ESCAP is the regional development arm of the United Nations and serves as the main economic and social development centre for the United Nations in Asia and the Pacific. Its mandate is to foster cooperation between its 53 members and 9 associate members. ESCAP provides the strategic link between global and country-level programmes and issues. It supports Governments of the region in consolidating regional positions and advocates regional approaches to meeting the region's unique socio-economic challenges in a globalizing world. The ESCAP office is located in Bangkok, Thailand. Please visit our website at <www.unescap.org> for further information.

The white shaded area of the map represents the members and associate members of ESCAP

United Nations publication

ST/ESCAP/2453

Environment and Sustainable Development Division
Economic and Social Commission for Asia and the Pacific
United Nations Building
Rajadamnern Nok Avenue
Bangkok 10120, Thailand
<www.unescap.org/esd>

This paper is produced from 100% eucalyptus plantations without consuming the materials from natural forests and using the elemental chlorine-free blenching process.

Climate Change Action in Asia and the Pacific:
Lessons Learned and Policy Implications

A Guide to Clean Development Mechanism Projects Related to Municipal Solid Waste Management

United Nations
ESCAP

ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC

ACKNOWLEDGMENTS

The United Nations Economic and Social Commission for Asia and the Pacific wishes to gratefully acknowledge the support and involvement of Bionersis in developing this publication. Our particular gratitude goes to Mr. Alban Casimir of Bionersis, Bangkok for preparing the draft.

The publisher is also grateful to the following experts who reviewed the draft and provided helpful comments:

Mr. Makoto Kato : Researcher, Overseas Environmental Cooperation Centre, Japan.

Mr. Chow Kok Kee: Director, Sustainable Technology Resources Centre (STREC), Ltd. Malaysia.

Mr. A.H. Maqsood Sinha: Executive Director, Waste Concern, Bangladesh.

Mr. Daniele Violetti: Secretariat of the United Nations Framework Convention on Climate Change.

The ESCAP publication team included:

Mr. Rae Kwon Chung: Director, Environment and Sustainable Development Division

Mr. Masakazu Ichimura: Chief, Environment Section, Environment and Sustainable Development Division

Mr. Hongpeng Liu: Economic Affairs Officer, Sustainable Development and Water Resources Section, Environment and Sustainable Development Division.

Mr. Eric Roeder: Associate Environmental Affairs Officer, Environment Section, Environment and Sustainable Development Division.

Ms. Wipavee Kasemsawasdi: Team Assistant, Environment Section, Environment and Sustainable Development Division.

Ms. Phadnalin Ngernlim: Team Assistant, Environment Section, Environment and Sustainable Development Division.

BIONERSIS

Bionersis is a private enterprise which provides services on identifying the potential sites, negotiating and promoting strategic alliances with municipalities/private operators in order to design, develop and operate landfill gas to energy projects by carrying on the following stages:

- Technical and economic f]easibility studies.
- Project design, engineering and obtaining permits.
- Project construction and commissioning.
- Operation and maintenance.

Contact:

Mr. Alban Casimir: Development Manager, Asia and the Pacific Branch,
Bionersis 17-03 Sukhumvit Soi 4, Bangkok 10110, Thailand
Telephone and fax: +66 22 54 51 69, e-mail: alban.casimir@bionersis.com
website: www.bionersis.com

