c/w 400mm dia. pipe, fittings, valves				
	c) Header c/w 350mm dia. pipe, fittings, valves				
	d) Header c/w 300mm dia. pipe, fittings, valves				
	e) Header c/w 250mm dia. pipe, fittings, valves				
	f) Header c/w 200mm dia. pipe, fittings, valves				
7	a) Subheader c/w 200mm dia. pipe, fittings, valves	l.m.			
	b) Subheader c/w 150mm dia. pipe, fittings, valves				
	c) Subheader c/w 100mm dia. pipe, fittings, valves				
8	Pipeline cleanouts and chambers	l.m.			
9	Lateral piping to wells c/w 150mm dia. pipe, fittings, valves	l.m.			
	Lateral piping to wells c/w 100mm dia. pipe, fittings, valves	l.m.			
10	Condensate trap chamber	EA.			
11	Condensate forcemains	l.m.			
12	Culverts and road crossings	l.m.			
13	Buried airline and fittings	l.m.			

TABLE 8.3

CHECKLIST AND PRELIMINARY COST ALLOWANCES
LFG COLLECTION SYSTEM FOR CANDIDATE SITES
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

Item		Description	Unit	Quantity	Unit Price ($US)	Sub-total
C.		**Building and Services**				
	1	LFG Flare/Blower Package (800cfm, -50 in WC) c/w piping, valves & accesso	L.S.			
		as noted below;				
		flame arrestor				
		propane pilot system				
		flame scanner				
		temperature control dampers				
		purge blowers				
		thermocouples				
	2	Blower Buildings, incl. Utility connections				
		a) foundations and slabs	m^2			
		b) pre-engineered buildings	L.S.			
		c) access road (unpaved)	m^2			
		d) access road (paved)	m^2			
		e) fencing and gates	l.m.			
		f) asphalt pavement	m^2			
		g) concrete pads	m^2			
		h) landscaping (clay, topsoil, seed and mulch)	m^2			
		i) cover repair	m^2			
		j) water supply system	m			
	3	Mechanical Systems and Controls	L.S.			
		a) centrifugal blowers	EA.			
		b) pipes, valves, and accessories	l.m.			
		c) plumbing	l.m.			
		d) compressed air system	L.S.			
		e) ventilation system	L.S.			
	4	Electrical Service and Controls	L.S.			
		a) general electrical				
		b) service entrance				
		c) motor control center				
		d) control panels				
		e) SCADA system				
		f) instrumentation				
D.		**Commissioning and Start-up**				
	1	System start-up and Initial Balancing	L.S.			
	2	Demobilization and Project Closeout	L.S.			
	3	Prepare system manuals, record drawings	L.S.			
	4	Operator training	L.S.			
	5	Field monitoring equipment	L.S.			
E.		**Contingency and Other Allowances**				
	1	Drilling Refusal	L.S.			
	2	Over-excavation and Handling of Wastes	L.S.			
	3	Leachate Handling and Disposal System	L.S.			
	4	Emissions Testing Allowance	L.S.			
	5	Initial CER Testing and Certification Allowance	L.S.			
	6	General Contingency Allowance	%			

generate the equivalent multiple of megawatts (MW) of electrical power. Using the example provided, it follows that a 7 MW facility could be fully supported for a 20 year or longer term with no significant risk of available fuel resource to supply the facility. A similar statement can be made for up to a 9 MW facility if there are no significant reductions in the future waste disposal quantities that are received at the site. However, for above a 7 MW facility, there is some risk that the landfill may not be able to supply adequate LFG fuel for the full term of a 20 year contract if there are any significant changes in the future waste filling program for the landfill. These issues and associated risk sensitivities are more evident as the size of the utilization facility increases. At the pre-investment stage, the use of this type of screening approach can help to ascertain a "proceed" or "terminate" decision. For example, if the economics of a 7 MW facility offer a suitable ROI to interest the development team in proceeding, the pre-investment study can be completed with a staged approach that recognizes a baseline condition and that additional benefits and further improvements in the overall economics may be achieved by a larger project. If the 7 MW facility is economically viable, the "go" or "no go" decision for the candidate site has been met. However, if the economics indicate that a minimum 9 MW facility or larger would be required to make the candidate project viable, then it will be necessary to spend additional efforts to assess the risks of achieving the minimum project capacity. The level of effort and need for site-specific data and information is increased before a decision whether to proceed or not is made. It is important that clear investment criteria and constraints be known and established to make effective use of the pre-feasibility assessment.

Table 8.4 provides an outline of the key functional elements of a LFG utilization system. Using this format, a preliminary capital cost estimate can be developed for the size of facility that is being considered. Sensitivity analyses may look at various sizes of facilities (e.g., 4,5&6 MW plants) to understand the relative economics of each option. The principles being used to apply to a power generating facility will also apply to any other end-use of the LFG fuel resource. Some additional or differing considerations for a direct fuel use project are:

- fuel use profile of the markets. This means an understanding of hourly, daily, weekly, monthly and annual fuel use profile;
- access to the markets throughout new or existing pipelines and easements;
- fuel delivery requirements, including pressure, gas quality, and water content; and
- term length of agreements for sale of LFG fuel. The contracts will need to address guarantees for purchase of minimum defined quantities of LFG and any implications with respect to shortfalls or non-supply of LFG fuel.

Using all of the information discussed above and throughout this Handbook, the project team for a potential project at a candidate site should be equipped with the information and knowledge to allow them to start to establish the framework for an offer to obtain and utilize an LFG resource.

TABLE 8.4

CHECKLIST AND PRELIMINARY COST ALLOWANCES
LFG UTILIZATION SYSTEM FOR CANDIDATE SITES
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

Item		Description	Unit	Quantity	Unit Price	Sub-total
A.		**Project Development and Management**				
	1	Project management/administration	L.S			
	2	Pre-Investment Studies and Assessments	L.S			
	3	Project Developments and Due Diligence Reviews	L.S			
	4	CER or Equivalent Application Costs/Fees	L.S			
	5	Permits and Approvals	L.S			
	6	Mobilization and Project Startup	L.S			
	7	Bonds	L.S			
	8	Insurance	L.S			
	9	Health and Safety Plan	L.S			
B.		**LFG Utilization System**				
		(A number of equipment and system choices are available. Use the space below to insert the selected systems and equipment. Some of the potential options are listed below.)				
	1	Furnace/Boiler				
	2	Steam turbine - Electrical Power Generation				
	3	Microturbine				
	4	Reciprocating gas engine systems - Electrical Power Generation				
	5	Gas turbine systems - Electrical Power Generation				
	6	Combine cycle systems (gas turbine and direct heating) -Electrical Power Generation				
	7	Pipeline quality gas refining and processing				
	8	Commercial grade separation and processing of CO_2				
	9	Fuel cells				
	10	Vehicle fuel				
C.		**LFG Processing Options**				
	1	***Moisture removal***				
		moisture separator				
		mist eliminator/coalescing filter				
		air/air heat exchanger				
		air/liquid heat exchanger				
		compression and cooling				
		molecular sieves				
		absorption columns				
		absorption spray				
	2	***Particulate removal***				
		particulate filters				
	3	***Trace gas removal***				
		granular activated column				
		selective solvent treatment				
		iron sponge				
	4	***CO_2 stripping***				
		molecular sieves				
		membrane separators				

TABLE 8.4

CHECKLIST AND PRELIMINARY COST ALLOWANCES
LFG UTILIZATION SYSTEM FOR CANDIDATE SITES
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

Item	Description	Unit	Quantity	Unit Price	Sub-total
D.	**Building and Services**				
	1 Blower Buildings, incl. Utility connections				
	a) foundations and slabs	m^2			
	b) pre-engineered buildings	L.S.			
	c) access road (unpaved)	m^2			
	d) access road (paved)	m^2			
	e) fencing and gates	l.m.			
	f) asphalt pavement	m^2			
	g) concrete pads	m^2			
	h) landscaping (clay, topsoil, seed and mulch)	m^2			
	i) cover repair	m^2			
	j) water supply system	m			
	2 Mechanical Systems and Controls	L.S.			
	a) centrifugal blowers	EA.			
	b) pipes, valves, and accessories	l.m.			
	c) plumbing	l.m.			
	d) compressed air system	L.S.			
	e) ventilation system	L.S.			
	3 Electrical Service and Controls	L.S.			
	a) general electrical				
	b) service entrance				
	c) motor control center				
	d) control panels				
	e) SCADA system				
	f) instrumentation				
E.	**Commissioning and Start-up**				
	1 System start-up and Initial Balancing				
	2 Demobilization and Project Closeout				
	3 Prepare system manuals, record drawings				
	4 Operator training				
	5 Monitoring equipment allowance				
F.	**Contingency and Other Allowances**				
	1 Supplementary Gas Processing Allowance	L.S.			
	2 Condensate Treatment and Disposal Allowance	L.S.			
	3 Emissions Testing Allowance	L.S.			
	4 Initial CER Testing and Certification Allowance	L.S.			
	5 General Contingency Allowance	%			

The last, and potentially most crucial, element of the technical input to the pre-investment studies is the allowances necessary for the operations and maintenance of both the LFG collection and utilization systems. Any economics assessment should be based on a full life-cycle cost analyses for the candidate site and potential project. Although it is difficult to assign budgets for operating costs without specific knowledge of the candidate system and the technology selected for use, Table 8.5 provides some preliminary guidelines that can be used at the pre-investment stage.

Table 8.5 - Operating and Maintenance Cost and Applicability Ranges

Description	***Applicability***	***Annual Cost Range***	***Comments***
LFG Collection and Flaring			
Base Cost	All sites	$30,000 to $40,000	Assumes that active collection system exists
	>10 hectares	Add $1500 to $2500 per hectare for each additional hectare in disposal area	Only applicable as a preliminary rule of thumb and must be reviewed at detailed development stage E.g., a typical 30 hectare site would have an annual O&M cost ranging from $75,000 to $115,000
	>50 hectares	Add $1000 to $2000 per hectare for each additional hectare in disposal area	E.g., a typical 75 hectare site would have an annual O&M cost ranging from $105,000 to $190,000
LFG Utilization			
	<1 MW	NA	These sites are typically not viable for utilization if they must bear the cost of LFG collection Could be considered if active gas collection cost is not included
	>1MW, < 3MW	$0.012 to $0.015/kWh	E.g., a typical 2 MW facility would have an annual O&M cost in the ranging from $210,000 to $260,000
	> 5	$0.011 to $0.014/kWh	E.g., a typical 6 MW facility would have an annual O&M cost in the ranging from $580,000 to $735,000

Description	*Applicability*	*Annual Cost Range*	*Comments*
	>10 MW	$0.009 to $0.012/kWh	E.g., a typical 12 MW facility would have an annual O&M cost in the ranging from $950,000 to $1,260,000

The above gives some guidance with respect to the O&M costs for a facility. The costs for a direct fuel facility must be developed on a case-by-case basis, but the same basic principles will apply. The costs provided in this section have not included any provisions for any administrative overhead costs, which will be discussed in the context of market specific conditions.

It is important that any project in LAC or the Caribbean consider the timing and costs of import duties and tax issues for all spare parts and equipment replacement in both the feasibility and detailed assessment phases. It is not simply the cost of the items that is critical but rather the effect of lost time on the revenue streams for the project. The nature and size of any spare parts inventory should have an inverse relationship to the ease of getting replacement parts and services to undertake necessary periodic regular and any emergency maintenance activities.

8.2 Market Access and Arrangements for Power/Gas Off-Take, Pricing, and Contract Structure

The previous sections have focused on understanding the LFG fuel resource and the costs to collect, and use it. The second area of key input data needed to undertake a preliminary economics analysis is a thorough understanding of the market specific conditions applicable to the site and the country in which it is located. Sections 3 and 4 outlined the technologies and energy market issues that must be considered. These principles have been used to develop the cost component for the utilization options, which along with the market/revenues that may potentially be available to the project, will permit the pre-investment review to be completed.

It is necessary to identify all legal and technical requirements applicable to a candidate project. Similarly, the site setting and market conditions may clearly eliminate some of the fuel use options and focus the development team on one or two prospective technologies or customers.

Access to market is the first key issue of this aspect of the pre-investment review. Section 4 provided an outline of the regulatory and policy considerations related to the direct sale of the LFG or related energy products. Typically, a LFGTE project could not bear the costs of any extensive infrastructure to transport and deliver the energy or fuel products, except over relatively short distances or to facilities located immediately on, or adjacent to, the landfill site. This makes most of these potential projects reliant upon the infrastructure that presently exists. Often the geographic and/or political region where the candidate site is located may have very specific rules and limitations with respect to the sale, access and/or distribution of the energy products. The LFGTE projects are typically considered small projects from an energy perspective, but many utilities and bureaucracies are very protective of their mandate and market control, with limited interest in making exceptions to their current rules and policies. This is both a problem, and an opportunity, for the LFGTE projects. In areas where there are severe regulatory or cost prohibitive constraints for access to non-utility generators or suppliers, these types of projects should be treated as a separate category of generator.

To proceed with the pre-investment assessment it is now necessary to assign all of the revenue input ranges and any other soft cost allowances for a candidate project. The revenues would take the form of an expected value for any CER's ($ per tonne of eCO_2) generated by a candidate project and the fuel product revenue net of all connection charges, tariffs or other related charges. It is recommended that sensitivity analyses be undertaken using both expected and more conservative (pessimistic) estimates of net energy and CER sales.

8.3 Project Economics

All of the market data and costs must then be input to a simple spreadsheet model to determine whether or not the project may be viable and to identify the boundaries within which the project could be developed. Table 8.6 provides an initial spreadsheet model as a screening tool to assist in the pre-investment review. (Note that an electronic copy of the key input spreadsheets, including Table 8.6, are provided on a computer disk at the end of the Handbook.)

Table 8.6 is designed with all of the necessary data inputs across the top of the spreadsheet and shaded input cells to facilitate candidate project inputs. A number of default parameters have also been suggested with an input explanation provided in the computer disk. Moving the cursor over the input cell reveals these explanations and suggested inputs. The values provided in the input cells are used to calculate the various cash outflows and inflows displayed down the left-hand side of the table. These values are projected over the assumed 20-year timeline of the project and are used to assess the preliminary economic feasibility of the project.

The cost issues and areas of concern can be quite different between developed countries and developing countries. The Handbook has been consistently trying to emphasize the importance of understanding site and geographic specific issues with respect to both designing and constructing a facility, as well as operating and maintaining a facility through an extended service life. The need for skilled resources to both operate and maintain a LFG collection system and/or an LFGTE system are extensive. For projects in LAC and the Caribbean, there should be a great deal of stress placed on the operations and maintenance aspects of a project. This consideration may affect the decisions regarding the preferred technology that is most appropriate for a specific site in a particular county, state or country. For example, installing an electrical generating facility in a location that has frequent and extended power outages may make a project

TABLE 8.6

COST / REVENUE ASSESSMENT - PRE-INVESTMENT PHASE
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO EVERGY PROJECTS
The World Bank

LFG UTILIZED FOR ELECTRICAL POWER GENERATION

Capital Cost (1000's)	$15,000
LFG Collection System	$2,500
LFG Utilization System	$12,500
Annual Operating Cost (1000s)	
LFG Collection System	$150
Administrative Allowance	$100
LFG Utilization System	$1,337

Annual Financing Cost	
Financing Rate	6.5%
Finance Period (years)	10
Financing (1000's)	$2,087
Inflation Rate	2%
Power Sales Royalty	0%
Direct Fuel Sales Royalty	0%
Royalty for CERs	0%
Guaranteed Royalty	$0.00

Assumptions	
LFG Heat Value (Btu/cf)	500
Greenhouse Gas Credits ($/tonne of CO_2)	$0.00
Net Electrical Power Revenue ($/kWh)	$0.050
Global Warming Potential	21
Methane Density (kg/m^3)	0.717
Natural Gas Supplement Cost ($/m^3)	$0.090
Recovery System Efficiency	70%

Electrical Production Assumptions		
Each Reciprocating Engine (kW)		925
Parasitic Power Reduction Factor (%) (kW)		3%
Availability		95%
Conversion Efficiency		35%
LFG Required per Engine (cfm)		339
Number of Engines	year 1 to 5	11
	year 6 to 10	11
	year 11 to 15	10
	year 16 to 20	9

Year (assumed start 2005)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
LFG generation potential (m^3/yr)	82,832,000	87,244,000	91,441,000	95,434,000	99,232,000	102,844,000	106,281,000	109,549,000	112,659,000	115,616,000
LFG generation potential (cfm)	5596	5894	6178	6448	6704	6948	7180	7401	7611	7811
LFG recovery potential (m^3/yr)	57,982,000	61,071,000	64,009,000	66,804,000	69,462,000	71,991,000	74,397,000	76,685,000	78,861,000	80,932,000
LFG recovery potential (cfm)	3917	4126	4324	4513	4693	4864	5026	5181	5328	5468
Electrical Generation Potential (kWh)	12051	12693	13304	13885	14438	14963	15463	15939	16391	16821
Natural gas supplement (cfm)	0	0	0	0	0	0	0	0	0	0
Number of Engines	11	11	11	11	11	11	11	11	11	11
Net Electrical Generation (kWh)	9376	9376	9376	9376	9376	9376	9376	9376	9376	9376
CO_2 Equivalent from LFG (CERs)	417,000	440,000	461,000	481,000	500,000	518,000	536,000	552,000	568,000	583,000
CO_2 Displaced by power generation	40,100	40,100	40,100	40,100	40,100	40,100	40,100	40,100	40,100	40,100
Costs (1000s)										
Capital, Contract Administration and	$3,705	$3,738	$3,771	$3,804	$3,839	$3,874	$3,910	$3,946	$3,983	$4,021
Natural Gas Supplement Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Guaranteed Royalty to Site Owner	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Power Sales Royalty	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Direct Fuel Sales Royalty	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Royalty for CERs	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Revenue (1000s)										
Greenhouse Gas Credits	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Sale of electricity	$4,189	$4,273	$4,358	$4,445	$4,534	$4,625	$4,717	$4,812	$4,908	$5,006
Direct Sale of LFG Fuel										
Waste Heat Recovery Value										
Cash Flow (prior to Taxes, etc.)	$484	$535	$587	$641	$696	$751	$808	$866	$925	$985

Year (assumed start 2005)	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
LFG generation potential (m^3/yr)	118,430,000	121,106,000	123,652,000	126,074,000	119,925,000	114,076,000	108,513,000	103,220,000	98,186,000	93,398,000
LFG generation potential (cfm)	8001	8182	8354	8518	8102	7707	7331	6974	6634	6310
LFG recovery potential (m^3/yr)	82,901,000	84,774,000	86,556,000	88,252,000	83,948,000	79,853,000	75,959,000	72,254,000	68,731,000	65,379,000
LFG recovery potential (cfm)	5601	5727	5848	5962	5672	5395	5132	4882	4643	4417
Electrical Generation Potential (kWh)	17231	17620	17991	18343	17448	16597	15788	15018	14285	13589
Natural gas supplement (cfm)	0	0	0	0	0	0	0	0	0	0
Number of Engines	10	10	10	10	10	9	9	9	9	9
Net Electrical Generation (kWh)	8524	8524	8524	8524	8524	7671	7671	7671	7671	7671
CO_2 Equivalent from LFG (CERs)	597,000	610,000	623,000	635,000	604,000	575,000	547,000	520,000	495,000	471,000
CO_2 Displaced by power generation	36,500	36,500	36,500	36,500	36,500	32,800	32,800	32,800	32,800	32,800
Costs (1000s)										
Capital, Contract Administration and	$1,973	$2,013	$2,053	$2,094	$2,136	$2,179	$2,222	$2,267	$2,312	$2,358
Natural Gas Supplement Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Guaranteed Royalty to Site Owner	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Power Sales Royalty	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Direct Fuel Sales Royalty	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Royalty for CERs	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Revenue (1000s)										
Greenhouse Gas Credits	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Sale of electricity	$4,642	$4,735	$4,830	$4,926	$5,025	$4,613	$4,705	$4,799	$4,895	$4,993
Direct Sale of LFG Fuel										
Waste Heat Recovery Value										
Cash Flow (prior to Taxes, etc.)	$2,669	$2,722	$2,777	$2,832	$2,889	$2,434	$2,483	$2,532	$2,583	$2,635

uneconomic unless the power sales rate is adequate to offset the lost time. Another example could be the level of automation and control designed into a facility. In developing countries, it may be more cost effective to build in additional redundancy for key portions of the system that may not be warranted for developed countries. Simply stated, make sure that the specific conditions and constraints applicable to a candidate site are identified and considered in the feasibility assessments. The following paragraphs provide a brief outline of the input values and how they are utilized in the economics assessment.

Capital Cost

The capital cost refers to the costs calculated through the use of Table 8.3 and Table 8.4 for the LFG collection and utilization systems respectively.

Annual Operating Costs

The annual operating costs for the LFG collection and utilization systems were discussed in the previous section. The annual operating costs for the LFG utilization system are dependent upon the type of technology chosen to utilize the LFG and the amount of LFG processing required to operate the system. In both the LFG collection and utilization systems there is a balance between the capital cost of the system and the annual operating cost. This balance is somewhat determined by the size of the project and the specific technologies that are being used. The administrative allowance refers to the cost allowance for the administrative support necessary to maintain the facility and monitor the business related aspects of the project.

BOX 11: IMPORTANCE OF PARTS AVAILABILITY AND REGULAR MAINTENANCE

The Gdansk LFG utilization facility in Poland is a combined heat and power (CHP) plant. The two Wola LFG engine/generators are produced in Poland and the construction and operation is relatively simple. It has therefore been easy to get spare parts and servicing for the unit as compared to the other three LFG CHP plants presented in the Poland case study. In particular, maintaining the German-manufactured engines at the CHP plant in Krakow has been costly and time consuming because they require servicing from Germany.

The availability for the Gdansk plant is given below.

Year	Operating Hours	Availability
1999	7406	84.5%
2000	7006	80.0%
2001	7705	88.0%
2002	8380	95.7%

Note that the availability of the engines increased significantly in 2002. This was the result of the introduction of a service agreement with a local motor company, which included the supply of spare parts so that delivery time delay was reduced.

This example serves to reinforce the emphasis on attention to the operating and maintenance contracts for facilities in LAC and the Caribbean. Recognizing the implications to lost revenue for a reduction in plant availability from 95% or more to 90% or less can be a "make or break" consideration for a project.

Annual Financing Cost

The following inputs describe the investment environment in which the project is being considered. The values of these inputs should be varied to determine the envelope for which the conditions are such that the project is financially viable.

The financing rate provides recognition of the value of the money being invested in the project. The financing period can be adjusted to assess the economic window in which the project is operating. These input parameters are combined to calculate the "Financing" value. The inflation rate should be assigned based on historical and predicted national economic trends for the location of the candidate project.

The power sales, direct fuel sales, CER and guaranteed royalties are determined through negotiations with the applicable utility companies and amongst the project participants. The relationship between these inputs and the general economic viability of the project are discussed in more detail in Section 9.0. Sensitivity analyses should be undertaken to assess the price ranges and 'break points' in the composite of the revenue streams that make the project potentially economically attractive.

Assumptions

The following section outlines the assumptions that must be made in order to assess the project feasibility.

The heating value of LFG is generally taken to be 50 percent methane by volume or approximately 500 BTU/ft^3, but can change depending on the operating conditions of the LFG collection system. The CER's or GHG credits currently have short-term and speculative value, but which is expected to have real and increasing long-term value in the future in a carbon-restricted economy. The net electrical power revenue is determined as the difference of the electricity generation costs and the price at which the power can reasonably be sold to the utility net of all connection and wheeling charges for access to the power grid. The Section 8.2 briefly outlined the minimum threshold range of prices needed to make various sizes of LFGTE project viable. The input for a natural gas supplement is for projects that could gain some benefit through augmenting the LFG fuel during peak periods that yield better revenue to the generator or during the declining phase of LFG generation to optimize the use of the equipment and maximize the potential long-term revenue.

The recovery system efficiency states the reasonable percentage of the total theoretical LFG production that can be recovered for the purpose of utilization. A default efficiency of 75 percent has been used but can be modified based on knowledge of site-specific conditions.

Electrical Production Assumptions

This section outlines assumptions made about the equipment used for the purpose of utilizing the LFG. This spreadsheet was designed with a focus on direct heating and electricity generation as the prime uses for the LFG. A similar financial analysis should be undertaken for projects considering the use of another LFG utilization technology.

The fuel demand and generation potential of the various electrical generating devices that are being proposed should be input. Most of the projects to generate electrical power will utilize reciprocating engine technology. The use and application of the spreadsheet model is identical for other electrical generating technologies but will require input of technology specific input parameters and the default values noted may vary substantively. The parasitic power reduction factor, energy conversion efficiency and required flow of LFG or supplemental gas for each engine or turbine being assessed should be provided by the engine manufacturer based on the LFG projections assembled previously and transferred into the spreadsheet. The on-line availability of the electrical generating equipment will vary somewhat over time as a function of the age of the equipment as well as the operation and maintenance protocols followed. Maintenance of the equipment is a critical factor is keeping the energy conversion efficiency of the equipment at, or close to, its peak.

The number of engines available at the site will generally change to reflect the profile of the LFG production curve produced using the inputs in Table 8.2 and explained in Figure 8.3. As a function of the value of the energy products, electrical generating equipment will generally need to be in use for 10 years or more for their purchase and operation to provide acceptable financial returns to investors.

No attempt has been made in the pre-investment economics review to assign an expected ROI and IRR. There are numerous variables that remain to be defined at this stage and the purpose of this first stage economics review is to assess the basic cash flow for the project and to give some appreciation of the project economics for negotiations and discussions with the various partners, regulatory authorities, contractors and site owners that will need to be undertaken for the detailed project development. It should be very clear at this pre-investment level what the basic market pricing and revenue streams would be necessary to make the project viable. In some cases, grants and other supporting funding sources can be found for qualifying projects that meet specific screening criteria. There may also be a need to open discussions with potential financing partners, which will require the level of information identified to open up preliminary negotiations.

Following the flowchart provided as Figure 8.1a, the project team for a candidate project should have assessed the interest in applying for CDM or other funding that may have specific application and verification requirements. These supplementary applications and assessments will rely on all of the same information and data being acquired during the pre-investment assessments and should be pursued concurrently with the general project development if access to this funding source is being pursued for the project.

Also at this stage in the pre-investment phase, the lead equity participant or proponent should have a reasonable idea regarding the project economics and trigger revenue values that are necessary to encourage a project moving to the detailed development stage. The key equity participant or proponent should also have identified the resources and partnering arrangements that would be necessary to develop a project team with all of the requisite skills and resources necessary to undertake the candidate project. The nature and extent of the project team will always need to be assigned on a project-specific basis.

8.4 Project Structure (Partners and Roles) and Preliminary Business Plan

There are as many different contracting and execution strategies that could be developed and applied to LFG management Projects as exist for all other infrastructure and related projects. However, specific aspects of LFG management projects may have atypical risks or expertise requirements that may not be as available in all areas of LAC. Each of the various areas and types of contractual and business arrangements will be discussed along with the applicability to both large and small projects.

8.4.1 Rights to LFG Fuel Resource

It is assumed that the pre-investment review has indicated that there is the potential for a financially viable project, depending upon the detailed validation of the inputs and assumptions that have been made. One of the first aspects of a project that must be confirmed for it to become viable is the rights to the LFG and the conditions or criteria under which these rights are provided or transferred.

The more closely that the owner of the LFG resource is tied to the project, the more likely will be the project viability. The owner of the landfill site and the LFG fuel resource has the simplest and easiest prospect for developing a LFG management project. However, often the owner of a landfill site is a public entity with limited or no ability to act as a developer of the LFG resource. The expertise and resources to develop a LFG management project, especially a LFGTE project, are beyond the mandate, expertise and experience of the typical municipality or state-run waste management facility. This is one of the primary reasons that many potential projects remain, as yet, undeveloped. In many jurisdictions in LAC, the recognition of potential value inherent in the GHG emission reductions may make the economics to use the LFG resource a future reality. One of the key requirements for the GHG emission reductions to have a beneficial input to these projects is the clear title and validation of the CER's. The specific manner in which a project is developed and the GHG emission reductions are validated and transferred are critical to the success of a project.

It is also important for the Owner of the LFG fuel resource to understand that the manner in which the waste management system is developed and operated has a direct bearing on the viability of a project. The ongoing disposal of the solid wastes in a landfill site ensures the future presence of the LFG resource and protects its inherent value. The risk-return aspect of a LFG management project is a function of the nature of the involvement of the Owner of the site and fuel resource. For example, the Owner could elect to simply provide access to the LFG for a specified royalty from the project. Many questions must be answered and contractually resolved.

- What is the point of delivery of the LFG fuel?
- Who operates and maintains the LFG collection system and how/by whom are the associated costs paid for?
- What guarantees or obligations are there for the delivery of the LFG fuel? Issues such as minimum fuel purchase or delivery quantities must be identified and addressed.
- Who owns the CERs and who is contractually responsible to validate the CERs?

The simplest form of involvement for the Owner is to allow access to the fuel for a pre-agreed price and under specific terms. The sale of the LFG fuel can be based on flow rate and gas quality information that is collected and recorded on a continuous basis and paid for on a pre-agreed payment schedule. In this form of contract, the formula and pricing structures should ideally be kept as simple as possible. Some very involved royalty payment schemes with extensive adjustment factors have been used but are not recommended, except under special circumstances. Essentially the simplest and most transparent measuring basis should be used. Royalty schemes that are contingent on factors beyond the control of the contracting parties are discouraged.

Although the direct sale of the fuel resource to a developer appears to be quite simple, it has some major disadvantages:

- the royalty cost is an inherent liability to the project that can inhibit financing arrangements and make it more difficult to get the project initiated; and
- the commitment to the efficiency and performance of the LFG collection system is not under the direct control of the project and can lead to future operational and performance conflicts and disputes.

In a somewhat modified arrangement, the Site Owner can become a part of the project team, benefiting from the project in some pre-agreed manner as a function of the overall performance of the LFGTE project. In this case, the financing is typically much easier to obtain and the risks in the project are distributed through the project team members.

Regardless of the direct involvement of the LFG resource Owner in the project, it is mandatory that this issue be specifically identified and resolved before further work or investment in a candidate project should proceed.

8.4.2 Partnership Strategies

The most efficient and cost effective approach to undertake any project or venture is to utilize the smallest group of participants that collectively have the necessary technical, financial, market access and project management resources to successfully construct and operate a facility over the life of the recoverable LFG fuel resource. Often risk sharing and lowering risks may also have a bearing on the number and characteristics of project partners.

As far as energy sector projects are concerned, the LFGTE projects would typically be considered as small projects. The capital costs for the projects, including the capital for both the collection and utilization systems, would range from less than $1,000,000 (US$) to a maximum for the largest potential sites in the range of $20,000,000. As a general rule of thumb guideline, the utilization component cost will typically represent approximately 70 percent or more of the total project cost. One of the most attractive features of the LFGTE projects is the relatively large emission reduction benefit that is achieved by these small to mid-sized energy recovery projects. Notwithstanding the modest project size, the project development requirements and the dissimilar expertise requirements for these projects may require a number of different contractual arrangements and/or joint venture arrangements in addition to the various contracts that may be necessary to gain access to the applicable energy markets.

In all cases the level of inherent risk is balanced by the potential return. For example, the sale of LFG as a fuel commodity may entail little or no risk, but it may reduce the likelihood that a project will proceed. Although the projects are a modest size from a capital cost perspective, there are multiple parties and numerous contracting strategies that could be utilized based on project specific constraints and local market conditions.

For any LFGTE project the following outlines possible contractual arrangements and strategies to implement a project together with key considerations and constraints. Note that some of the contractual arrangements noted below are not necessarily mutually exclusive and could be utilized in differing combinations to suit site-specific conditions.

<u>Owner as Developer</u>

The simplest form of implementation would be when the site or resource owner elected to remain the sole equity owner for the project. In this case the following agreements are required:

- an agreement for the validation of CERs with clear definition as to title to the emission reductions;
- an agreement for the sale of the specific energy product from the use of the LFG resource. This could include any of the available utilization options and technologies. In the case of electrical power sales or direct fuel sales, there may need to be multiple agreements for both the sale of the energy products and for access agreements to the distribution system to get the electrical power to the consumer. There may also be easement agreements to gain right of way to the market etc.;

- an agreement for the design and construction of the facility. There are differing contracting/implementation strategies that could be employed for both the collection system and the utilization equipment that include Build/Own/Operate Contracts, turnkey project management contracts, design-build contracts etc.; and
- an agreement or agreements for operating and maintenance of the various facilities. These could include lease type of arrangements that could minimize the initial demand for capital to construct and commission the facility.

The Owner as Developer approach has the lowest overall cost to develop because of the simpler ownership structure. However, in this approach all of the financial risks of the project are retained by the Site Owner, some of which may be outside the expertise, experience and mandate, particularly if the Owner is a municipality or some other government body. Although this approach is contractually the simplest, it sets the Owner up essentially as a utility company. In many jurisdictions, there may be franchise limitations preventing the Owner from supplying fuel to multiple parties unless the fuel user(s) is located immediately adjacent to the landfill site with a common property line. In cases where this is an option, it should be explored and will almost certainly have the best return on investment with the lowest risk if there is a suitable market available and prepared to execute a long-term agreement for use of the fuel. This assumes that the fuel use profile is compatible with the LFG generation in the Site and that the market is always available at all times to receive the LFG.

<u>Landfill Owner Sale of LFG to Developer</u>

The next simplest form of implementation would be when the site or resource owner elects to sell the LFG that is collected to a developer. In this case, there would be no partnering or joint venture arrangements. All of the Agreements noted previously would still be required and another contract would be required to sell the LFG and all of the associated rights to the Developer. The Developer may be given access to leased lands to develop the project for the term of an agreement. This approach places a higher onus on the developer to arrange for project financing and will make the project a higher risk requiring a higher overall return on investment before the project may proceed. The sale of LFG to the Developer will be viewed as a direct project cost and unless guarantees are made with respect to LFG fuel supply (quality and quantity), the project may be deemed as a higher risk by any prospecting financing partner or investor.

<u>Landfill Owner Sale of the Rights to LFG to Developer</u>

The sale of the rights to the LFG to a developer is similar to the previous arrangement with the only real difference being that the developer may have the added responsibility and cost to install and manage some portion or all of the collection system. This approach has the advantage that one party is responsible for all aspects of the LFG management and utilization systems. One additional drawback is that the LFG developer becomes much more directly involved in a number of operational aspects of the landfill development and operation, which can at times lead to conflicts and disputes if not clearly addressed in the contractual agreements for the project.

Landfill Owner Public/Private Partnering Arrangement or Joint Venture with Developer

A public/private sector partnering arrangement is somewhat more complex from a contractual standpoint to the previous options but the project risks are better distributed between the parties with the specific expertise and resources to assess and manage their respective risks.

In all of the approaches noted previously, the status and condition of the landfill operation remain as critical elements in the pre-investment review, regardless which party retains responsibility for collecting and managing the LFG resource. The best LFG resource will typically be associated with landfill sites that are still active and being filled with waste. Understanding the implications and interactions between the landfilling activities and those associated with effectively collecting and utilizing the LFG resource remain fundamental to understanding the project economics, risks and returns.

8.4.3 Preliminary Business Plan

At the end of the pre-investment phase, it is necessary to document the results of the technical and economics assessments in a draft business plant that includes:

- an outline of the basic size and scope of the proposed project;
- the preliminary assessment of the LFG fuel resource documenting any required follow-up confirmatory information or investigations that may be necessary prior to completing the due diligence phase and proceeding into the detailed project development phase;
- the preliminary market assessment and the preferred approach to utilize the LFG resource;
- a conceptual design at an adequate level of detail to permit preliminary cost estimates;
- a project implementation plan including identification of the preferred strategy to contract for and utilize the LFG resource;
- a review of the capital and operating costs of the preferred technology and conceptual design;
- an economics and financial analysis of the preferred option; and
- identification of the financing approach to undertake the project; and
- any other site-specific or project-specific information needed to obtain the required management or other approvals necessary to proceed to the next stage of the project.

The overall Handbook outline has been developed in a manner that can be used as the preliminary outline and table of contents for the key elements of business plan to support a LFGTE project. The various tools and tables provided can be used as templates to input the basic information needed to complete a preliminary business plan.

8.5 Scoping of Social and Environmental Impact Assessment Study

The impacts associated with LFG are largely dependent upon the pathway by which the LFG is exposed to humans or introduced into the environment. The generation and presence of LFG can result in a variety of adverse impacts, including emission of greenhouse gases, safety and health hazards, and nuisance effects such as odor.

The primary benefits of recovering LFG are the control of potential adverse impacts and reduction of site owner liability. LFG control and utilization benefits the public by effectively reducing and removing the negative impacts of LFG. Additionally, the economic return from utilizing collected LFG can defray some of the costs of operation and maintenance of a landfill, and be used to improve other aspects of the waste management system.

The development of a comprehensive LFG utilization program will benefit the local community in a number of important ways. These benefits include a variety of economic, employment, environmental, human health, and aesthetic factors. The construction of facilities for the collection and processing of LFG will be undertaken using local labor resources, presenting employment opportunities for local residents. Some of these benefits are long term for 20 or more years to operate and maintain the facilities. These functions also represent increased levels of education and training to develop the local labor resources to operate and maintain the equipment and facilities.

Since the success of the LFG utilization project depends on the production of saleable products (i.e., electricity), LFG extraction will be optimized and actively monitored to ensure maximum utilization, and the health and safety risks of exposure to uncollected LFG will therefore be reduced. It is expected that the production of energy by the utilization project will be popular with local residents, and public information sessions are an integral part of the proposed project.

To realize the full benefits of the utilization project, it is important that those directly affected by the project be fully informed of the project being undertaken, and its environmental and community benefits. A public involvement plan should be constructed to establish how the public should be involved in the project and how to allow a forum for discussion that includes all those who will affected. Of special importance in developing this plan, is the inclusion of vulnerable groups. Once the concerns of the affected groups are made known to those managing the utilization project, considerations should be made to address those concerns and mitigate any negative impact to the affected populations.

Waste pickers are a group of specific concern since they are prevalent in less prosperous regions of Latin America, and rely on the landfill as a direct source of income. In areas where the waste pickers are living directly on the waste mass and setting fires on the mass to cook, or recover material from the waste, they are risking harm because of the presence of potentially flammable and/or explosive LFG. An example of mitigating this risk are some cities in LAC have succeeded in organizing waste pickers such that they can recover material from the waste prior to it being landfilled (Johannessen, 1999).

Another consideration that must be made when the landfill is open to the public is that of security. The extraction wells in the LFG collection system would be visible and accessible to anyone on the waste mass. In the interest of preserving a well-maintained and functioning LFG collection system, protecting individuals present on the waste mass, and maintaining a congruent relationship between the utilization facility owners and the waste pickers, it is important that the well heads be secure from tampering and vandalism. Consideration must be made with regards to the chosen well head design and the proper casings and locking devices to be employed, should this be a potential issue at the site.

A reduction in global methane emissions by 15 to 20 percent would stabilize methane in the atmosphere at current levels (Thorneloe and Peer, 1990). Utilization of LFG in energy production replaces the load of fossil fuel use in the production of equivalent amounts of energy. LFG is a relatively "clean burning" fuel when compared to most other fuels. Any group undertaking a LFG utilization initiative would concretely and significantly contribute to global greenhouse gas reduction efforts, as well as reducing impacts to the local environment. Participation in such a project would convey that the group(s) involved in the project was affirming the importance of the United Nations Framework Convention and Climate Change and the Kyoto Protocol by reducing greenhouse gas emissions. The indirect economic benefits might include future support from development agencies or private enterprises and a reputation for being environmentally and socially conscious.

8.6 Project Team Assembly

One of the critical aspects inferred throughout the Handbook is that a successful project requires the assembly and coordination of a project team that has all of the requisite skills and expertise together with market and geographic specific knowledge of a candidate site. Figure 8.4 presents an outline of all of the required elements necessary to assess, design, implement and operate a successful LFGTE project. All of these elements are required for every project with the possible exception that a few projects may not elect to pursue a formal CER verification process in lieu of some other type of "green energy" certification process. Although all of the functions noted are required for all projects, it is expected that individual firms or their representatives may fill multiple roles that reflect their expertise and the size of the specific project. As previously noted, it is preferable to keep the project team as small as is practical. These concepts are not mutually exclusive but do pose a challenge to any project development. The importance of assembling a team that can satisfy all of the requirements can not be overstated. A review of the case studies will further help to reinforce the need for assembling a balanced project team with the fewest participants that have the expertise and resources to make a project a reality.