CONTENTS

List of Tables

List of Figures

List of Boxes

ABBREVIATIONS AND ACRONYMS

CDM	Clean Development Mechanism
C_e	Collection efficiency
CERs	Certified Emission Reductions
CH_4	Methane
CO_2	Carbon Dioxide
COP	Conference of Parties
DNA	Designated National Authority
DOE	Designated Operational Entity
EB	Executive Board
EiT	Economies in Transition
ERs	Emission Reductions
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
ET	Emissions Trading
EU	European Union
GAC	Granular Activated Carbon
GHGs	Greenhouse Gases
GWP	Global Warming Potential
H_2S	Hydrogen Sulphide
HAP	Hazardous Air Pollutants
HFCs	Hydrofluorocarbons
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
JI	Joint Implementation
kg	kilogramme
kWh	kilowatt hour
LFG	Landfill Gas
LFGTE	Landfill Gas To Energy
LoA	Letter of Approval
m^3	cubic metre
MSW	Municipal Solid Waste
N_2O	Nitrous Oxide
NGOs	Non-Governmental Organization
NMOCs	Non-Methane Organic Compounds
O_3	Ground-level Ozone
OECD	Organisation for Economic Co-operation and Development
O&M	Operation and Maintenance
PDD	Project Design Document
PFCs	Perfluorocarbons
SF_6	Sulphur Hexafluoride
SWM	Solid Waste Management
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNGA	United Nations General Assembly
VOCs	Volatile Organic Compounds
WMO	World Meteorological Organization

"

The dramatic effects of climate change are well articulated in the media. Most of the scientific world acknowledges a future fraught with disasters associated with erratic weather such as more severe flooding and droughts. What has not come out, however, is that economic growth can be compatible with efforts to address climate change, and the tools are available at our disposal.

"

Kim Hak-Su,
Under-Secretary-General of the United Nations and
Executive Secretary of ESCAP

I. Introduction

The Asia-Pacific region contains approximately three fifths of the world's population, or about 3.75 billion people, and spans roughly one third of the Earth's land area. A total of 13 cities count more than 10 million inhabitants and 5 cities have more than 7 million, creating various threats to the environment, including problems related to municipal solid waste management.

The high rate of population growth, urbanization and economic expansion not only accelerates consumption rates in the region's developing cities, but also accelerates the generation of waste. Currently, municipal solid waste (MSW) generation ranges between 0.5 kg and 1.4 kg per capita per day in all countries within the Asian and Pacific region. Consequently, waste generation is rising to levels that are difficult and costly to manage.

Financial constraints are among the most important barriers to proper MSW management in the developing countries of Asia and the Pacific. The reform of fiscal measures and the adoption of economic instruments could help local governments by increasing revenue, causing MSW management authorities in the region to attempt to recover costs by levying fees for their services. However, the polluter pays principle[1] is not easy to enforce in countries where the population has never paid the actual cost of public services aimed at mitigating environmental damage. Since it directly affects their available income, local people often do not understand why they should pay for these services while at the same time, rising public awareness of environmental issues is making it more difficult to implement low-cost solutions, such as the creation of new disposal sites.

The fermentation of waste in open dumps and landfills generates landfill gas (LFG), a major component of which is methane, a powerful greenhouse gas (GHG). Proper management of MSW which includes utilizing this LFG, can thus contribute to climate change mitigation. Opportunely, a new financing instrument became available on 16 February 2005: the clean development mechanism (CDM). One of the three "flexible mechanisms" of the Kyoto Protocol, it allows developing cities to obtain financial resources and state-of-the-art technology from industrialized countries in order to mitigate their GHG emissions. Incineration, biogasification and landfill gas recovery are the main types of waste treatment that can mitigate GHG emissions and could be promoted in developing cities through CDM projects.

This Guide has been published by the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) to the attention of the local administrations and Governments in order to do the following:

- Explain generally what the Kyoto Protocol and CDM scheme consist of;
- Identify the environmental, social and financial benefits associated with the development of a CDM project from their existing MSW disposal site;
- Assess whether a disposal site meets the basic technical and economic feasibility criteria and what could be the barriers to implementing.

1 The "polluter pays" principle states that polluters should pay the costs associated with halting the environmental degradation caused by their actions. When polluters do not pay, society as a whole must pay instead.

II. CDM: Genesis and rationale

Global warming is a modern problem that affects everyone. It is complicated and intertwined with difficult issues such as poverty, economic development, population growth, and national sovereignty and policies. Dealing with it will not be easy. Ignoring it will be worse.