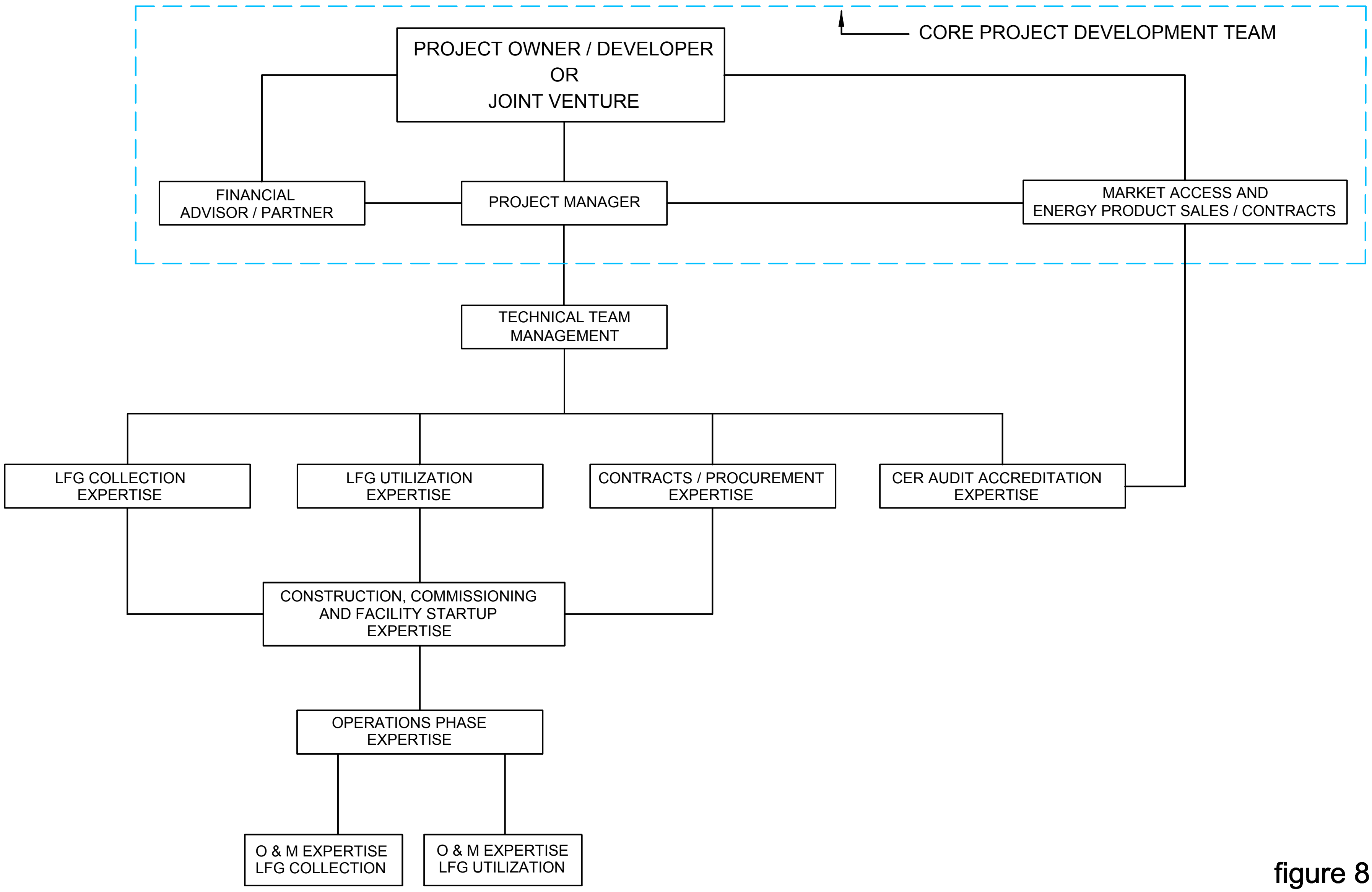


figure 8.4

PROJECT TEAM ASSEMBLY
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

19399-10(006)GN-WA012 OCT 16/2003

In assembling a project team, the lead proponent or developer must assess its own resources and identify which aspects of the project that it can undertake with its own forces and which aspects must be added with other participants. There must be a clear understanding of the project and investment goals and objectives before the project team is assembled. The key team roles that must be in balance and which must all be satisfactorily addressed before a project development plan can move forward are:

- Project Management — There must be a good overall understanding of the business and financial goals and objectives together with at least an appreciation of all of the technical elements of a successful project.
- LFG Resource Expertise — All economic projections, financial requirements, market access arrangements etc. will rely heavily on the ability to: assign the quantity of LFG that is available; obtain the LFG fuel that is available; to continuously provide the LFG fuel over the term of any agreement that is negotiated. The entire project team must have confidence in these projections and be willing to base the project success on the expertise of this team member.
- LFG Utilization Expertise — The ability to utilize the LFG fuel is a necessary prerequisite for a successful project. This expertise is generally available through the major equipment manufacturers, suppliers and consultants in the industry and it is somewhat easier to obtain performance guarantees in this area.
- Financial Expertise — The ability to assess and manage the financial aspects of the project and to understand the risk aspects of this type of project are crucial to making key decisions with respect to approval to proceed with a project based on the market values negotiated for the energy products and CERs.
- Market Access Expertise — The ability to secure long-term contracts for the sale of energy products and CERs generated by a LFGTE project is fundamental to the success and risk management of a project.

8.7 Summary of Development Approaches

The objective of the Handbook is to provide a user-friendly documentation of LFG management project background and development that can help to facilitate, to the extent practical in one document, approaches and guidance to assist and encourage the development of LFG management projects throughout LAC. The projects that are the subject of the Handbook range in value from less than \$5 million to more than \$20 million in capital cost. As far as typical resource industry and energy recovery/utilization projects are concerned, the project sizes are not overly large. However, from the perspective of candidate emission reduction projects, the LFG management industry represents one of the largest areas of potential emission reductions at one of the lowest costs per tonne of equivalent carbon dioxide reductions. Given this fact, the relative importance of the LFG industry to the global objective of GHG emission reduction as expressed in the Kyoto Accord is undeniable.

This emission reduction benefit is most simply achieved through encouraging and supporting development of LFG management projects that can realize real and significant gains now and into the future. There are many development approaches that could be successful. The following outlines two development approaches that could be considered or which could be modified to reflect site or project specific preferences or conditions.

Development Approach A – Site Owner/CER Consumer Joint Venture with Design-Build Implementation Program

This type of approach could be successful for initiating a LFG collection and flaring project to generate CERs, but it has not been generally successful with initiating LFGTE projects in North America or LAC. Generally the primary business of the Site Owners is operating waste management systems. The business of LFGTE facilities requires different skill sets and expertise from those generally available for the operation of a waste management system. As a result, projects can tend to get stalled at the pre-investment stage and, regardless of potentially attractive economics, may never be developed.

A good approach that would reduce risks and improve the likelihood of a successful LFGTE project would be to develop some portion of the LFG resource for the CER value at a candidate site. This type of approach would presume that the revenue from CERs would be adequate to support the installation of the LFG recovery system for combustion in an enclosed drum flare. This alone provides an incentive to improve the design and operation of the landfill. It would only require a partial site development to demonstrate the credibility and reliability of the LFG fuel resource. This would allow the Site Owner to then solicit tangible offers from developers to utilize the LFG energy resource.

Development Approach B – Developer Build-Own-Operate Implementation Program in a Public/Private Partnering Arrangement

The majority of LFGTE projects are initiated and driven by a private sector proponent. A review of the key team roles for the development of LFGTE projects listed in Section 8.6 illustrates that the business of LFGTE facilities requires different skill sets and expertise from those generally available for the operation of a waste management system. It becomes clear that a private sector lead proponent is generally the most likely to develop a successful LFGTE project.

At a minimum, the Site Owner will be required to be an active participant in the overall project from the standpoint of cooperation with the active landfilling and LFG collection systems operations. Ideally, the Site Owner should see a return for any LFG rights transferred as a share of the returns of a successful project rather than as a straight fee for fuel. This will allow some risk sharing between all project participants.

BOX 12: SELECTION OF DEVELOPMENT APPROACH

There are a number of development approaches that can be successful for LFGTE projects. The Regional Municipality of Waterloo (RMOW) reviewed all of the available options and made its choice, the selection of an independent developer for the Waterloo LFGTE project. The RMOW had installed and been operating a LFG collection and flaring system for a number of years prior to the startup of the LFGTE project. Actual LFG quantity and quality data from the active collection system was used to undertake the economic analysis for the LFGTE project. The RMOW elected not to be the owner operator, primarily because of lack of in-house expertise in running a LFG utilization facility, and the fact that this type of capital project was not deemed to be within the general mandate of the RMOW. Instead, a request for proposals was issued to the private sector to solicit offers to develop a LFGTE project at the site using the proven resource.

The private developer that submitted the winning proposal for the project was Toromont Energy Inc.(Toromont), a subsidiary of Toromont Industries Ltd., and the supplier of Caterpillar™ reciprocating LFG engines for Ontario, Canada. Toromont elected to use reciprocating engines to generate electricity from the LFG for sale to the provincial power utility. The third project party was Ontario Hydro, the provincial electricity monopoly whose participation was required to permit the sale of electricity generated by the project to the power grid.

The contract between Toromont and the RMOW guarantees that the LFG utilization facility is to be on-line 90 percent of the time that the RMOW is supplying LFG to the facility. If this guarantee is not met, Toromont is required to pay the RMOW an amount equivalent to the royalty that would have resulted if the plant had been running at 90% availability. The RMOW was not required to make any guarantees to Toromont, thus RMOW was protected from all risk associated with the LFGTE plant. The Toromont plant has substantively exceeded the minimum availability factor for each year of operation, with almost no unscheduled shutdowns. In fact, almost all of the unscheduled shutdowns have been a result of problems with the Ontario Hydro grid and not the plant operations. The following picture provides a view of the LFG collection facility and piping to the LFGTE plant at the Waterloo Landfill Site in Canada.

It should also be noted that the final motivating factors that made the project a reality were that Ontario Hydro provided an enhanced revenue stream for the electrical power generated at the facility, while it received transfer of any emission reduction consideration that may eventually accrue from the generation of electrical power using the LFG as the fuel supply.

8.8 Lessons Learned From Pre-Investment Phases Of Case Studies

The lessons learned from the eight case studies serve to reinforce the application and use of the various tools and information that collectively comprises the Handbook to this point. Table 8.7 summarizes the applicable requirements of the pre-investment phase and provides a summary of the case study experiences.

It should be noted that the case study projects are currently at varying stages of development. The projects in South Africa and Brazil are currently in the middle of the pre-investment phase, while construction has been stalled at the LFGTE project in Liepaja, Latvia because of a large team of project participants that have complex funding approval requirements. The rest of the projects have completed the detailed development phase and are into the operating phase of the completed/commissioned facility. The

TABLE 8.7A

COMPARISON OF CASE STUDY PRE-INVESTMENT PHASES – DEVELOPING PROJECTS
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

	Nova Gerar, Brazil	**eThekwini South Africa**
Site Facts: 1. Total Site Area/Filling Area (ha) 2. Existing Waste Quantities (2003)/ Waste Quantity at Site Closure (tonnes) 3. Date Site Open/Projected Closure Date 4. Average Annual Precipitation (mm/yr) 5. Average Daily Temperature (° C)	Adrianopolis 1. 120 2. 100,000/10,000,000 3. 2003/ not available 4. 1595 mm 5. not available Marambaia 1. 20 2. 1,845,000 3. 1986/2003 4. 1595 5. not available	Bisasar Road 1. 44 2. 10,6000,000/20,000,000 3. 1980/2014 4. 1009 5. 21 Mariannhill 1. 10.5 2. 800,000/7,000,000 3. 1997/2024 4. 1009 5. 21 LaMercy 1. 7 2. 1,100,000/1,200,000 3. pre 1996/2004 4. 1009 5. 21
Pre-Feasibility Phase		
Technical pre-feasibility	• Minimal LFG generation modeling performed • Concern that mayoralty changes on 4 year cycle necessitates moving quickly to avoid changing political/approval conditions • Well documented understanding of regulatory limits and required approvals	• LFG extractions test done in 1991 • LFG modeling done in 1994 confirmed in 2003 modeling
Market access and arrangements	• Landfill operations contracted to company for a period of 20 years. Long-term contract provides stability, also locks in development options. • All LFG rights granted to LFGTE operator in contract	• Monopoly of the electricity market by Eskom
Project economics	• Without the added consideration of carbon credits, project is not viable because of current energy pricing	• Unable to generate electricity at a competitve rate to make the project viable without the addition of ERCs

TABLE 8.7A

COMPARISON OF CASE STUDY PRE-INVESTMENT PHASES – DEVELOPING PROJECTS
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

	Nova Gerar, Brazil	**eThekwini South Africa**
Project structure (partners and roles) and preliminary business plan	• City administration to receive 10% of extra revenue generated by the operation of the landfill • Landfill operation contract is to be a 50/50 partnership of environmental finance company and local construction company with landfill experience • GHG aspect of project contractual partner with NCDF	• All partners contained with the Municipality of eThekwini (Cleansing and Solid Waste Management, Finance, Environmental Management) • Absence of formal business plan and formal internal approval from eThekwini Municipality
Scoping of social and environmental impact assessment study	• Extensive social and environmental impact assessment undertaken • Methods created to minimize the impact of the project on waste pickers	• Undertaking of EIA according to National Environmental Act of South Africa, requiring significant public input has caused a major delay in project • The project requires a large capital input from the Social Investment Fund from the World Bank to develop and invest in community to make the project viable.
Project Risks	• No GEF funding and with low electricity price, project economics are not favorable. Changes in electricity marketing may materialize but represents a major uncertainty, a high value for CERS would be required to initiate the project and it would need to be for a long-term commitment. • Gas supply may be an issue as condensate management will be a major consideration.	• Uncertainty about the future value of ERCs could undermine the financial viability of the project.

TABLE 8.7A

COMPARISON OF CASE STUDY PRE-INVESTMENT PHASES – DEVELOPING PROJECTS
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

	Monterrey, Mexico
Site Facts: 1. Total Site Area/Filling Area (ha) 2. Existing Waste Quantities (2003)/ Waste Quantity at Site Closure (tonnes) 3. Date Site Open/Projected Closure Date 4. Average Annual Precipitation (mm/yr) 5. Average Daily Temperature (° C)	SIMEPRODESO landfill 1. 44 2. 6.87/ not available 3. 1990/ not available 4. >200 5. 21
Pre-Feasibility Phase	
Technical pre-feasibility	• Site selected from a total of 33 sites based on optimal physical and political conditions • LFG generation evaluated using 3 models • Consideration of four different end uses for LFG: electricity, pipeline quality, direct fuel use, and vehicle fuel use
Market access and arrangements	• Mexico has restrictions on exclusive rights to the State for electric power production • Permitted to sell electricity for to the municipality for high electricity tariff usage at 5% discount – streetlighting, pumping, subway and recycling facility • Letters of interest signed by two electricity buyers but awaiting exact price schedules
Project economics	• IRR not adequate to support private sector development without GEF funding. 27.6% IRR with GEF funding. • Economic sensitivity undertaken on effect of electricity price change, LFG generation, project delays and investment costs
Project structure (partners and roles) and preliminary business plan	• SEDESOL hopes to replicate the project throughout the rest of Mexico. • Require investment by Strategic Patner with experience in LFG collection and utilization to run the project and train staff. • Strategic partner contract awarded to Bioelectrica of Monterrey Consortium in Nov. 2001
Scoping of social and environmental impact assessment study	• Analysis of social barriers to project success. • Ns scavengers present on the site, no relocation required. • Methodologies for mitigating the impact of projects on scavengers to be undertaken as part of the project replication process.
Project Risks	• Stability of high tariff charged for street lighting may disappear with electricity deregulation.

TABLE 8.7B

COMPARISON OF CASE STUDY PRE-FEASIBILITY PHASES – DEVELOPED PROJECTS
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

Item	**Waterloo** **Canada**	**Istanbul** **Turkey**
Site Facts: 1. Total Site Area/Filling Area (ha) 2. Existing Waste Quantities (2003)/ Waste Quantity at Site Closure (tonnes) 3. Date Site Open/Projected Closure Date 4. Average Annual Precipitation (mm/yr) 5. Average Daily Temperature (° C)	Waterloo 1. >100 2. 5,000,000/12,000,000 3. 1972 – 2025 4. ~ 800 5. 10	Kemerburgaz Landfill Site 1. Information not available at time of publication 2. Information not available 3. Information not available 4. Information not available 5. Information not available
Pre-Feasibility Phase		
Technical pre-feasibility	• LFG modeling done using Scholl-Canyon model including sensitivity analysis for alternative waste tonnages • Model refined using LFG extraction texts • LFG collection and utilization systems designed for staged development to coincide with landfill development • Technical consideration of five uses for LFG: direct fuel use; electricity; pipeline quality; production of CO_2, production of methanol	• Comprehensive investigation of waste disposal practises in Turkey undertaken in 1992 by CH2M Hill identified possibility for LFG utilization • Estimated initial 4MW capacity • Landslide of two million m³ of garbage in 1997 initiates site re-engineering /remediation • LFG pumping test carried prior to design by contractor. • In hindsight, pumping test should have been performed under supervision of developer with stake in results.
Market access and arrangements	• Electrical power generation & transmission was essentially a monopoly. • Utility policies did not encourage non utility generation, delaying project development for 5 years. • Site exists at boundary of three local utilities causing challenges in connecting to the power grid.	• Project undertaken while government still held monopoly over electricty market. • Specific procedure followed to obtain Power Purchase Agreement (PPA) • New producers must sign a contract based on the Electricity Market Law.
Project economics	• Detailed market assessment, including IRR calculation, performed for four scenarios: LFG fuel usage, electricity from reciprocating engines, electricity from turbines, and pipeline quality gas. • Negotiated special price for "green power", approx. $0.015/kWh (Cdn) higher than	• The government no longer buys electricity. Industrial/domestic electricity prices are currently the same (0.09USD/kWh) • Energy demand is expected to grow 2.9 percent per annum through 2020. • Project not assessed on the basis of financial viability, but rather as a social project aimed at

TABLE 8.7B

COMPARISON OF CASE STUDY PRE-FEASIBILITY PHASES – DEVELOPED PROJECTS
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

Item	**Waterloo Canada**	**Istanbul Turkey**
	standard wholesale price was required to make project viable.	improving Turkey's waste management practises.
Project structure (partners and roles) and preliminary business plan	• Toromont Energy Ltd. Won the bid to be the LFG utilization developer • Toromont responsible for all costs for utilization facility • Site Owner retained ownership of landfill and operation of LFG collection system to point of delivery at utilization facility.	• Project tendered by Instanbul Municipal Authority which assembled a project working committee within the public works department. • Contractor selected from short-list of candidates based on price. • Local consultant appointed by Municipality to supervise works. • Expert sub-consultants hired by consultant for assistance during design and construction phases. • Finance obtained by contractor from Austrian Bank with guarantee from Istanbul Municipality.
Scoping of social and environmental impact assessment study	• Social and environmental impacts addressed as proactive measures, not regulatory requirement. • LFG collection system built with dual header to mitigate local odor concerns and ensure that high quality gas made available. • Silencers for LFG utilization facility required to mitigate noise concerns	• Site is located a distance from Istanbul , near a military encampment and therefore social impact assessment was not required. • Project was undertaken voluntarily to alleviate the environmental stress caused by garbage landslides and open dumping practises • Concern over closu.re of open dump causing a shortage of food for stray dogs at the site.
Project Risks	• Supply of LFG to developer is not guaranteed by Owner and is managed on a "best effort" basis with no penalties to either party.	• Instability and change in the electricity market structure and rules • Instability of the Turkish economy

TABLE 8.7B

COMPARISON OF CASE STUDY PRE-FEASIBILITY PHASES – DEVELOPED PROJECTS
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

Item	**Santiago Chile**			
	Valparasio (El Molle)	**Lo Errázuris**	**Lepanto**	**La Feria**
Site Facts: 1. Total Site Area/Filling Area (ha) 2. Existing Waste Quantities (2003)/ Waste Quantity at Site Closure (tonnes) 3. Date Site Open/Projected Closure Date 4. Average Annual Precipitation (mm/yr) 5. Average Daily Temperature (º C)	• Information not available at time of publication.	• Information not available at time of publication.	• Information not available at time of publication.	• Information not available at time of publication.
Pre-Feasibility Phase				
Technical pre-feasibility	• Information not available at time of publication.			
Market access and arrangements	• Information not available at time of publication.			
Project economics	• Information not available at time of publication.			
Project structure (partners and roles) and preliminary business plan	• Information not available at time of publication.			
Scoping of social and environmental impact assessment study	• Information not available at time of publication.			
Project Risks	• Information not available at time of publication.			

TABLE 8.7B

COMPARISON OF CASE STUDY PRE-FEASIBILITY PHASES – DEVELOPED PROJECTS
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

Item	**Latvia**			
	Getlini (old landfill)	**Getlini (energy cells)**	**Liepaja (old Landfill)**	**Liepaia (energy cells)**
Site Facts: 1. Total Site Area/Filling Area (ha) 2. Existing Waste Quantities (2003)/ Waste Quantity at Site Closure (tonnes) 3. Date Site Open/Projected Closure Date 4. Average Annual Precipitation (mm/yr) 5. Average Daily Temperature (° C)	1. 87 2. 4,000,000 3. 1972 – 2002 4. 600 5. -20/+28	1. 87 2. 360,000/ 1,000,000 3. 2002 – 2018 4. 600 5. -20/+28	1. 10 2. 800,000/ 900,000 3. 1973 – 2004 4. 630 5. -20/+25	1. 10 2. 800,000/1,000,000 3. 2004 – 2022 4. 630 5. -20/+25
Pre-Feasibility Phase				
Technical pre-feasibility	• Basis of LFG modeling not known (Getlini) • Concern with initial LFG collection system design in terms of ability to operate, as designed (Getlini) • Proposed with option for expansion of utilization plant (Getlini) • Waste composition information not available, limiting estimates of gas production			
Market access and arrangements	• Monopoly for electricity generation/supply. Getlini negotiated an enhanced power purchase price but delay in project implementation caused a lapse and now being used by electrical utility to avoid paying green power price premium.			
Project economics	• Higher green power price of 52 US$/MWH was necessary to make project economically vialbe. • CER value is built into electricity price (Getlini)			
Project structure (partners and roles) and preliminary business plan	• Multiple partners with multiple reporting and approval requirements (Liepaja) • Owner and operator are the same entity, a highly favorable structure if the necessary expertise support is available (Getlini).			
Scoping of social and environmental impact assessment study	• Holding public meetings and media exposure (Liepaja) to support project. • Relocation of scavengers to recycling activities at Getlini is necessary.			
Project Risks	• Uncertainty with respect to the ability to sucessfully extract and maintain LFG fuel supply to utilization project.			

TABLE 8.7B

COMPARISON OF CASE STUDY PRE-FEASIBILITY PHASES – DEVELOPED PROJECTS
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

<table>
<tr><th>Item</th><th colspan="4">Poland</th></tr>
<tr><th></th><th>Torun</th><th>Gdansk</th><th>Krakow</th><th>Olsztyn</th></tr>
<tr><td>Site Facts:
1. Total Site Area/Filling Area (ha)
2. Existing Waste Quantities (2003)/ Waste Quantity at Site Closure (tonnes)
3. Date Site Open/Projected Closure Date
4. Average Annual Precipitation (mm/yr)
5. Average Daily Temperature (°C)</td><td>1. Not available
2. 1,600,000/ 2,200,000
3. 1964 – 2013
4. 650
5. -20/+35</td><td>1. Not available
2. 4,800,000/ 6,000,000
3. 1973 – 2018
4. 670
5. -15/+30</td><td>1. Not available
2. 3,300,000/ 5,500,000
3. 1974 – 2013
4. 500
5. -20/+35</td><td>1. Not available
2. 1,400,000/ 1,700,000
3. 1975 – 2009
4. 630
5. -20/+35</td></tr>
<tr><td>Pre-Feasibility Phase</td><td colspan="4"></td></tr>
<tr><td>Technical pre-feasibility</td><td colspan="4">• Lack of weigh scales or other equivalent records produced some uncertainty about waste quantities.
• Modelling of LFG generation done for each site.
Torun and Olsztyn – multi-phase model used by Danish company (Hedeselskabet), predicted 400m³ LFG/hour in 2003 (Torun) and 530m³ LFG/hour (Olsztyn), and results were verified by pump test.
Gdansk – feasibility study done by Swedish company (SWECO), no info.available.
• LFG extraction tests were performed in 1994 (Krakow) and 1997 (Torun, Gdansk Olsztyn).
• Utilization options studied include production of electricity, heat for district heating system, high quality gas sales, and vehicle fuel production.
• Design selected for combined heat and power projects (CHPs) , because it is most profitable option in Poland.</td></tr>
<tr><td>Market access and arrangements</td><td colspan="4">• In 1995 it was legislated that power companies had to buy "green power" for at least 80% of normal power price (in 1996 that was $0.051US$/kWh). In 1998 this rule was eliminated, but reinstated in 1999.
• Torun – application for permission to connect to the district heating plan submitted to Department of Public Utilities and Technical and Investment Department of the Municipal Office
• Plants producing >1MW electricity require a special government license
• Timeframe for a specific contract between the local power and heating companies is 3 – 5 months</td></tr>
<tr><td>Project economics</td><td colspan="4">• Torun economic evaluation included investment costs, revenue from energy sale, O&M costs, and design, supervision and administration costs for the EU project
• O&M costs for Gdansk and Krakow could not be separated from the operation of the landfill
• Olsztyn economic evaluation is confidential.
• Calculations of emission reductions were calculated for Torun for the EU application and for Gdansk for the EkoFund application but not included in economic evaluation.</td></tr>
</table>

TABLE 8.7B

COMPARISON OF CASE STUDY PRE-FEASIBILITY PHASES – DEVELOPED PROJECTS
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

Item	Poland
Project structure (partners and roles) and preliminary business plan	• Torun project supported by 30% grant from EU Thermie program. • Gdansk project was funded by a grant from EkoFund (13.5%), a loan from NUTEK/ENERGIMYNDIGHEDEN in Sweden (41%), and a loan from Regional Fund of Environmental Protection and Water Management in Poland (24%). • All the landfills are owner and operated by Miejskie Przedsiebiorstwo Oczyszczania Sp.z.o.o. (MPO) • Torun LFG plant is owned and operated by Biogaz Inwestor Co., which has shareholders from the municipality, MPO, power company, heating company and a private contractor. • Gdansk and Krakow LFG plants are owned and operated by the MPO • Olsztyn LFG plant is a BOO by Legajny Renewable Energy Generation SP.z.o.o. which is owned by two Danish investors: ESCO (75%) and Capital Investment Fund for Centraland Eastern Europe (25%).
Scoping of social and environmental impact assessment study	• Polish law requires that an environmental assessment be conducted for LFG plants, including emissions and noise. • The Krakow LFG collection and utilization project was in reaction to odour complaints from the landfill neighbours. • There was extensive press coverage about all Sites.
Project Risks	• A previous 1993 feasibility study for the Krakow site concluded that the site was too small to collect LFG. The reliability of the fuel supply remains the largest risk to these projects.

Waterloo LFGTE project has been in operation since 1999, whereas the Chilean projects have completed their operation and are no longer in service.

The case studies serve to consistently reinforce the importance of the following key points made throughout Section 8 of the Handbook, including:

i. careful assessment of LFG resource;

ii. securing markets for energy products and CER's;

iii. establishing a sound project structure and contracting framework;

iv. addressing permit, policy and regulatory requirements; and

v. understanding and incorporating operating and maintenance requirements as key elements in the success of a project.

9

Project Development

9.1 Finalize Partnership Arrangements and Business Plan

This section of the Handbook assumes that the preliminary business plan has been completed, and that the project team has negotiated or been awarded the rights to the LFG resource for a defined period. A defined period typically ranging from 90 days to six months, will then be used to undertake any final due diligence assessments or reviews, execute the necessary agreements or contracts and obtain any approvals that may be required before the project implementation phase can begin. At this stage of the project, the project team will start to incur significant expenses to refine and develop the project.

Typically conditional contracts for the LFG resource that may link to specific events and milestones must be executed before a potential owner/developer will proceed to make the significant time and cost commitments to move the project forward. First, the final rights to the LFG and the conditions under which they are to be received must be established in an executed agreement (assuming that this is not a complete owner equity project). There will likely be specific milestone events or conditions identified in this agreement that must be completed or the contract could be frustrated. The types of conditional terms would include:

- verifying any key assumptions or conditions related to the LFG resource through field assessment programs that have been identified, along with any target criteria that have been established;
- completion of market access and sales agreements for energy products and CERs;
- final agreement of any royalty or revenue sharing arrangements applicable to the project;
- final agreement with respect to all operations and maintenance responsibilities for both the LFG collection and utilization systems;
- any financing approvals required; and

- any regulatory permits and approvals.

With the primary conditional contract now in place, the project team can now proceed to develop the detailed design and advance the project. As much as 5 to 10 percent of the overall project cost will be spent before the field implementation of the prospective project could commence.

9.2 Conduct Final Project Appraisal

For most LFG management projects the project economics include consideration of the value of CERs. It is necessary that any applications or supporting documentation to ensure that any future emission reductions generated from a candidate project achieve the full accreditation and associated value be prepared and submitted concurrently. This will likely require information generated in a due diligence review to support the accreditation process. There will also need to be cost allowances and agreements with third parties approved by the agency or organization granting the CERs to validate them. These cost allowances need to be incorporated into all estimates for both initial capital and annual operating expenses. The costs can range from $25,000 to $50,000 for the initial assessment and from $15,000 to $25,000 for subsequent annual verifications.

Depending upon the relative size of the project and the sensitivity in the project economics to the fuel availability, the due diligence review of the LFG may be quite simple or may involve an extensive field program. If the project economics are marginal, there is more sensitivity to the overall plant and systems capacity. Because landfills are large and very heterogeneous, care must be used in extrapolating any field data from one portion of a site to another. The LFG yield and representative gas characterization from a site will not truly be known until the collection system is installed and functional. As a result, it is recommended that a project be staged and built with both flexibility and redundancy to ensure that the system can be operated economically. It is often easier and less risky to stage some of the equipment installations until the initial phase of the project has been completed and commissioned.

To review this principle, consider again the example presented in Figure 8.2. Using the projected recoverable gas curve, there appears to be adequate LFG available to support an 11 MW electrical power generating facility at full load for more than 15 years. At a 10 MW generating capacity, the modeling indicates that the facility could run at full load for more than 20 years. However, if we look at the lower curve on Figure 8.3 that has been generated assuming a reduced future waste quantity being disposed of into the candidate site, we can see that the amount of LFG that could be collected and utilized would only fully support a smaller 7 MW facility for a full 20 year term. The level and extent of due diligence assessment into this project should depend upon how critical the size consideration is to viable project economics. If the project were marginal at the 7 MW capacity, it would be necessary to undertake extensive confirmation to mitigate the project risks. The focus would be to understand and assess the risks of the future waste stream. It is apparent from looking at the projections that there is relatively little or no risk of adequate fuel resource over the short-term. Therefore, the time and resources at the due diligence phase would be best spent on understanding the waste management system that supplies the organic wastes to the Site and any risks that future volumes and waste characteristics are not likely to change in a manner detrimental to the project.

In the example presented in Figure 8.3, we are using an active expanding landfill site as an example. If we were to be considering developing a LFG management project at a closed site or one that was closing in the relatively near future, the sensitivity and due diligence efforts would have to place a much higher emphasis on the current LFG generation and recovery characteristics. This basic approach requires and emphasizes an understanding of the waste management systems rather than simply the current conditions at the site. The data inputs used in Tables 8.1 and 8.2 should be reviewed and revised if any data refinement is obtained at this stage. It is also recommended that a series of sensitivity runs be undertaken using differing assumptions with respect to waste quantities available and time of placement. This allows the development of a LFG generation "envelope" which will show the theoretical "best" and "worst" cases for LFG generation volumes.

The due diligence review of the resource potential can range from as little as $20,000 to more than $100,000 if a field pumping test is deemed necessary. The costs will vary as a function of the existing data base and information that may be made available regarding both the site and the waste management system that supplies the waste to the site.

Following the reconfirmation of the LFG resource assessment, it is then necessary to advance the designs of the respective collection and utilization systems to refine the cost inputs to the economics models. This entails essentially completing the collection system design. A detailed topographic survey of the candidate site is required. The specific major equipment vendors and suppliers must be established and quotations obtained based on the design. The level of refinement and completion required in the design is a function of the expected margins and market values expected for the energy products and CERs. Typically, the capital and operating costs must be upgraded to plus or minus 10 percent. Tables 8.3 and 8.4 can be expanded and refined to include the detailed costing information necessary to complete the capital and operating cost inputs for the detailed project development phase.

The pre-investment phase economics were presented in Table 8.6. At this stage, the inputs to this spreadsheet can be refined and updated to reflect the information obtained in the due diligence review. If the project economics are strong, there may be no need to refine the model beyond that presented. However, if the project economics are marginal and the financing is difficult to obtain, a more complex economics modeling approach may be required. There are several tools available to undertake this type of analyses. One of them is highlighted in Box 13.

BOX 13: RETSCREEN INTERNATIONAL

One of the LFG management project modeling tools available is RetScreen® International, a standardized and integrated renewable energy project analysis software developed by the Canadian Department of Natural Resources. RETScreen is presently being upgraded to add a biogas/LFG assessment model. This module will be available from the RETScreen website (www.retscreen.net) in early 2004. A screen shot from the model is shown in the following figure.

This module provides an initial economic project assessment and can be used to provide refinements to the assessment of the ROI and IRR. Additionally, the benefits and implications of waste heat recovery and other augments to the overall systems can be reviewed.

Typically a LFG management project is considered a significant environmental and social benefit. Effectively managed and operated, this type of project can both enhance local quality of life, health and safety of the citizens and can give some additional local employment to operate and maintain the facility. Specific funding or supporting agencies may require specific reporting and other activities, such as public meetings and information sessions to qualify for funding support. The specific local, national and international programs that may be applicable should be reviewed and, where required, the applicable requirements should be met. Generally LFGTE projects can be positive for social and environmental change and the projects should be utilized for their positive public relations value and associated social benefits to the respective communities in which they would be located.

9.3 Negotiate Energy Sales Contract and Secure Incentives

With all of the due diligence and verification work completed, all of the final contracts for the sale of the energy products must be completed and executed. There are numerous approaches and formats for contracts that could be suitable for this purpose. In some jurisdictions, there may be standardized base model contracts already in place for the intended use for power sales or energy sales contracts. An important and often ignored principle for any contract is that 'simpler is most often better', from the standpoint of the understanding of the parties and for the implementation and application of the contract's principle of agreement. Unfortunately, the nature of the contracting arrangements, often with multiple parties involved and with varying objectives/expectations for the project make the agreements often more complex than desirable. The complicating factors for LFGTE projects include the nature of the typical participants with their often widely varying backgrounds and business mandates. Often multiple agreements must be negotiated that are contingent (conditional) on other negotiated agreements that may not be fully under control of the parties involved. Additionally, contracts may be conditional upon successful completion of certain events or milestones such as: key environmental or energy permits or approvals; grant funding approvals; financing approvals; or other third party agreements that could include access agreements or easements.

Market access studies undertaken at the pre-investment stage may cost in the range from \$10,000 to \$30,000. The total cost allowance to negotiate and finalize market access agreements can vary greatly as a function of the market regulations and their complexity. Total cost allowances for this item can be from \$50,000 to \$100,000 or more for complex agreements at large facilities. Smaller projects would have difficulty bearing these costs and it is hoped that standard form agreements can eventually be developed based on models used in other countries/jurisdictions.

BOX 14: MULTIPLE PARTNERS AND PROJECT FUNDING COMPLEXITY

The LFGTE project in Liepaja, Latvia is being financed by a combination of grants and loans from a total of seven different institutions. The funding is generally directed to a particular component of the project, such as the LFGTE plant or the LFG collection field. In order for the project to qualify for the funding or loan, there are particular approval processes, unique to each institution, which must be followed.

The largest contributor to the project is a loan from the European Union (EU) Instrument for Structural Policies for Pre-Accession (ISPA). The ISPA funding is directed toward the combined heat and power (CHP) plant that is being constructed to utilize the LFG. To obtain funding, an ISPA representative placed in the Latvian Ministry of the Environment must approve the tender documents. The selected contractor for the project must receive approval from both the ISPA representative and the Ministry of Finance before being sent to the EU Delegation in Riga for approval. An evaluation report must also be written. The draft and then final contract with the contractors must then be approved through the following measures. For this project this process took a total of eight months before any of the work could commence.

The lengthy approval process for the ISPA, as well as the six other donors, has made it very difficult to create and maintain construction schedules, and to assure that the construction phase for the project can be coordinated without costly delays. This has led to stalemates with respect to certain technical, legal and market issues necessary to sustain a project. Currently, the project has not yet been implemented.

Typically, the more donors contributing to the LFGTE project, the more approvals must be obtained to receive funding. This is especially problematic when there are lengthy approval processes and differing application procedures. Any delays that interfere with the LFGTE project schedule are risky because of the time-sensitivity of LFG generation. In addition, construction delays can often significantly increase the project costs.

Generally, the simpler the project team and financing arrangements, the easier it is to smoothly implement the project. It is very difficult to obtain private sector support for a project that is subject to too many constraints beyond the control of the project participants.

Revenue streams may stem from more than one source, sometimes many more sources depending upon the commodity value and sale of CERs. If, as is most often the case, the project economics do not work without multiple revenue streams, the complexity of the project development phase can increase substantively. Finance partners look at "new and developing" revenue streams and markets as a higher risk, particularly for projects that have a relatively long payback period for the initial capital investment.

However, even given all of the above, the significant environmental, social and practical benefits associated with LFG management projects can still be attractive to investors that know and understand the current energy and environmental markets and believe in the nature of the evolving energy markets.

The framework of contracts for a typical LFG management project typically requires the types of agreements listed below. Specific language for contracts suitable for use throughout LAC is beyond the scope of the Handbook. However, a brief outline of the suggested terms that should form part of each of these types of contracts is provided in Appendix C.

Agreement for the Sale of the LFG including All Rights to the Gas

It is assumed that the ownership and control of the rights to the LFG are clearly assigned and controlled. The revenue sharing arrangement must be clear and unambiguous or it may act as an impediment to the project proceeding. An arrangement where the LFG rights and any CER's are paid for based on net returns from the project is the most likely to encourage a project to proceed. This agreement may be conditional but must be in-place to give a proponent or developer the ability to negotiate subsequent agreements.

Agreement for Sale of CERs

An agreement to sell or transfer CERs could be a term of an agreement for the primary energy product or it could be severed and sold as a commodity to other parties. For LFGTE projects, this revenue stream is often the factor that will make a LFG management project financially viable, and it must be negotiated concurrently with any agreement for the primary energy product and either executed concurrently or linked conditionally. There may be a perceived complicating factor given that the certification process is evolving and the emission reductions are not certified as "real" until after the project has been implemented and the performance results have been documented by an approved third party reviewer.

Agreement for Sale of the Primary Energy Product

The proponent or developer must negotiate terms for sale of the primary energy products from the LFGTE facility. This negotiation could be simple if there are standard form agreements in place and if the net price of the energy product under the current "business as usual" can meet or exceed the investor or developer's expected ROI. However, for most candidate projects, the attraction of the LFG fuel as a "green" fuel may be necessary to obtain an enhanced fuel value that is necessary to make the project economically viable. This "green" requirement may take most LFGTE projects out of standard form contracts and into negotiated terms and conditions. It is also critical to negotiate the term length for the revenue streams and the conditions under which the energy products must be provided. The nature of any guarantees for supply and performance are critical factors to the economics and project viability.

Financing, Grant and Other Agreements

There may be a series of other agreements that must be negotiated and executed concurrently with those noted above. For example, a LFGTE project may require a separate agreement to gain access to a system or network for the sale and/or transmission of the energy products. Agreements may be conditional upon execution of grant or financing arrangements. In all cases the links between these various agreements must be understood and factored into the project development phase on a site-specific basis.

9.4 Secure Permits and Approvals

The process of obtaining the necessary permits and approvals can be time consuming and critical to the overall development and implementation schedule for the project. The permitting requirements and steps should be incorporated as specific task items into the design plan and deliverables for the project development. The nature and extent of the permits and approvals will be a function of the site-specific location/jurisdiction and the specific type/size of LFGTE project that is being proposed. This process can take from a few weeks to a number of months and up to a year depending upon the specific requirements.

It is always strongly recommended that the developer or proponent meet with the approval agencies/authorities to review the scope and timing of the required submissions and obtain inputs necessary for the design development. The key areas specific to LFGTE projects are as follows:

Environmental Permits and Approvals

- Waste Management or Landfill Permits: Any modifications or revisions to the permitting for the waste management systems that prescribe, limit or otherwise affect the placement and management of the wastes that generate the LFG must be addressed. This is a particularly important item since it is the future waste filling that will control the size of the future resource and the ability of the proponent or developer to readily access and utilize the resource efficiently. Some jurisdictions may require public meetings and circulation of proposed plan outlines to stakeholders and adjacent property owners.
- Air Quality and Emissions Testing Permits: Any required air permitting for the equipment used in the LFGTE facility must be obtained. Noise assessment and permitting can sometimes become a key consideration.

- Condensate and Liquid Waste Disposal Permits : Any required permitting for the disposal of the condensate, waste oils or other liquid waste products of the LFGTE facility must be obtained.

Planning and Building Related Permits and Approvals

- Zoning and Planning Approvals: There may be a requirement to obtain approval for the specific industrial land use for the LFGTE facility. Some jurisdictions may require public meetings and circulation of the proposed plan outlines to stakeholders and adjacent property owners.
- Various Building Permits and Approvals: These permits can vary greatly based on site-specific and jurisdiction specific requirements. Although these permits are usually readily attainable, the time and cost to obtain these should be considered in the development planning for the project. There may be specific building code and safety standards applicable to use of combustible gases that should be specifically assessed and addressed in the design development.

Interconnect Related Permits and Approvals

- There may be specific connection system permits and approvals necessary to get the energy products to their prospective markets. In the case of electrical power generation and sale, the interconnection costs and requirements can become a significant item on the critical path for the project development and deserves particular focus during the project development phase.

The proponent/developer will need to maintain close communications with the approval authorities throughout their review process to ensure that any issues or considerations are addressed and incorporated into the design development. This will help to ensure that the commissioning and startup of the facility can proceed in a timely manner as outlined in the overall project schedule. This type of project may fall outside the typical frame of reference for many of the reviewing agencies. As such, the nature of any requirements or obligations can often be negotiated to the best interest of all parties if a good communications plan is developed and implemented with the various agencies and stakeholders.

The cost of permits and approvals can vary greatly depending upon the location and site specific requirements. It is not possible to establish a generic allowance for permits and approvals. The costs would include the permit or approval application fees together with the time and resources necessary to develop the supporting technical documentation for the applications. A crude allowance of 1 to 2 % of the capital cost of the project might be a starting point for preliminary estimates for these allowances. This must be refined on a site and jurisdiction specific basis.

Some of the permits and approvals may entail the need for a public consultation process. Depending upon the scope of the process, this cost could be negligible to $50,000 or more, depending upon the specific requirements. If there were major zoning or planning approvals associated with the siting and construction of a project, these costs could be higher still.

9.5 Contract for Engineering, Procurement and Construction, and O&M Services

Design and construction strategies can vary depending upon the makeup of the Project Team and the resources that it may have available to it. Every project team will require a design team assigned to the project at the Pre-Investment phase of the project. The design development will need to proceed concurrently with the detailed development phase of the project. It is assumed that a good conceptual design has been developed and established during the Pre-Investment Phase. At this development stage, the detailed design is being prepared for the construction and implementation phase as well as for the supporting documentation necessary to prepare and submit any required permit and approval applications. These design documents must be prepared for all projects irrespective of the construction/implementation strategy that may be employed. Typically these applications will require a completed design drawing package and a detailed materials/equipment specifications that defines the scope of the works in a manner that is suitable to construct. The nature of the final design deliverables is driven by 2 basic factors: the permit and approval requirements; and the contracting/implementation strategy.

The discussion for each work phase described below includes an overview of its objectives and tasks. Any considerations and/or design constraints that may affect the work schedule or budget are also presented.

All key design criteria and any alternative design review will be established and approved by the Project Team on an ongoing basis throughout the design phase of the project to ensure that the project schedule can be optimized.

Design development is generally considered as a four-stage process: Pre-design/Conceptual Design; Preliminary Design; Intermediate Design; and Final Design.

PRE-DESIGN/CONCEPTUAL DESIGN

These activities will have been completed at the Pre-Investment Phase as outlined in Section 8 of the Handbook. A completed conceptual design for the collection field, building, services and LFG utilization systems should be used as the basis for the full-scale design.

PRELIMINARY ENGINEERING

The primary objective of the preliminary engineering phase of this project will be to extend and develop the conceptual design. Any project specific constraints and design criteria that are to govern the project should have already been identified and fully defined.

Prior to preparation of any design submissions, certain data acquisition activities would be completed as a component of the preliminary design to augment the information that was available to undertake the conceptual design. The information needs would typically include:

- completing a detailed survey of the existing Site in order to augment and complete identification of Site features, utility services, drainage systems, and on-Site structures which may impact the project requirements;
- conducting a confirmatory geotechnical evaluation as may be required; and
- review and evaluation of the current and project landfill development practice being used at the Site.

All completed data acquisition activities, design criteria, and constraints should be summarized in a Preliminary Design Report (PDR). The PDR, including schematic layouts, feasible alternatives, and drawings should be prepared to confirm the direction and scope of the development engineering phase that will be conducted. The PDR submission should include but not be limited to:

- a detailed presentation and rationale for all required specific elements to demonstrate how the proposed design will meet the overall project objectives;
- a detailed description of the proposed components in the design that demonstrates knowledge of the relationship, compatibility, and performance of components;
- a summary of the design alternatives with respect to the requirements of the applicable Ministry of the Environment and Energy regulations and guidelines, and other regulatory agencies that require notification and input to the project;
- details of the equipment and instrumentation design criteria that will be used in the final equipment selection process;
- a section which describes the existing conditions information and field data acquisition activities that were undertaken and, if required, identification of any further data to be obtained during the Development Engineering Phase Activities;
- a preliminary construction schedule will be prepared and presented. Key major equipment or material supply items that may have extended delivery lead times will be identified for the subsequent design phases. This item is critical in any approach towards optimizing the future construction phase;
- preparation of all existing conditions drawings completed to 100 percent as they will be used as the base for many of the subsequent drawings;
- an outline and table of contents for the expected drawing package that will comprise the final design. Some additional drawings for the preferred alternative designs will be provided that would typically include Site plans, typical sections, and details, along with process flow diagrams; and

- an updated cost estimate at a suitable level of detail that incorporates all of the assessments and investigation works undertaken to date.

Each succeeding design stage should be an extension to the PDR to progressively complete design details to meet design criteria requirements.

INTERMEDIATE DESIGN PHASE

The Intermediate Design Phase is the primary design development phase in which the approved design concept is extended and each of the individual elements are identified, selected, and coordinated into a functional package. The primary objective of this phase is therefore, simply stated, to continue development of the preliminary design. There is no opportunity to revisit the design concept but rather this phase includes extensive review and verification of the design concept.

During the Intermediate Design Phase, design documentation will be typically be prepared, which will include the following information:

- an expanded table of contents for the drawings list that begins to fill in specific drawing names and provides the client with an understanding of the scope and content of the eventual final design package; and
- a partial set of drawings including:

  1) Existing Conditions,
  2) Site Plan (95 percent),
  3) Plan/Profiles for all major features,
  4) Typical Details,
  5) Facility Layout Drawings,
  6) Major Equipment Drawings, and
  7) Process and Instrumentation Diagrams.

  Note: Generally the drawings and details provided will be complete except for additional notes and cross-references to drawings not as yet completed. The drawing package is typically considered adequate for submission as supporting documentation to any required permit and approvals application packages that may be required for the specific LFGTE project.

- manufacturers product literature and specification for key or critical items;
- a detailed materials list will be prepared;
- a design report may be required to support any permit applications. Supporting information that confirms the materials selected meet the design criteria established would be provided as part of the report;

- an updated draft construction schedule that provides key dates and the sequence of construction. Any key items or equipment deliveries that are critical will be specifically identified on the project schedule;
- a draft outline of the proposed construction inspection and materials testing programs that will be required (i.e., structural, soil gradation, compaction testing, pressure testing, etc.);
- draft copies of required permit submissions identified during the Preliminary Design Phase and timing requirements for approvals; and
- a draft outline of an O&M Plan complete with updated cost allowances.

FINAL DESIGN PHASE

Preparation of the final design will be carried out following the completion of the Intermediate Design Phase activities and review of any comments or modifications associated with agency/authority review of application documents. This stage of the project may include but not be limited to:

- completing a final design report;
- completing a set of drawings that are ready for construction;
- completing the equipment and materials procurement arrangements for construction;
- finalizing a final design report which includes all design calculations, and equipment and materials selection information, etc.;
- providing an updated construction schedule;
- providing a capital cost expenditure schedule to assist in the budget management/control. Updated cost estimate will be prepared, only if required due to any scope changes;
- providing a construction quality assurance program which will detail all elements and requirements for the inspection/quality control program to demonstrate that the design is being implemented in accordance with its intent;
- obtaining all necessary regulatory approvals; and
- preparation and submittal of the complete O&M Plan.

The steps and sequence outlined for all of the design phases prior to the final design are identical for all project delivery modes. At the final design stage, the delivery mode to construct and commission the facility must be selected or there would be some redundancy and wasted expense in the document and contract development areas.

BOX 15: IMPORTANCE OF CLEAR AND CONCISE CONTRACTUAL AGREEMENTS AND TECHNICAL SPECIFICATIONS

The development of the Kemerburgaz LFG Project in Turkey took place over a ten-year period beginning in 1992. The plant was finally commissioned in November 2002. The contractor for the LFG project was a consortium consisting of the local contractor for the site rehabilitation, and two English companies, one specializing in LFG extraction systems and the other in LFG utilization equipment. The consultants for the project were a local firm, who hired a German company, as a sub-consultant to advise on LFG related issues.

The conceptual design and specification for the project were prepared as a draft by an American company long before the detailed site evaluation had commenced. This meant that it lacked a great deal of detail and site specific information. It was translated into Turkish and then back to into English. The design and specification were subsequently utilized by the local contractor and consultant, with some input from the German sub-consultant. This led to confusion, interpretation issues and many delays in the project implementation because there was a great deal of miscommunication and misunderstanding between the various project partners and parties to the project.

The preparation of clear and concise agreements and technical documentation is essential to a successful project regardless of the number of parties involved and the length of development phase for the project. This case study also serves to reinforce that there should be clear lines of accountability for performance of the project and that ,where practical, the minimum number of parties having the required expertise will be the most efficient and cost effective approach to design and implement the project.

The steps and sequence outlined for all of the design phases prior to the final design are identical for all project delivery modes. However, there are a number of delivery modes that one can select from to complete the project. Each delivery model differs in its approach, contracts and cost, while still completing the job. A delivery mode will be selected to suit the project and the project participants and investors. A brief outline of optional project delivery approaches and the inherent characteristics of each are provided below.

Conventional Owner/Engineer/Contractor Project Delivery Method

In this approach, the Owner of the LFG resource engages an engineering/design team familiar with all aspects of the LFG resource to design the LFG utilization facility and LFG collection infrastructure. Once the Owner has approved a design for the proposed facility, the engineer/design team then prepares contract documents in a package for bidding by interested contractors. Potential contractors prepare bids for the construction project, prepare contracts with subcontractors as required and once awarded, undertake construction with appropriate sub-contractors in accordance with the specified design package. Typically, the engineering/design team also monitors construction progress, quality, payments, and performance on behalf of the owner. Positive factors influencing the selection of this project delivery method include:

- this is the most widely used method that is understood with all parties understanding their role and potential risks being undertaken;
- in most cases lowest bid from interested contractors constructs facility; and
- the owner has complete control over design elements and specified features for the facility.

Potential disadvantages and concerns for using this project delivery method include:

- the project delivery method is somewhat more time consuming as project activities are conducted in a stepwise approach as design activities are complete prior to construction;
- the owner accepts liability for the design as laid out in the construction documentation with potential increases in contractor claims for design/constructability issues;
- there is potential for adversarial working relationships between owner, engineering/design team, and contractors; and
- since contractor uses a least cost approach to completing the project, potentially significant oversight time may be required by the owner or engineering/design team to manage project performance and quality.

Design-Build Project Delivery Method

The design-build project delivery method has grown in popularity in the last few years. For a design-build project, the owner of the LFG resource contracts with a single entity to design and build the project. Typically, a contractor associated with an engineering firm or firms who have in-house engineering staff provide this type of delivery method. It has also become common where engineering firms offer design-build services by having either contractor on retainer or in-house construction/contracting personnel. A design-build turnkey contract goes a step further, by selection, procurement, and installation of furnishings, equipment, and training that gives the owner a complete facility that is ready to occupy and operate. Positive factors influencing the selection of this project delivery method include:

- typically the project costing is guaranteed and project start-up times shortened compared to traditional design-bid-build system;
- an owner deals with a single entity for all design and construction issues which also reduces potential for claims for extras; and
- there is potential for financing portions of the project by the design-build team.

Potential disadvantages and concerns for using the design-build project delivery method include:

- there are potentially fewer checks and balances between contractor and design team with the potential for technical adversity for the owner of the LFG resource;
- it is critical for both the designer and constructor understand the process and design concepts behind the LFG resources to obtain optimum project performance with this project delivery method;
- the owner accepts less control of the project design intent with fewer and less complete design documents available for information. This can be mitigated with clear requirements of project intent, performance, and communication requirements prior to project initiation;
- there is potential for fewer competitive bids given the lack of firms expert in all aspects of the LFG utilization resource and contracting expertise; and
- there may be difficulty in providing design-build services to owners of the LFG resource in the public sector with regulatory hurdles to this type of project delivery method.

Design-Build-Operate Project Delivery Method

The design-build-operate project delivery method is similar to the above discussion of the turnkey design-build method by extending the responsibility of the design-build team to operate the LFG utilization facility. Essentially, the owner of the LFG resource outsources as a bundle of services the design, construction, and operation of the proposed facility. Factors influencing the selection of the project delivery include:

- the owner deals with one contractual entity for capital costs and operation and maintenance activities for typically a fixed term revenue stream with renewable operating terms;
- there is a reduction in risk to the owner by having performance warranties with one entity designing, building, and operating the utilization facility; and
- the owner transfers risk of operational failures to design-build-operate team.

Potential disadvantages and concerns for using the design-build-operate project delivery method include:

- the availability of firms with expertise and personnel to manage the LFG resource may not provide the most competitive costing; and
- the owner has reduced influence and control of the LFG resource over the life of contract.

Build-Own-Operate Project Delivery Method

A variation on above design-build-operate project delivery method is where the owner contracts with entities capable of building, owning, and operating a LFG utilization project. Essentially this amounts to selling the LFG to the highest bidder and granting certain rights of access and occupation to portions of the candidate site for the term of an agreement. Positive factors influencing the selection of the project delivery include:

- the Owner has a reduced risk approach to managing the LFG resource; and
- this Owner is not committed to capital and operating expenses associated with the facility.

There are also variations and permutations regarding the above that could be used to adapt to project specific conditions. Performance and incentive contracts could be developed. Buy-out or lease to own approaches could be utilized, where a site owner may be interested in the future right to acquire ownership of a facility at some time during the contract term. There are also different forms that the ownership of a facility could take. The facility could be owned and operated by a corporation or a joint venture of more than one corporation. A project could also be set up a stand-alone limited company that has one or more shareholders that control the corporation. Although there are many variations regarding the above, the delivery methods discussed are capable of meeting the requirements to establish and operate a viable LFGTE project to suit the site-specific requirements at sites throughout LAC.

9.6 Implement Project and Start Up Commercial Operation

The previous section provided a general outline to the overall design development process for LFGTE facilities. The following key steps are applicable to all LFGTE projects regardless of the delivery mode or nature of the project ownership.

Specific construction management tasks are subdivided into two major areas of activity: construction administration and construction supervision. The major items that will be undertaken in each of these two areas are:

<u>Construction Administration</u>

- establish and administer all contracts with subcontractors and suppliers;
- tracking of construction work tasks and schedules;
- measurement, calculation and recording of quantities and preparation of progress payment certificates;
- review any changes in scope and, where required, negotiate change order requests;
- interface with any regulatory authorities as required;
- ensure permit terms and conditions are satisfied and addressed;
- ensure review of all shop drawings and materials data sheets completed by appropriate design staff;
- assist in development of training tools and coordinating staff training;

- organize and administer the commissioning phase complete with resolution of any warranty and/or guarantee documentation that is required; and
- provide all payment information for both substantial and final completion of project.

Construction Supervision

- supervise all field construction activities;
- review of subcontractors work to ensure compliance with the intended design;
- arrange for materials and equipment testing and review results;
- coordinating and attending regularly scheduled construction progress meetings, including preparation and distribution of meeting minutes and agendas;
- measurement and recording of actual installations for preparation of Record Drawings;
- providing all construction layout; and
- coordination of QA/QC inspection and testing of all required materials and systems.

Commissioning and Facility Startup/Operations Phase

Optimally one designated entity will retain overall responsibility for the commissioning, training and initial operations of the collection system and utilization facility with assistance from the owner of the resource. Specific commissioning and facility startup and operation activities for LFG utilization facility include the following:

- prestart commissioning, electrical and mechanical checkouts of LFG collection and utilization equipment;
- initial operation of LFG collection field;
- setup, balance and optimize well field in landfill site;
- setup and balance gas blowers and any gas processing equipment;
- setup and stabilize utilizing equipment (i.e., engine/generators);
- commission/testing of utility interconnect systems and controls;
- troubleshoot and instrumentation, calibration and or programming issues;
- complete operator training;
- complete checks and authorize start of regular operations; and
- finalize O&M manuals and as recorded drawings within 6 months of system startup.

Post Commissioning Regular Operation

- periodically monitor and balance LFG well field (recommend a minimum of once every two months);

- operate the overall system and monitoring equipment within specified criteria;
- maintain and service the engines in accordance with manufactures requirements; and
- regularly assess the gas quality for gas processing and engine maintenance interval consideration.

Public Relations and Communications

- maintain good public relations (ribbon cutting, public tours, press releases).

9.7 Monitor and Evaluate Contract Performance and Project Impacts

One of the items that must be stressed throughout this Handbook is the nature of a LFG fuel resource. LFG collection, while it can be both reliable and relatively steady over time, it will only be so if there is appropriate operator care and attention both in the operations of the systems and in the modification/progressive extension of the LFG collection system during the life of the project. The LFG resource should never be thought of, or treated as, a static or passive resource. This places additional emphasis on understanding the dynamic operation of the landfill site and the operating and maintenance plans that will be required to ensure effective operation and overall performance of the LFGTE systems.

OPERATIONS AND MAINTENANCE PLAN

A detailed O&M Plan that provides a user friendly document to efficiently and cost effectively operate and maintain the facility is a prerequisite for a successful project. It has often been found that typical Contractor prepared O&M Plans are often lacking in certain basic information to make the document user friendly. An outline for the O&M documentation is as follows:

- Volume 1 - Summary Document

  This volume provides the following:

  - overview of facility;
  - governing criteria;
  - plain language description of facilities operations;
  - regular maintenance activities and cycle times;
  - recommended spare parts lists;
  - health and safety protocols/procedures;
  - alarm conditions and response measures;
  - name and contact for all suppliers and technical support resources; and
  - overview of scope, content, and organization of technical appendices which follow in subsequent volumes;

- Volumes 2-4 - Technical Documentation

  The technical documentation for the facility, materials, and equipment is organized in a format consistent with the Master format organization for construction specifications. For large projects this may entail three or four large volumes but the organizational format is essentially the same. Volume 2 would typically include the "as recorded drawings" and the site works and services documentation. Volume 3 would include the mechanical, piping, valves, and related information; and Volume 4 would include the electrical, instrumentation, and controls documentation.

Performance and Compliance Monitoring Programs

There are separate monitoring programs required for the ongoing operations of both the LFG collection system and LFG utilization systems as well as for compliance monitoring program for the facilities. Each of these programs will need to be set up and integrated into an overall monitoring program for the LFG management systems. The most critical item to reinforce is the dynamic nature of the landfill site and collection field that will continually change over time. A LFG collection system will have to be continuously maintained, repaired and expanded based on the results of the monitoring programs. Some of the key elements that will need to be included in these programs are:

- operational parameters (vacuum, gas quality and temperature) for each of the individual gas wells or trenches and for the overall system;
- inspection and monitoring of the landfill site particularly with respect to any differential settlement issues;
- gas flows and volumes for individual wells/trenches and the various branches that comprise the overall system;
- LFG fuel quantities utilized and tracked over time;
- blower system operational parameters;
- condensate and other liquid waste characterization and quantities; and
- LFG utilization system operational parameters including emissions monitoring as required.

There will always be site-specific monitoring programs that must be developed that incorporate all of the above and any permit or approval specific requirements. The most important consideration in monitoring LFG management systems is to remember that the landfill site is dynamic and continually changing requiring proactive attention to all of the supporting components and systems.

9.8 Lessons Learned from Detailed Development Phases of Case Studies

All but three projects represented in the eight case studies have proceeded beyond the pre-feasibility phase of project development. Table 9.1 summarizes some of the lessons learned through these project developments and the following briefly reinforces some of the key items learned from the case studies.

Waterloo LFGTE Project (Canada)

This project has been operational for approximately five years and is working well and is the only case study that would be categorized as being in a relatively steady state operating mode. There are two key lessons learned from this project. First, it took more than six years to negotiate and finalize a contract to market and sell the electrical power from the facility. This serves to reinforce the need to establish market access as an important area to address and prevent from becoming an impediment to developing LFGTE projects in LAC. Secondly, this site is being operated with clear separation of responsibilities between the LFG collection and the LFG utilization functions. This approach can be made to work if both the owner and developer have clear and contractually well-defined areas of responsibility.

The cost to collect the LFG from this site is approximately $300,000 (US$) per MW of electrical generating capacity. This cost is variable and subject to site specific conditions and the configuration of the site.

The cost for Waterloo plant in Canada is for less than 1.5 million (US$) per installed MW of generating capacity and it incorporates a number of systems to facilitate future system expansion. The project received no grant funding or other financial support and has been a financial success for the participants at a base revenue for electrical power of approximately $0.045/kWh (US$). Further information regarding the capital cost allowances and funding allocations is provided in the case study provided as an Annex to this Handbook.

El Molle, Lo Errazuris, Le Panto and La Feria LFGTE Projects (Chile)

The Chilean case studies were the only case studies that presented an example of direct use of LFG as a fuel. In one case the LFG was processed, mixed with petroleum gas, and piped into the city of Santiago. In another case, the LFG was utilized by a large, nearby agricultural industry. A third project flared the LFG initially and then later pumped it to a local gas company for use. These projects help to demonstrate that the preferred solution can take many forms and the pre-investment phase should be implemented with this in focus.

Getlini LFGTE Project (Latvia)

There are two LFGTE projects being developed in Latvia: the Getlini project and the Liepaja project. The Leipaja project has been stalled prior to construction because of the differing approval requirements of the large number of investors. The Getlini project has

TABLE 9.1

COMPARISON OF CASE STUDY PROJECT DEVELOPMENT PHASES
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

Item	**Waterloo** **Canada**	**Istanbul** **Turkey**
Site Facts: REFER TO TABLES 8.7a and 8.7b FOR ALL BASIC SITE FACTS.		
Project Development Phase		
Finalize partnership arrangements and business plan	• Toromont took primary risk for LFG supply with no penalty clause or guarantee of LFG supply • Toromont responsible for all aspects LFG utilization facility • RMOW retained all responsibility for landfill operations and LFG collection • Potential emission reduction credits transferred to Ontario Hydro	• Project tendered by Instanbul Municipal Authority which assembled a project working committee within the public works department • Municipality retained ownership of the landfill • Contracor, Yapisal-Soiltec-Organics, selected from short-list of candidates based on price, responsible for providing finance, turnkey for supply and commissioning of facility, and negotiation of connection to grid. • Local consultant, Bimtas, appointed by Municipality to supervise works • Expert sub-consultants, IGA Ingenieurgesellschaft Abfall mbH of Stuttgart, hired by consultant for assistance during design and construction phases.
Conduct final project appraisal	• RMOW could not guarantee LFG quantities because of the risk • Five year opeating record of the LFG collection system mitigated Toromont's risk • Use of proven LFG utilization technology helped secure approval from the regulators	• Contractor guarantees to run engines for two years removed during contract negotiations because it was considered a great risk and would cost the Municipality a lot as part of the contract..
Negotiate energy sales contract and secure incentives	• Ontario Hydro negotiated and executed a contract to purchase "green power"at a premium price (approximately $0.015 above the wholesale purchase price) for a period of 5 years after placing plant into service. • Beyond 5 years, price to be at current market rates.	• No special rates for electricity from utility. Producer had to find customers and sell electricity for a negotiated price. • No consideration given to ERCs because of Turkey's status as non-EU country.
Secure permits and approvals	• EcoLogo certification obtained and maintained through period monitoring and the payment of	• Power Purchase Agreement (PPA) negotiated on an individual customer basis.

TABLE 9.1

COMPARISON OF CASE STUDY PROJECT DEVELOPMENT PHASES
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

Item	**Waterloo Canada**	**Istanbul Turkey**
	an annual fee. • C of A Air required to operate the LFG engines. • Annual testing required to maintain plant certification. • Emission testing program undertaken to assess and confirm engine emission levels.	• Delays encountered as a result of perceived risk from new project. • Energy contract negotiated for the minimum period of 10years due to uncertainty about the availabitity and reliability of supply of LFG now that the landfill has closed. • Tedas, electricity company, refused to pay for electricity generated prior to the formal commissioning of the plant.
Contract for engineering, procurement and construction, and O&M services	• Toromont hired out most of the design and construction operations work to qualified contractors. All commissioning, operating and maintenance by own forces. • Significant effort to negotiate and finalize interconnection requirements that had to be met to tie engine-generators into the electrical grid.	• The contractor, Yapisal-Soiltec-Organics, was selected from a short-list of five contractors. Selection was done during an open meeting of the shortlisted contractors who were allowed to bid in turn to provide the lowest price for the project, resulting in a savings of nearly $ 8.5 million USD. • Bid and contract documents should have been reviewed by a quailified expert prior to issuing the project to bid.
Implement project and start up commercial operation	• Plant commissioning and startup was a smooth process with minimal difficulty. • LFG collection and flaring system had been operating for more than 5 years prior to LFGTE system startup. • On-line availability has been very high (>98%) and most off-line time has been for scheduled maintenance activities or power grid disconnections that were initially for external causes not related to the facility. • Phased plant development. Initially 4 engines on line. Fifth engine added in 2003. Sixth expected to be added in 2005.	• LFG plant to be constructed in two phases: Phase 1 4MW and Phase 2, 2 MW • There were delays in bringing equipment into the country as it did not fit into a specific import category and therefore required significant discussion and evaluation to determine the import duty to be levied. • The displacement of the incumbent mayor of Istanbul caused a works stoppage and caused extended delays in payments to the Contractor.
Monitor and evaluate contract performance and project impacts	• High water/leachate levels in the landfill have limited the	• In hindsight, the pump trial should have been carried out

TABLE 9.1

COMPARISON OF CASE STUDY PROJECT DEVELOPMENT PHASES
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

Item	Waterloo Canada	Istanbul Turkey
	recovery and efficiency of some of the LFG extraction wells • Some minor operational limitations imposed by odor control demands for site and maximizing electrical power generation.	under the supervision of the LFG plant developer • The supervising consultants (Bimtas) contract should have been tied to the success of the project in terms of remaining on time and on budget. The lack of these ties allowed for an adversarial relationship between the contractor and the consultant and encouraged fault-finding by the consultant, which delayed the project.

TABLE 9.1

COMPARISON OF CASE STUDY PROJECT DEVELOPMENT PHASES
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

Item	**Santiago Chile**			
	Valparasio (El Molle)	Lo Errázuris	Le Panto	La Feria
Site Facts: REFER TO TABLES 8.7a and 8.7b FOR ALL BASIC SITE FACTS.		.		
Project Development Phase				
Finalize partnership arrangements and business plan	• LFG extracted from 1986 to 1998 by the local gas company GASVALPO (Valparaiso); • Lo Errázuris Landfill (Santiago) was exploited by the local gas company (GASCO) from 1984 to 1994, when the landfill ceased operations			
Conduct final project appraisal	• No information available at time of publication.			
Negotiate energy sales contract and secure incentives	• No information available at time of publication.			
Secure permits and approvals	• No information available at time of publication.			
Contract for engineering, procurement and construction, and O&M services	• No information available at time of publication.			
Implement project and start up commercial operation	• When in operation, **Lo Errázuris** landfill (Santiago) generated 4.5 million m^3 of LFG. The LFG (30%of total) was mixed with petroleum gas and piped to the city, supplying 18 to 20% of the total gas demand for the City of Santiago. • **Le Panto** landfill was a large facility but totally uncontrolled. It received wastes from 21 municipalities around Santiago, receving an average of 4,000 tonnes/day of wastes. The landfill was closed in 2002. The LFG generated at the landfill was used by a nearby agricultural industry. • **La Feria** landfill was operated from April of 1977 until August of 1984. Subsequent to July of 1982, the LFG generated at the Site was piped to the local gas company (GASCO). Prior to that date, the LFG was simply flared. The landfill was closed at the end of the 80's. In 1993, a project to rehabiltate the Site was started with the University of Valparaiso. The program ended in 1997 and it consisted of reforestation of the Site.			
Monitor and evaluate contract performance and project impacts	• No information available at time of publication.			

TABLE 9.1

COMPARISON OF CASE STUDY PROJECT DEVELOPMENT PHASES
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

Item	Latvia			
	Getlini (old landfill)	Getlini (energy cells)	Liepaja (old Landfill)	Liepaia (energy cells)
Site Facts: REFER TO TABLES 8.7a and 8.7b FOR ALL BASIC SITE FACTS.				
Project Development Phase	• Liepaja construction to begin in Sept. 2003			
Finalize partnership arrangements and business plan	• Finalizing the ISPA contractor approval resulted in a delay to the start of the detailed design and construction phases (Liepaja).			
Conduct final project appraisal	• No information available at time of publication			
Negotiate energy sales contract and secure incentives	• Delay in construction caused energy contract with "green" power pricing to expire (Getlini) and reduced the project revenue substantively.			
Secure permits and approvals	• Required permits and approvals were obtained from from 11 different groups or agencies resulting in a slow and protracted process (both Getlini and Liepaja).			
Contract for engineering, procurement and construction, and O&M services	• No information available at time of publication			
Implement project and start up commercial operation	• No information available at time of publication			
Monitor and evaluate contract performance and project impacts	• Variable LFG flows have been extracted during the first 8 months of operation to gain an understanding of the gas generation characteristics of the site and to optimize the system operation (Getlini). • Estimates of LFG production were too high, with result that energy production not being met.			

TABLE 9.1

COMPARISON OF CASE STUDY PROJECT DEVELOPMENT PHASES
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

Item	**Poland**			
	Torun	Gdansk	Krakow	Olsztyn
Site Facts: REFER TO TABLES 8.7a and 8.7b FOR ALL BASIC SITE FACTS.				
Project Development Phase				
Finalize partnership arrangements and business plan	• Torun LFG plant is owned and operated by Biogaz Investor Co., which has shareholders from the municipality, MPO, power company, heating company and a private contractor. • Gdansk and Krakow LFG plants are owned and operated by the MPO. • Olsztyn LFG plant is a BOO by Legajny Renewable Energy Generation SP.z.o.o. which is owned by two Danish investors: ESCO (75%) and Capital Investment Fund for Centraland Eastern Europe (25%). • Olsztyn – Legajny Renewable Energy Generation Sp.z.o.o. leases the CHP plant land, electricity sales contract is with Zaklad Elektroenergetyczny w Olsztynie S.A., heat sales contract is with Gosp. Orgrodnicze "Legajny"”Sp. z.o.o. • For Gdansk and Krakow, there are no royalties because the landfill owner is also the plant owner • There are no royalties paid to the landfill owner in Torun. • The royalty agreement for Olsztyn in confidential.			
Conduct final project appraisal	• No information available at time of publication.			
Negotiate energy sales contract and secure incentives	• Actual prices for the electricity and heating contracts are confidential. • All energy sales contracts were negotiated and signed before plant design was started. • Gdansk project could not secure a long term project, so the contract is renegotiated in shorter term lengths (~4 years).			
Secure permits and approvals	• Torun – construction of the LFG plant required permits from 10 different departments and took fromMay 1994 to December 1995. • Olsztyn utilization building construction was given approval by the Municipality and construction proceeded. It was then found out that the County had jurisdiction over certain aspects of the project and the County took the contractor to court. The project was held up for 1.5 years before a resolution was in place.			
Contract for engineering, procurement and construction, and O&M services	• Torun and Gdansk have a one year guarantee from the contractors. Krakow has a two year guarantee. In addition, there were penalities for delays in the construction work or poor efficiency of operations.			

TABLE 9.1

COMPARISON OF CASE STUDY PROJECT DEVELOPMENT PHASES
HANDBOOK FOR THE PREPARATION OF LANDFILL GAS TO ENERGY PROJECTS
The World Bank

Item	Poland
Implement project and start up commercial operation	• Torun plant was comissioned in September 1997, Gdansk in September 1998, Krakow in May 1998, and Olsztyn in March 1999. • All four sites are using a staged development approach. Torun – 40 wells installed in 1997, 12 more in 2002 Gdansk – 39 wells installed in 1998, 10 more in 2002 Krakow – 41 wells installed in 1998,10 more in 2002, 32 additional wells planned for 2004 Oltsztyn - 40 wells installed in 1997 • The wells are collecting LFG with a very high CH_4 content, but the quantity is very low: Torun (2.3m^3 LFG/tonne waste/year), Gdansk (1.9 m^3 LFG/tonne waste/year), Krakow (2.2 m^3 LFG/tonne waste/year), Oltszyn (1.8 m^3 LFG/tonne waste/year) • All four plants sell electricity to the grid, Olsztyn feeds a boiler plant for adjascent greenhouses, Torun sells waste heat, Krakow and Gdansk use waste heat for on-site buildings.
Monitor and evaluate contract performance and project impacts	• Oltszyn is experiencing serious problems with the LFG collection system due to flooding of several of the extraction wells, which has reduced the amount of LFG available for the boiler plant. • The horizontal LFG collection pipes in Krakow appear to be blocked filled with condensate and are no longer collecting the LFG effectively. As a result, the site operator has elected to only install vertical wels in future. • Gdansk operational hours increased significantly in 2002 because of the signing of a service agreement with a motor company and the stocking of spare parts nearby to reduce down time. Prior to that date, on-line availability was lower than expected and resulted in lost revenue from projections. • All four plants take measurements of several parameters to monitor the operation of the plants and all have worked well. • Project experience dictates that using a local supplier for the equipment and parts supply decreases the amount of time required to obtain parts and perform repairs.

been commissioned within the past two years, but has experienced difficulty with market access and market pricing as well as technical difficulties in the collection of LFG due to high leachate level within the site. This case study project serves to reinforce a number of key elements, including:

- ensuring that there is a secure long-term market for the energy products and CERs; and
- ensuring that the collection system is designed and constructed with the capacity to continuously extract and reliably supply the LFG fuel.

The actual budget cost for Getlini plant in Riga is for less than 1.5 million (US$) per installed MW of generating capacity. The total capital and development cost for the waste management system at this site included the LFGTE plant and included a GEF grant and other supporting funds that makes it difficult to fully identify the LFGTE plant and collection field costs. Further information regarding the capital cost allowances and funding allocations is provided in the case study provided as an Annex to this Handbook.

Monterrey LFGTE Project (Mexico)

This project had just recently been commissioned and would be characterized as being in the initial startup and optimization phase. The project has been well supported to gain both access to electrical power market and a reasonable price for the electricity sold. This case study illustrates that successful LFGTE projects can be developed and operated in LAC and the Caribbean if there is a well developed business plan and cooperation between the various levels of government, industry, finance and the resource sector. The cost to develop the project is considered high but the overall revenue structure is adequate to support an adequate return on investment for the developers. Future value for CERs are expected to further enhance the project value.

The cost to collect the LFG from this site is approximately $325,000 (US$) per MW of electrical generating capacity. This cost is variable and subject to site specific conditions and the configuration of the site.

The actual budget cost for the 7 MW plant and all associated studies was $13,250,000 (US$) or approximately 1.9 million (US$) per installed MW of generating capacity. This total capital and development cost included GEF of approximately $6,000,000 (US$). Further information regarding the capital cost allowances and funding allocations is provided in the case study provided as an Annex to this Handbook.

Torun, Gdansk, Krakow and Olsztyn LFGTE Projects (Poland)

The Torun LFGTE project was commissioned in 1997. The Gdansk LFGTE project was commissioned in 1998. The Krakow LFGTE project was commissioned with one engine in 1998. A second engine was added in 1999 and then a third engine in 2002. The Olsztyn LFGTE boiler plant project was commissioned in 1999.

These are generally small LFGTE projects that have employed varying partnership approaches including private-public partnership, and ownership and operation by the landfill owner/operator. Two of the projects have also relied on investment and equipment from firms outside of Poland.

Problems were encountered in determining the full extent of information for applications and approvals. In one case permission to start construction was given by an authority outside its jurisdiction, sparking protest from the both the public and authorities. The other problem that has plagued all four sites is limited fuel recovery of the LFG collection system, likely as a result of condensate blockage problems. In many cases parts of the LFG collection systems are flooded and no longer collecting LFG efficiently, if at all.

The electrical generating plants for the sites in Poland are all less then 1 MW in generating capacity per site. The actual cost for these plants ranged from slightly less thanb $1.5 to more than $2.2 million (US$) per installed MW of generating capacity. Further information regarding the capital cost allowances and funding allocations is provided in the case study provided as an Annex to this Handbook.

Kemerburgaz LFGTE Project (Turkey)

The Kemerburgaz LFGTE project near Istanbul, Turkey, came out of a rehabilitation project that resulted from a catastrophic waste slide. The LFGTE plant was commissioned in late 2002. Turkey has a relatively high price for both industrial and domestic energy at approximately $0.09 USD/kWh, making a LFGTE a promising project. Although all of the capital and operating costs were not provided, it is projected that this facility would have an adequate return on investment to encourage developers with a reasonable return to the site owner/operator.

The project ran into several problems during its development. This was the result of poorly written specification and cross-cultural interpretation differences. In addition, the lack of a clear project leader led to a lot of role confusion that initially stalled construction. There were also conflict of interest issues, which presented themselves and increased the cost of the overall project, but which were subsequently resolved and the facility is now in operation.

Case Study Summation

In summary, the case studies consistently reinforce the need to understand the LFG resource and its site specific application. From a technical perspective, the technology to utilize the LFG is generally well developed. The technical issues were very focussed towards the reliability of the fuel supply, with condensate and liquid management being the dominant issue in this regard. From a business and administrative standpoint, the key issues were primarily associated with: access to energy markets; market price for energy products; project team organization and coordination; and the extent and implications of permits and approvals.

REFERENCE MATERIALS

SECTION 1 REFERENCE MATERIALS:

Johannessen, Lars Mikkel, "Guidance Note on Recuperation of Landfill Gas from Municipal Solid Waste Landfills", Working Paper Series #4, Urban Development Division, World Bank, Washington, DC, 1999.

Johannessen, Lars Mikkel and Gabriela Boyer, "Observations of Solid Waste Landfills in Developing Countries: Africa, Asia, and Latin America", Working Paper Series #3, Urban Development Division, World Bank, Washington, DC, 1999.

Landfill Gas and Composting: A Potential GEF Strategy for LCR, prepared for the World Bank's Latin America and Caribbean Region Office (LCR) by K. Ahmed and C. Bartone, March 2001.

Estimates taken from Prototype Carbon Fund: Annual Report 2002, World Bank, Washington, DC, 2002.

SECTION 2 REFERENCE MATERIALS

Augenstein, D., and J Pacey, "Landfill Methane Models" 14th Annual Landfill Gas Symposium Proceedings, Research Triangle Park, 1991. Ed. SWANA. Triangle Research Park. 1991. III-87 – III-111.

Canada's Greenhouse Gas Inventory 1990-2000 Greenhouse Gas Division, Environment Canada, June 2002

http://www.ec.gc.ca/pdb/ghg/1990_00_report/appa6_e.cfm#scroll

Christensen, Thomas H., and Peter Kjeldsen, "Basic Biochemical Processes in Landfills" in *Sanitary Landfilling : Process, Technology and Environmental Impact* ed. Thomas H. Chistensen, Raffaello Cossu, and Rainer Stegmann (Academic Press, New York, 1989) p.29

Conestoga-Rovers & Associates (for Waste Treatment Division, Hazardous Waste Branch), Guidance Document for Landfill Gas Management, (Environment Canada, Ottawa, 1996)

CRA, "Design and Operation of Non-Hazardous Solid Waste Landfills to Optimize the Generation and Recovery of Landfill Gas and Energy", report to Environment Canada, Ottawa, Ontario, January 2000.

Emission Factor Documentation for AP-42 Section 2.4 Municipal Solid Waste Landfills (Revised) Office of Air Quality Planning and Standards Office of Air and

Radiation U.S. Environmental Pretection Agency Research Triangle Park, North Carolina, 2771 August 1997

Ham, Robert K., and Morton A. Barlaz, "Measurement and Prediction of Landfill Gas Quality and Quantity" in *Sanitary Landfilling : Process, Technology and Environmental Impact* ed. Thomas H. Chistensen, Raffaello Cossu, and Rainer Stegmann (Academic Press, New York, 1989) p.155-158

Intergovernmental Panel on Climate Change. Geneva: IPCC, 1995.

IPCC, "Solid Waste Management and Wastewater Treatment" *in Methodological and Technological issues in Technology Transfer* ed. Carlos Pereyra. 1999

<http://www.grida.no/climate/ipcc/tectran/255.htm>

Lu, James; Morrison, Robert; Stearns, Robert, March 1981. "Leachate Production and Management from Municipal Landfills, Summary and Assessment", In-Land Disposal Municipal Solid Waste EPA-600/9-81-200a.

McBean, E.A., F.A. Rovers, and G.J. Farquhar. Solid Waste Landfill Engineering and Design, New Jersey: Prentice Hall, 1995.

Mosher, F.A., and J.R. Yardley. "Landfill Gas Collection System Efficiencies: Facts and Fallacies" 19th Annual Landfill Gas Symposium Proceedings, Research Triangle Park, 19-21 March 1996. Ed. SWANA. Triangle Research Park. 1996. 133-45.

Reinhart, D.R., and B. Al-Yousfi. "The Impact of Leachate Recirculation on Municipal Solid Waste Landfill Operating Characteristics." Waste Management & Research 14 (1996): 337-346

U.S. E.P.A., Technology Transfer Network Clean Air Technology Center

<http://www.epa.gov/ttn/catc/products.html#software>

U.S. EPA, March 94, "Recommended Changes to the Proposed Municipal Solid Waste Landfill New Source Performance Standards and Emission Guidelines", presented at SWANA Landfill Gas Symposium

McBean, E., Rovers, F., and Farquhar, G., "Solid Waste Landfill Engineering and Design", Prentice-Hall Publishing Co., New Jersey, 1995.

McCreanor, P.T., and D.R. Reinhart, 1996. "Hydrodynamic modeling of leachate recirculating landfills" Wat. Sci. Tech. (1996) Vol. 34, No. 7-8, pp. 463-470.

McCreanor, P.T., and D.R. Reinhart, 2000. "Mathematical modeling of leachate routing in a leachate recirculating landfill" Wat. Res. (2000) Vol. 34, No. 4, pp. 1285-1295.

Reinhart, Debra; Townsend, Timothy (Reinhart and Townsend), 1998. Landfill Bioreactor Design and Operation.

Reinhart, Debra, 1995. "The Impact of Leachate Recirculation on Municipal Solid Waste Landfill Operating Characteristics", Waste Management & Research (1996).

Reinhart, Debra, 1995b. "Full-Scale Experiences with Leachate Recirculating Landfills: Case Studies", Waste Management & Research (1996).

United States Environmental Protection Agency and Buncombe County General Services Department (U.S. EPA), June 2001. Educational Workshop on the Landfill Bioreactor Process, pp. 4-5.

Zison, S.W., "Landfill Gas Production Curves, Myth vs. Reality" GRCDA '90

SECTION 3 REFERENCE MATERIALS:

Capstone Micro Turbine Fact Sheet. Chatsworth: Capstone Turbine Corp., 2002.

Conestoga-Rovers & Associates (for Waste Treatment Division, Hazardous Waste Branch), Guidance Document for Landfill Gas Management, (Environment Canada, Ottawa, 1996)

Environment Canada. "Ottawa Landfill – Microturbine Pilot Project." Landfill Gas Technical Bulletin June 19 (2002).

Pappas, Sibyl with SCS Engineers, Presentation "Conventional and Emerging Technology Applications for Utilizing Landfill Gas", New York, May 2002

< www.epa.gov/lmop/conf/02_newyork/emergingtechprsent.ppt>

Section 5.0 - Environmental Resources Management (ERM), "Strategic Planning Guide for Municipal Solid Waste Management", CD-ROM, Collaborative Working Group, World Bank, Washington, DC, 2000.

SECTION 5 REFERENCE MATERIALS:

Environmental Resources Management (ERM), "Strategic Planning Guide for Municipal Solid Waste Management", CD-ROM, Collaborative Working Group, World Bank, Washington, DC, 2000.

SECTION 6 REFERENCE MATERIALS:

Intergovernmental Panel on Climate Change. Geneva: IPCC, 1995.

Ebro, K. and Leakey S., January 18, 2000. *World Bank launches first-of-its-kind market-based carbon fund.* The World Bank, News Release No. 2000/176/S http://prototypecarbonfund.org

Fernandez-Asin, Francisco. *En Breve, Nov. 2002, No. 13* http://lnweb18.worldbank.org/External/lac/lac.nsf/en+breve/

Kyoto Protocol to the United Nations Framework Convention on Climate Change, December 1997 http://unfccc.int/resource/docs/convkp/kpeng.html

Makarenko, Jay, (March 21st, 2002) *The Kyoto Protocol & Global Warming* http://www.mapleleafweb.com/features/environment/kyoto/05.html

PCF Team, November 2000. *Research Report 01. Preliminary Validation Manual* http://prototypecarbonfund.org/docs/pvm_guidelines.ppt

Pronove, Gao, (February 2002) *The Kyoto Protocol and the Emerging Carbon Market* r0.unctad.org/ghg/sitecurrent/download_c/pdf/Emerging_Carbon_Market.pdf

PCF, *Additionality Baseline, Validation and Verification Presentation* <www.protoypecarbonfund.org>

PCF, January 7, 2002. *Canadian National Workshop on the Clean Development Mechanism (CDM) and Joint Implementation (JI),* <www.protoypecarbonfund.org>

PCF, *PCF Project Cycle Training Module* <www.protoypecarbonfund.org>

The World Bank, *Prototype Carbon Fund, Second Annual Report (September 2001 - September 2002)* www.protoypecarbonfund.org

SECTION 8 REFERENCE MATERIALS:

Thorneloe, S. A. and Peer, R. L., 1990, "Landfill Gas and the Greenhouse Effect". Technical paper, International Conference on Landfill Gas, October 1990.

Johannessen, Lars Mikkel, 1999, "Observations of Solid Waste Landfills in Developing Countries: Africa, Asia and Latin America". Working Paper Series #3 for the World Bank, June 1999.

APPENDIX A

LANDFILL GAS COLLECTION SYSTEM COMPONENTS

LIST OF APPENDIX A FIGURES

APPENDIX B

EXAMPLE LEGISLATION – CANADA‘S ECP-79 LEGISLATION

Environmental ChoiceM Program

CERTIFICATION CRITERIA DOCUMENT

CCD-003

Product: Electricity - Renewable Low-impact

Preamble

Environment Canada's Environmental ChoiceM Program (ECP) is pleased to publish the following national certification criteria document **Electricity - Renewable Low-impact.**

The Environmental Choice Program is designed to support a continuing effort to improve and/or maintain environmental quality by reducing energy and materials consumption and by minimizing the impacts of pollution generated by the production, use and disposal of goods and services available to Canadians.

Based on a review of currently available life cycle information of the production, use and disposal stages, the product category requirements will produce an environmental benefit through:

(a) the displacement of non-renewable fuels by renewable, more sustainable fuel sources;

(b) the reduction of air emissions that contribute to global warming, smog, acid rain and air-borne particulate pollution;

(c) the reduction of solid wastes arising from both the mining and extraction of non-renewable fuel sources, and the disposal of toxic metal emissions and nuclear wastes; and

(d) the reduction of impacts on aquatic, riparian and terrestrial ecosystems from electricity generating activities.

Life cycle review is an ongoing process. As information and technology change, the product category requirements will be reviewed and possibly amended.

Environment Canada anticipates that generators and marketers of electricity that conform to this criteria document will apply to the Environmental Choice Program for verification and subsequent authority to label the qualifying products with the Environmental Choice Program's EcoLogoM. The ECP maintains verification protocols that clearly define the terminology and associated criteria limits of this criteria document.

Notice

Throughout this document, any reference to a standard or guideline means to its latest edition.

The Environmental ChoiceM Program (ECP) reserves the right to accept equivalent test data for the test methods specified in this document.

Notice of Intent

In respect of future developments of regulatory systems related to climate change, the requirements regarding the disposition of environmental benefits (Section 13) will be reviewed within a two to three year timeframe and possibly changed to reflect new policies and/or regulatory requirements that may emerge.

Interpretation

1. In this set of requirements, please note the following definitions:

"alternative-use electricity" means electricity generated from the installation of a supplemental process and/or equipment to alter and/or add to the processes of an existing operation in order to generate electricity from a renewable energy source. The existing operation must not have been originally designed or intended for electricity generation, nor have had any processes in place at the time of commissioning that would have facilitated electricity generation. Examples of alternative-use electricity generation sources include, inter alia, irrigation control dams, waterways with locks and waste heat captured from an industrial or commercial process that is fuelled by renewable energy sources. Although certain types of biogas-fuelled electricity (e.g., the capture and combustion of landfill gas) are also forms of alternative-use electricity, biogas-fuelled electricity is defined as a separate category by this criteria document;

"biogas" means gaseous products (primarily methane and carbon dioxide) produced by the anaerobic decomposition of organic wastes. Facilities producing biogas include *inter alia* landfill sites, sewage treatment plants and anaerobic digestion organic waste processing facilities;

"biogas-fuelled electricity" means electricity generated from a system in which biogases are captured for combustion and conversion to electricity;

"biomass-fuelled electricity" means electricity generated through the combustion of clean biomass as it is defined by the ECP;

"bypassed reach" means that area in the waterway between the initial point where water has been diverted through turbines or other mechanical means for water-powered electricity generation and the tailrace;

"CITES" means the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES Secretariat, 15, chemin des Anémones, CH_1219 Châtelaine-Genève, Suisse. Tel. (+4122) 979 9139/40, fax (+4122) 797 3417);

"clean biomass" means organic materials as listed below that have, at no stage in their lifecycle, been treated with organic and/or inorganic substances to change, protect or supplement the physical properties of the materials (including *inter alia* synthetic chemical pest-control products, fungicides, wood preservatives, paints, varnishes or other surfaces coatings, halogenated compounds and/or compounds containing heavy metals). Specific types of clean biomass recognized under this criteria document include:

(a) the wood-wastes and agricultural wastes that are solid residues arising from the harvesting and processing of agricultural crops or forestry products that might otherwise be sent to landfill and/or incinerated,
(b) dedicated energy crops,
(c) liquid fuels derived from biomass as defined in items (a) and (b), including *inter alia* ethanol, biodiesel, and methanol; and
(d) clean organically-sourced material that has been separated from municipal solid waste (MSW), and subsequently processed (e.g., pelletization, gasification) to serve as a combustion fuel.

Clean biomass does not include materials for which other diversion methods are a viable alternative (e.g., soil amending, farm land applications, horticultural applications), nor the treated by-products of manufacturing processes (e.g., treated chipwood or plywood, painted woods, pressure treated lumber);

"CO" means carbon monoxide, and should be measured using the testing frequency, conditions and methods specified in Appendix 1 of this criteria document;

"concentrating solar thermal technology" means a system that concentrates the heat of the sun through collectors, and uses the collected heat to drive a generating system to produce electricity;

"dedicated energy crops" means those non-food crops grown specifically for their fuel value, and in the case of this criteria document, for electricity generation. These sources include *inter alia* short-rotation woody crops (such as poplar trees) and herbaceous energy crops (such as switch grass);

"de-inking sludge" means solid material filtered out of the wastewater from the process used to remove ink and other undesirable materials from printed wastepaper;

"diversion" means the construction of works to divert water into a canal, tunnel, penstock or similar conduit to supply water for electricity generation purposes;

"elemental chlorine bleaching" means the chemical process of purifying and whitening pulp, specifically through the use of chlorine in its gaseous, elemental form (Cl_2);

"fish habitat" means spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes;

"fish passage" means both the upstream and downstream migration of fish that can be ensured with the use of natural and/or human-made methods. Human-made methods include *inter alia* fishways, fish ladders, fish locks, fish elevators, powerhouse collection galleries, diversion screens, and by-pass facilities;

"generator" means an entity that produces electricity;

"greenhouse gas" means a gas that is considered to contribute to global warming and includes, *inter alia*, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O);

"habitat compensation" means replacing habitat which has been subjected to harmful alteration, disruption or destruction with newly created habitat or improving the productive capacity of some other natural habitat;

"**harmful alteration, disruption or destruction**" means, in respect of fish habitat, any change to fish habitat that reduces, or eliminates, its productive capacity in relation to one or more life processes of fish;

"head pond" generally means the body of water immediately upstream of the intake structure of electricity generating facilities. Head ponds may be natural or human-made (lands inundated and/or water bodies created as a result of the construction of the generating station and/or the associated diversion structure(s)), or a combination thereof. Head ponds may serve one or more purposes including, but not limited to: (i) providing the appropriate hydraulic characteristics, such as submergence, for the intake structure; (ii) increasing the available head of the generating facility; and (iii) storing water for subsequent discharge through the generating facility. Head ponds also include changes caused by the diversion of a portion of a river through a canal or penstock;

"instream flow" means the water volume flowing in a waterway;

"ISO" means International Organisation for Standardisation;

“marketer” means an entity that receives electricity from a generator(s), possibly combines electricity from various sources, and markets and/or sells the electricity. Note that in some cases, marketers may also be generators;

“MW” means megawatt or 10^6 watts, and a unit of electrical power;

“MWh” means megawatt-hour, and a unit of electricity equal to one megawatt of power produced, consumed or flowing for a period of 1 hour;

“multi-sourced power product” means a combination of electrical power that is offered by marketers, and is comprised of electricity from more than one source and/or generator, where the sources and/or generators may or may not be certified under this criteria document;

“NO_X” means nitrogen oxides, and should be measured using the testing frequency, conditions and methods specified in Appendix 1 of this criteria document;

“null electricity” means electricity distributed on the grid that has no associated environmental attributes. Once the environmental attributes have been separated from the electricity - renewable low-impact, the electricity becomes “null”. Electricity that does not meet the requirements specified in this criteria document is also considered to be “null”;

“operational air emissions” means the quantity of air-borne emissions of a specified substance or compound that is released as a result of the generation of electricity;

“PCDDs and PCDFs” means polychlorinated dibenzo-para-dioxins and polychlorinated dibenzo-furans, and is a family of chlorinated organic compounds formed as trace contaminants or by-products in industrial processes. This includes the undesirable toxic contaminants generated when chlorine is used in the bleaching of wood pulp and when salt-laden wood is combusted;

“PM” means particulate matter, including particulate matter less than or equal to 10 microns in size, and should be measured using the frequency and methods specified in Appendix 1 of this criteria document;

“photovoltaic (PV) technology” means a cell, module, panel, array and/or array field that directly converts light energy from the sun into electricity;

“renewable” means replenished through natural processes or through sustainable management practices so that a resource is not depleted at current levels of consumption;

“riparian” means the land and habitat found along the banks of streams, rivers and lakes;

“salt-laden wood” means timber and forestry residues that have been impregnated with a high concentration of salt (NaCl), either from prolonged exposure to maritime air or from immersion in marine waters (generally for the purpose of transportation);

“solar-powered electricity” means electricity generated by converting the sun’s light energy and/or heat energy into electricity, and includes *inter alia* photovoltaic technologies and concentrating solar thermal technologies;

“sound environmental management practices” means those practices and goals used to manage forest and/or agricultural products within a sound environmental management system, as defined in the definitions section of this criteria document, that have the objectives of maintaining environmental values of the surrounding ecosystem. At a minimum, these practices must address *inter alia*:

(a) species selection;
(b) soil structure, temperature and fertility;
(c) soil composition rates, compaction and conservation;
(d) erosion control;
(e) hauling distance from the harvesting site to the combustion/generation site;
(f) silvicultural practices and techniques;
(g) harvesting practices including techniques, rates and waste minimization;
(h) crop regeneration;
(i) road/trail construction and maintenance;
(j) protection of biodiversity, wildlife and rare, threatened and endangered species;
(k) water quality and quantity;
(l) watershed conservation; and
(m) prior land use.

“sound environmental management system” means a system, including *inter alia* the ISO 14000 series of standards, used to manage forest and/or agricultural products that incorporates sound environmental management practices. At a minimum, system elements must include:

(a) planning elements such as: identifying forest and/or agricultural resources; identifying environmental aspects; assessing environmental impacts; identifying environmental legislative and regulatory requirements; and defining and committing to environmental policies, objectives and targets;
(b) operational elements such as: defining roles and assigning responsibilities; providing adequate staff training; communicating environmental aspects and policies both internally and externally; implementing an environmental management program based on identified environmental aspects and impacts; documenting all policies, goals and procedures; periodically reviewing and, where necessary, revising the system; performing public consultation and/or outreach; and establishing an environmental emergency preparedness and response plan; and
(c) monitoring and measurement elements such as: monitoring and measuring key aspects of the system; evaluating and mitigating negative environmental impacts; correcting non-conformance with the management system; performing internal reviews; and having third party audits performed;

“SO_X” means sulphur oxides, and should be measured using the testing frequency, conditions and methods specified in Appendix 1 of this criteria document;

“species designated as endangered or threatened” means any species that is listed as either “endangered” or “threatened” on recognized catalogues of such species. In Canada, the default listing shall be that of the federal Committee on the Status of Endangered Wildlife in Canada (i.e. COSEWIC), or relevant federal, provincial, territorial, state and/or local listings (e.g. Ontario’s Committee on the Status of Species at Risk in Ontario; i.e., COSSARO) that supercede the former, where designations are more stringent;

“tailrace” means the point at which water is released back into the waterway below a generating station after being passed through turbines or other mechanical means to produce water-powered electricity generation;

“TEQ” means toxic equivalent, and is determined by multiplying the measured concentration level of a given congener by the appropriate I-TEF. By converting the measured concentration levels to a common basis, the TEQ quantities may be summed to provide a single representative quantity. For the purposes of this criteria document, TEQs are determined for 2,3,7,8-TCDD and 2,3,7,8-TCDF.

The seven congeners for which 2,3,7,8-TCDD TEQs shall be determined are 2,3,7,8-TCDD; 1,2,3,7,8-P_5CDD; 1,2,3,4,7,8-H_6CDD; 1,2,3,6,7,8-H_6CDD; 1,2,3,7,8,9-H_6CDD; 1,2,3,4,6,7,8-H_7CDD; and OCDD. The ten congeners for which 2,3,7,8-TCDF TEQs shall be determined are 2,3,7,8-TCDF; 1,2,3,7,8-P_5CDF; 2,3,4,7,8-P_5CDF; 1,2,3,4,7,8-H_6CDF; 1,2,3,6,7,8-H_6CDF; 2,3,4,6,7,8-H_6CDF; 1,2,3,7,8,9-H_6CDF; 1,2,3,4,6,7,8-H_7CDF; 1,2,3,4,7,8,9-H_7CDF; and OCDF.

"Type I Electricity" means ECP-certified electricity from a generation facility that began operations (e.g. generating electricity) prior to January 01, 1991;

"Type II Electricity" means ECP-certified electricity from a generation facility that began generating electricity from January 01, 1991 to March 31, 2001 inclusive.

Incremental increases in electricity generated as a result of either facility upgrades (including inter alia efficiency improvements) or as a result of facility expansions (including inter alia new turbines or arrays) are eligible for Type II designation. In such cases, the average per annum generation capacity prior to the upgrades and/or improvements will provide the baseline on which to calculate the quantity of Type II electricity generation.

Facilities that have been completely decommissioned at any time and re-powered from January 01, 1991 to March 31, 2001 inclusive are also eligible for Type II designation. Facilities that are decommissioned and re-powered solely to achieve Type II designation will not be granted this designation unless the following conditions are met:

(a) the facility's useful life was less than two years prior to its decommissioning; and
(b) more than 75% of the fair market value of the business activity after re-powering is derived from the newly installed equipment and the changes resulting from the re-powering;

"Type III Electricity" means ECP-certified electricity from a generation facility that began generating electricity on or after April 01, 2001.

Incremental increases in electricity generated as a result of either facility upgrades (including inter alia efficiency improvements) or as a result of facility expansions (including inter alia new turbines or arrays) are eligible for Type III designation. In such cases, the average per annum generation capacity prior to the upgrades and/or improvements will provide the baseline on which to calculate the quantity of Type III electricity generation.

Facilities that have been completely decommissioned at any time and re-powered on or after April 01, 2001 are also eligible for Type III designation. Facilities that are decommissioned and re-powered solely to achieve Type III designation will not be granted this designation unless the following conditions are met:

(a) the facility's useful life was less than two years prior to its decommissioning; and
(b) more than 75% of the fair market value of the business activity after re-powering is derived from the newly installed equipment and the changes resulting from the re-powering;

"user" means *inter alia* an individual, household, commercial or industrial establishment or institutional facility that purchases electricity from either a generator(s) or marketer(s);

"water-powered electricity" means electricity generated from a system or technology that uses a mechanical method to capture and convert the potential energy of water into electricity;

"water quality" means characteristics of water, specifically including amount of dissolved oxygen, pH, total phosphorus, turbidity, transparency and chlorophyll, and any other item that is critical for or unique to the operating area;

“wind-powered electricity” means electricity generated from a wind turbine that converts the kinetic energy of the wind into electricity;

“wind turbine” means a system that uses air foils or blades attached to a drive shaft in order to capture the kinetic energy of the wind. The wind pushes against the blades/foils and spins a drive shaft. The drive shaft, either directly or indirectly through a series of gears, moves the generator to produce electricity; and

“wood-wastes and agricultural wastes” means a form of clean biomass, and includes *inter alia*:

(a) mill residues (e.g. waste by-products associated with the processing of forest materials such as bark, sawdust, solid trim, shavings, veneer clippings, clarifier sludge, pulping liquors),
(b) logging residues (e.g. residual materials left in the forest following harvesting such as slash, sortyard debris, thinning, stumps, roots),
(c) crop residues (e.g. materials not needed for soil re-incorporation such as straw, chaff, corn cobs, bean residues, and dried stalks of harvested grain), and
(d) untreated construction and demolition wastes.

Category Definition

2. This category comprises electricity from renewable energy sources which are apt to impose relatively low impacts on the environment and produce potential benefits including, *inter alia,* low net greenhouse gas emissions, limited or no depletion of non-renewable resources, reduced emissions of other pollutants and reduced impacts on aquatic, riparian and terrestrial ecosystems and species. Generating technologies specifically recognized in this criteria document include:

   (a) alternative-use electricity;

   (b) biogas-fuelled electricity;

   (c) biomass-fuelled electricity;

   (d) solar-powered electricity;

   (e) water-powered electricity; and

   (f) wind-powered electricity.

General Requirements

3. To meet the requirements of this Criteria document, the **electricity - renewable low-impact** must:

   (a) meet or exceed all applicable governmental, industrial safety and performance standards; and

   (b) be generated in such a manner that all steps of the process, including the disposal of waste products arising therefrom, will meet the requirements of all applicable governmental acts, by laws and regulations including, for facilities located in Canada, the Fisheries Act and the Canadian Environmental Protection Act, 1999, (CEPA, 1999).

Product Specific Requirements

4. To meet the requirements of this Criteria document, the **electricity - renewable low-impact** must:

   (a) be accompanied by evidence that appropriate consultation with communities and stakeholders has occurred, issues of concern have been reasonably addressed, and, where applicable, reasonable mitigation of negative impacts has been addressed;

   (b) be accompanied by evidence that prior or conflicting land use, biodiversity losses and scenic, recreational and cultural values have been addressed during project planning and development;

   (c) be accompanied by evidence that the project will not result in irreparable/unmitigable degradation or loss of the site's heritage, cultural, recreational and/or touristic values;

   (d) be generated in a manner that is reliable and practical (e.g. not in research and development stages, actually generating electricity);

   (e) be generated by only that proportion of fuel heat input attributed to eligible renewable sources in order to be designated as ECP-certified;

   (f) be generated in a manner such that no adverse impacts are created for any species designated as endangered or threatened; and

   (g) meet the criteria and associated definitions in this criteria document that are applicable to the generation technology employed.

5. To meet the requirements of this criteria document, **alternative-use electricity** must be generated in such a manner that all applicable certification criteria and definitions in this criteria document are met. The environmental impacts from the existing operation and the alternative-use process will be reviewed and allocated on a case-by-case basis.

6. To meet the requirements of this Criteria document, **biogas-fuelled electricity** must be generated in such a manner that the total of load points assessed for operational air emissions of carbon monoxide (CO), particulate matter (PM), nitrogen oxides (NO_X measured as NO_2) and sulphur oxides (SO_X measured as SO_2), as determined in Appendix 2, does not exceed 6.

   In cases where the biogas is used as a partial substitute in a generation facility that is designed to primarily utilize non-renewable fuels, load point calculations will be based only on those operational air emission values that can may be allocated to the combustion of the biogas.

7. To meet the requirements of this criteria document, **biomass-fuelled electricity** must be generated in such a manner that:

   (a) the total of load points assessed for operational air emissions of carbon monoxide (CO), particulate matter (PM), nitrogen oxides (NO_X measured as NO_2) and sulphur oxides (SO_X measured as SO_2) , as determined in Appendix 2, does not exceed 6;

   In cases where the clean biomass is used as a partial substitute in a generation facility that is designed to primarily utilize non-renewable fuels, load point calculations will be based only on those operational air emission values that can may be allocated to the combustion of the clean biomass.

(b) if generated from wood-wastes and/or agricultural wastes, *and* in cases where the generator and the waste source share common ownership:

i) use only wood-wastes and/or agricultural wastes that have been sourced from operations that have implemented a sound environmental management system and are adhering to sound environmental management practices,
ii) ensure the rate of harvest does not exceed levels that can be sustained, and
iii) not use wastes from species that are listed in the **CITES** Appendices;

(c) if generated from clean biomass fuel sources containing salt-laden wood, de-inking sludge or spent pulping liquors from mills using elemental chlorine bleaching, the facility must not emit polychlorinated dioxins and/or furans in excess of one of the following, whichever may be lower:

i) 100 pg I-TEQ/m^3; or
ii) the limits for new pulp and paper boilers burning salt-laden wood as specified in the Canada Wide Standards for Dioxins and Furans (Canadian Council of Ministers of the Environment); and

(d) if generated from **dedicated energy crops**:

i) use only dedicated energy crops that have been sourced from operations that have implemented a **sound environmental management system** and are adhering to **sound environmental management practices**, and
ii) ensure the rate of harvest does not exceed levels that can be sustained.

8. To meet the requirements of this criteria document, **solar-powered electricity** must be generated in such a manner that adequate arrangements (i.e., financial reserves) have been made for the proper disposal or recycling of all solid waste resulting from the generation of electricity, including the disposal of equipment or machinery used in the generation process itself, that contains measurable levels of cadmium.

9. To meet the requirements of this criteria document, **water-powered electricity** must be generated in such a manner that the generating facility:

(a) operates in compliance with all regulatory licenses, regulatory requirements and/or other authorizations pertaining to fisheries (including, for facilities located in Canada, the *Fisheries Act*), without regard to waivers or variances that may be granted or authorized;

(b) operates in compliance with all regulatory licenses, regulatory requirements and/or other authorizations regarding water levels and flows, without regard to waivers or variances that may be granted or authorized;

(c) does not operate under any authorization with terms and conditions allowing the **harmful alteration, disruption or destruction** of fish habitat unless:

i) such harmful alteration, disruption or destruction is not affecting the limiting factor controlling productive capacity,
ii) loss of the affected habitat is compensated by the creation of similar habitat, supporting the same stock, at or near the development site within the same ecological unit such that the created habitat replaces lost productive capacity, within an approved safety factor.

For facilities located in Canada, these conditional authorizations include those issued under Section 35(2) of the *Fisheries Act*, by the Minister of Fisheries and Oceans or under regulations made by Governor in Council under the *Fisheries Act*.

(d) within practical limits and subject to regulatory direction and approval, ensures that plant operations are coordinated with any other water-control facilities that influence water levels and/or flows operating on the same waterway, in order to mitigate impacts and protect indigenous species and the habitat upon which they depend;

(e) as a maximum, causes as much water to flow out of the head pond as is received in any 48-hour period;

In cases where this particular criterion cannot be met, the ECP will none-the-less consider certification if the applicant submits evidence that indicates those hydrological and ecological components key to sustainability of the surrounding watershed are maintained. As a minimum, this evidence must include environmental impact assessments and documentation from a formal public consultation process.

In cases where neither of the above conditions is met, the applicant can opt to apply to a multi-stakeholder and public Electricity Review Process to demonstrate equal or lower adverse environmental impacts.

(f) operates such that reduced water flows in the bypassed reach and reaches downstream of diversion dams and/or dykes are not detrimental to indigenous aquatic and riparian species;

(g) operates such that instream flows downstream of the tailrace are adequate to support downstream indigenous aquatic and riparian species at pre-project ranges;

(h) operates such that water quality in a head pond, a bypassed reach, reaches downstream of the tailrace and reaches downstream of any diversion dams and/or dykes remains comparable to pre-project quality in unaltered bodies of water or waterways within the local watershed;

(i) operates such that any changes in water temperature caused by the facility in the head pond or in reaches downstream of the tailrace or downstream of any diversion dams and/or dykes are not detrimental to indigenous aquatic species;

(j) where a human-made structure is placed across a waterway where no natural barriers exist, provides fish passage when necessary for the purpose of maintaining pre-existing migration patterns for fish communities both upstream and downstream; and

(k) provides any measures (including *inter alia* trash racks, oversized intake structures designed to slow intake velocities, underwater strobe and sound, fish screens) necessary to minimize fish mortality that would occur through impingement and entrainment.

10. To meet the requirements of this criteria document, **wind-powered electricity** must be generated in such a manner that:

(a) the generating facility and its structures are not detrimental to indigenous or migratory avian species;

(b) the generating facility and its structures are not located in an area that is protected for avian species designated as endangered or threatened;

(c) construction activities or routine turbine operations do not cause excessive soil erosion such as silting of nearby drainage, streams, ponds, or lakes that would be harmful to aquatic or riparian species and/or increase erosion from steep slopes, plateau edges, or access roadways; and

(d) excavated soil is replaced, and uprooted vegetation replanted, after construction or scrapping, where this can be done without interfering with the operation and servicing of the wind facility.

11. To meet the requirements of this criteria document, marketers of electricity must be able to demonstrate to the satisfaction of the Environmental Choice Program that the portion of their multi-sourced power product conforming to this criteria document incorporates a minimum of 50% Type II Electricity and/or Type III Electricity and a maximum of 50% Type I Electricity.

Verification

12. ECP-certified electricity must be generated by facilities that are also certified and, therefore, meet the general and technology specific requirements of this criteria document. When this certified electricity is sold, the seller must make available upon demand the sources of generation and/or the Type or blend of Types of electricity being sold.

13. For an electricity product to meet the requirements of this criteria document, the rights to all environmental benefits that may have been associated with the offsetting of the same quantity of null electricity from the grid must either be:

(a) transferred to the customer as part of the electricity product in any transaction; or

(b) retired by the marketer or seller of the certified electricity such that the environmental benefits may no longer be transferred, sold or donated.

Electricity product complying with this criteria document must originate from generation facilities operating in compliance with this criteria document, and cannot comprise electricity from planned generation facilities. Through a verification and auditing process, reconciliation measures will be implemented to ensure that sales levels of complying electricity product do not exceed production/ supply levels.

14. To verify a claim that a product meets the criteria listed in this document, the Environmental Choice Program and its agents will require access, as is its normal practice, to relevant quality control and production records and the right of access to production facilities on an unannounced basis.

    It is up to the applicant to provide sufficient information to allow verification of the claim that the facility is in conformity with the criteria documents. In particular, all documentation produced in the context of the environmental assessment of a facility for which certification is sought shall be made available to the ECP.

15. Compliance with sections 3(b), 9(a) and 9(b) shall be attested to by a signed statement of the Chief Executive Officer or the equivalent officer of the licensee. Compliance with sections 9(a) and 9(b) shall also be confirmed by additional evidence including *inter alia* correspondence from the authorized representative of each applicable government body that has issued a license and/or operating permit for the facility.

    The Environmental Choice Program shall be advised in writing immediately by the licensee of any noncompliance, which may occur during the term of the license. On the occurrence of any noncompliance, the license may be suspended or terminated as stipulated in the license agreement. In the event of a dispute related to the suspension or termination of the license, the license agreement provides for arbitration.

Conditions for EcoLogo Use

16. Where compliance with this criteria document is established under the Environmental Choice Program, the EcoLogo may appear in association with a product, subject to the following conditions:

    (a) Only those components of a multi-sourced power product that fully satisfy all pertinent ECP certification and licensing criteria are allowed to be identified as "ECP-certified" and to carry the EcoLogo; and

    (b) A criteria statement must appear with the EcoLogo whenever the EcoLogo is used in association with the electricity during sales and related transactions. The criteria statement must also appear with the EcoLogo in other promotional activities and materials.

    While the exact wording used in the criteria statement is left to the discretion of the licensee, the statement itself should provide clarification as to why the product was certified. The statement must not misrepresent the product nor the reason it received certification, and must contain at least the following information:

    i) for generators, identification of the amount of ECP-certified electricity generated and/or marketed in quantitative units (e.g. kWh or MWh);

ii) for marketers, identification of the amounts of ECP-certified electricity received from generators and/or supplied to users as either percentages of larger multi-sourced power products or in quantitative units (e.g. kWh or MWh); and

iii) for users, identification of the amounts of ECP-certified electricity purchased/used as either percentages of larger multi-sourced power products or in quantitative units (e.g. kWh or MWh).

17. All licensees must comply with the Environmental Choice Program's *Guide to Proper Use of the EcoLogo[M]* regarding the format and usage of the EcoLogo.

18. Any accompanying advertising must conform with the relevant requirements stipulated in this Criteria document, the license agreement and the Environmental Choice Program's *Guide to Proper Use of the EcoLogo[M]*.

For additional copies of this criteria document or for more information about the Environmental Choice Program, please contact:
TerraChoice Environmental Services Inc.,
1280 Old Innes Road, Suite 400, Ottawa, Ontario, K1B 5M7
Telephone: (613) 247-1900, Facsimile: (613) 247-2228, Email: ecoinfo@terrachoice.ca

Appendix 1: Air Emissions Testing Frequency, Conditions and Methods

Compound / Pollutant	**Testing Conditions and Frequency**
Carbon monoxide (CO) Nitrogen oxides (NO_X) Particulate matter (PM) Sulphur oxides (SO_X)	Frequency: As determined by the Environmental Choice Program specifically for the facility. Conditions: Testing must be performed at operational load. Emissions for load point values must be determined from the concentration measurements (ppm (v/v) converted to mg/m^3 at 25 C) and flow rate (dry basis at 101.3 kPa and 25 C) in the duct or stack.

Compound / Pollutant	**Testing Methods**
Carbon monoxide (CO)	(i) *Reference Method for the Monitoring of Gaseous Emissions from Fossil Fuel-fired Boilers*, Reference Method EPS 1/RM/15, September 1990; or (ii) Continuous Emissions Monitoring (CEMS) Code (REF. 107), Alberta Environment; or (iii) *Reference Method for Source Testing: Measurement of Releases of Carbon Monoxide from Stationary Sources* (EPS 1/RM/4, 1990) in conjunction with *Reference Method for Source Testing: Measurement of Release of Particulate from Stationary Sources* (EPS 1/RM/8, 1993), both from Environment Canada; or (iv) Method 10, Determination of Carbon Monoxide Emissions from Stationary Sources, in the Alberta Stack Sampling Code (REF. 89), Alberta Environment.
Nitrogen oxides (NO_X) measured as NO_2	(i) *Reference Method for the Monitoring of Gaseous Emissions from Fossil Fuel-fired Boilers*, Reference Method EPS 1/RM/15, September 1990; or (ii) Method 7E, Determination of Nitrogen Oxide Emissions from Stationary Sources, in the Alberta Stack Sampling Code (REF. 89), Alberta Environment; or (ii) Continuous Emissions Monitoring (CEMS) Code (REF. 107), Alberta Environment.
Particulate matter (PM)	(i) *Reference Method for Source Testing: Measurement of Releases of Particulate from Stationary Sources*, Reference Method EPS 1/RM/8, December 1993; or (ii) Method 5, *Determination of Particulate Emissions from Stationary Sources*, in the Alberta Stack Sampling Code (REF. 89), Alberta Environment.
Sulphur oxides (SO_X) measured as SO_2	(i) *Reference Method for the Monitoring of Gaseous Emissions from Fossil Fuel-fired Boilers*, Reference Method EPS 1/RM/15, September 1990; or (ii) Continuous Emissions Monitoring (CEMS) Code (REF. 107), Alberta Environment; or (iii) *Reference Method for Source Testing: Measurement of Releases of Sulphur Dioxide from Stationary Sources*, Report EPS 1-AP-74-3, September 1975; or (iv) Method 6C, *Determination of Sulphur Dioxide Emissions from Stationary Sources*, in the Alberta Stack Sampling Code (REF. 89), Alberta Environment
Velocity and Volumetric Flow Rate	Method B - Determination of Velocity and Volumetric Flow Rate of Flue Gases, from *Reference Method for Source Testing: Measurement of Release of Particulate from Stationary Sources* (EPS 1/RM/8, 1993)

Appendix 2: Load Point Determination

The process used to determine the load points for operational air emissions in this criteria document is based on a matrix of four environmental air emission parameters, each with a range of values based on actual industry performance. Each level of performance is assigned a specific load point value, and points are then totalled over all parameters. Products with different environmental profiles will thus be able to qualify under this Criteria document. The allowable number of points has been set so that, while tradeoffs between parameters is possible, very poor performance in any one parameter will disqualify a generating facility as a supplier of electricity meeting the requirements of this Criteria document.

The four parameters used to evaluate electricity generation under this Criteria document for ECP-certification are carbon monoxide (CO), particulate matter (PM), nitrogen oxides (NO_X) and sulphur oxides (SO_X). Load point calculations will be based on measured air emissions quantities of these compounds that are from measured emissions released as a result of only those operations directly used to generate electricity. The air emission measurements must represent annual emissions normalized to a per MWh basis, and include more than one datum point.

Measured emissions data and the quantity of annual electricity generated should be documented in *Part 1: Measured Data*, and load points should then be determined by using *Part 2: Load Point Calculation*. The load point for each compound should be taken from the top of each column corresponding to the emissions range for that compound's kilogram per MWh value.

PART 1: MEASURED DATA

1. Into the table, enter the Annual Quantity of Electricity Generated (in MWh) by the facility. This quantity should be measured net of all parasitic loads from the facility, and net of transformer and line losses up to the point of connection to the utility grid or the user's system (if directly connected).

2. Into the table, enter the Annual Measured Quantity of CO, PM, NO_X (measured as NO_2) and SO_X (measured as SO_2) emitted (in kilograms), noting that appropriate test methods and the prescribed frequency and conditions of testing are provided in *Appendix 1* for each compound.

3. Determine the Annual Measured Quantity per MWh of CO, PM, NO_X (measured as NO_2) and SO_X (measured as SO_2) emitted (in kilograms per MWh). These values will be used in the Load Point Calculations in Part 2.

Annual Electricity Generation (in MWh)	**Compound**	**Annual Measured Quantity (in kg)**	**Annual Measured Quantity per MWh (in kg/MWh)**
	CO		
	PM		
	NO_X (as NO_2)		
	SO_X (as SO_2)		

PART 2: LOAD POINT CALCULATION

1. Assign the load point value to each compound by taking the value at the top of each column corresponding to the emissions range for that compound's kilogram per megawatt-hour value determined in Part 1.

2. Determine the Total Load Points by summing the four individual load point values.

Compound	Load Points					Assigned Load Points
	0	1	2	3	8	
CO	< 2.15 kg/MWh	2.151 - 3.22 kg/MWh	3.221 - 4.30 kg/MWh	4.301 - 5.37 kg/MWh	> 5.371 kg/MWh	
PM	< 0.228 kg/MWh	0.2281 - 0.387 kg/MWh	0.3871 - 0.516 kg/MWh	0.5161 - 0.645 kg/MWh	> 0.6451 kg/MWh	
NO_X (as NO_2)	< 0.77 kg/MWh	0.771 - 1.15 kg/MWh	1.151 - 1.52 kg/MWh	1.521 - 1.90 kg/MWh	> 1.901 kg/MWh	
SO_X (as SO_2)	< 0.141 kg/MWh	0.1411 - 0.212 kg/MWh	0.2121 - 0.282 kg/MWh	0.2821 - 0.352 kg/MWh	> 0.3521 kg/MWh	
					TOTAL LOAD POINTS	

APPENDIX C

OUTLINES FOR KEY AGREEMENT TERMS FOR CONTRACTS NECESSARY TO IMPLEMENT LFG MANAGEMENT PROJECTS

OUTLINES FOR KEY AGREEMENT TERMS FOR CONTRACTS NECESSARY TO IMPLEMENT LFG MANAGEMENT PROJECTS

This is a sample guideline to an agreement between a Developer and a landfill Owner, where the landfill Owner sells the rights to LFG to the Developer. The partnership strategy between Developer and Owner may vary from project to project but there are many similarities in the basic contract set-up and general requirements. The following outline is to be used as a guide, and to be adapted to best suit the different legal structures in effect for candidate projects in the LAC regions.

Background:

- Provide a brief background of the project, including project outline.

ARTICLE 1 - DEFINITIONS

- Define the precise meaning of key words used in the contract.

ARTICLE 2 - TERM AND TERMINATION

- It is important to identify all of the key dates are timelines pertinent to a project.
  - Effective Date
  - Commencement Date
  - Term length
  - Early termination requirements or conditions

ARTICLE 3 – OBLIGATIONS OF DEVELOPER

3.1 Construction of Facility

- obtain all approvals and permits
- design the Facility and submit for approval
- negotiate energy sales agreements

- negotiate agreement for interconnection
- construct the Facility
- responsible for all costs and expenses

3.2 <u>Operation and maintenance of the Facility</u>

- operate and maintain the Facility
- expand, modify or remove the Collection System or the Utilization Facility
- be responsible for all costs and expenses

3.3 <u>Royalty Terms and Formula (if applicable)</u>

- a simple formula works best
- pay royalty to Owner

3.4 **<u>Reporting Requirements</u>**

- total volume of LFG collected
- total electricity generated
- gross revenues from energy sales
- total operating and maintenance expenses
- public complaints or concerns
- emission levels of nitrous oxide
- copies of any reports or submissions required to be provided to any regulatory body

3.5 **<u>Performance security</u>.**

3.6 **<u>Maintenance security</u>.**

ARTICLE 4 – OBLIGATIONS OF OWNER

4.1 **Grant of license of occupation and lease**

- license of occupation
- lease and Collection System license

4.2 **Permits and approvals**

- Owner to grant all permits and approvals required by Developer

4.3 **Grant of rights to Developer.** Owner to grant Developer the exclusive right to:

- design, construct, operate, maintain, modify and expand the Facility; and
- recover, collect and utilize the LFG

4.4 **Transfer and assignment of interest to Developer**

- the LFG collected
- any GHG Credits
- electricity generated

4.5 **Disposal of liquid and other wastes**

4.6 **Information**

4.7 **Tax liability**

ARTICLE 5 - TERMINATION

5.1 **Payment on termination**

5.2 **Completion of required maintenance upon termination**

ARTICLE 6 - INDEMNIFICATION

6.1 **Indemnification of Owner by Developer**

6.2 **Indemnification of Developer by Owner**

ARTICLE 7 – INSURANCE AND LIMITATION OF LIABILITY

7.1 **Insurance**

7.2 **Limitation of liability of Developer**

7.3 **Limitation of liability of Owner**

ARTICLE 8 - LIMITATION ON OBLIGATIONS

8.1 **Force Majeure Events**

8.2 **Government Intervention**

ARTICLE 9 - EVENTS OF DEFAULT AND REMEDIES

9.1 **Events of Default by Developer**

- Failure to pay
- Insolvency
- Winding up

9.2 **Events of Default by Owner**

9.3 **Remedies on Event of Default**

9.4 **Waivers**

ARTICLE 10 – DISPUTE RESOLUTION

10.1 **Efficient process**

10.2 **Dispute resolution process**

10.3 **Negotiations**.

10.4 **Mediation**

10.5 **Arbitration**

ARTICLE 11 - GENERAL PROVISIONS

11.1 **Interpretation**

11.2 **Attornment**

11.3 **Compliance with Applicable Law**

11.4 **Address and form of notice**

11.5 **Deemed receipt of notice**

11.6 **Restrictions on assignment**

11.7 **Enurement**

11.8 **Confidentiality obligations**

11.9 **Survival of termination**

11.10 **Entire agreement**

11.11 **Amendments**

11.12 **Severability**

11.13 **Due authorization and enforceability**

11.14 **Time**

- Time is of the essence

11.15 **Counterparts**