The average temperature of the earth's surface has risen by 0.74 degrees Celsius since the late 1800s. It is expected to increase by another 1.8 °C to 4 °C by the year 2100[2] should the necessary action not be taken. Even if the minimum predicted increase should occur, it will be the largest century-long warming trend in the last 10,000 years.

Although research on ice cores and lake sediments shows that the climate has fluctuated abruptly in the distant past, the climate appears to have tipping points that can send it into sharp lurches and rebounds, it is increasingly clear that world with 6.6 billion people <www.populationmondiale.com> is a risky place to be carrying out uncontrolled experiments with the climate.

Over a decade ago, most countries joined the United Nations Framework Convention on Climate Change[3] with the aim of considering what could be done to reduce global warming and to cope with whatever temperature increases are inevitable. Since 1988, an Intergovernmental Panel on Climate Change (IPCC) has reviewed scientific research and provided Governments with summaries and advice on climate problems. In 1997, a number of nations approved an addition to the treaty, called the Kyoto Protocol[4], which has more powerful and legally binding measures. The Protocol finally entered into force on 16 February 2005.

1. Intergovernmental Panel on Climate Change

It fell to scientists to draw international attention to the threats posed by global warming. Evidence in the 1960s and 1970s that concentrations of carbon dioxide in the atmosphere were increasing first led climatologists and others to press for action. It took years before the international community responded. In 1988, the Intergovernmental Panel on Climate Change (IPCC) was created by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP). In 1990, the Panel issued its first assessment report,[5] which reflected the views of 400 scientists. The report stated that global warming was real and urged that something be done about it.

IPCC now has a well-established role. Rather than conduct its own scientific inquiries, it reviews worldwide research, issues regular assessment reports[6], and compiles special reports and technical papers. Because IPCC's findings reflect a global scientific consensus and are apolitical in character, they form a useful counterbalance to the often highly charged political debate over what to do about climate change. IPCC reports are frequently used as the basis for decisions made under the Convention, and they played a major role in the negotiations leading to the Kyoto Protocol, a second, more far-reaching international treaty on climate change that entered into force on 16 February 2005.

---

2 Climate Change 2007: The Physical Science Basis, available on line at <www.ipcc.ch>.

3 United Nations, Treaty Series, Vol. 1771, No. 30822.

4 FCCC/CP/1997/7/Add.1, decision1/CP.3, annex.

5 Published in three volumes: Scientific Assessment of Climate Change – Report of Working Group I; Impacts Assessment of Climate Change – Report of Working Group II; and The IPCC Response Strategies – Report of Working Group III.

6 After the initial assessment report referred to above, reports were issued in 1995, 2001 and 2007. For further information, see <www.ipcc.ch>.

2. United Nations Framework Convention on Climate Change

The findings of the IPCC's spurred Governments to create the United Nations Framework Convention on Climate Change. In response to the recommendation of these specialist bodies, the General Assembly set up the Intergovernmental Negotiation Committee for formulation of the treaty. Based on negotiations from 1991 to 1992, the text of the United Nations Framework Convention on Climate Change was finalized in May 1992 and opened for signature at the United Nations Conference on Environment and Development, more popularly known as the Earth Summit, held in Rio de Janeiro in 1992.

The United Nations Framework Convention on Climate Change is aimed at stabilizing greenhouse gas (GHG) concentration in the atmosphere at a level that would prevent dangerous anthropogenic (human induced) interference with the climate system. According to the Convention, "such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner".

3. Kyoto Protocol

It took a full year for the Parties to the United Nations Framework Convention on Climate Change to decide that the Convention had to be augmented by an agreement with stricter demands for reducing GHG emissions. The Convention took effect in 1994, and by 1995 governments had begun negotiations on a protocol.[7] The text of the Kyoto Protocol was adopted unanimously in 1997 and it entered into force on 16 February 2005.

The Kyoto Protocol set limits in the emission of carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride (see box I.1). The Protocol allows the countries to decide which of these gases will constitute their emission-reduction programme. It does this by combining them in a "basket" so that reductions in each gas are credited to a single target number. Since these gases have a different global warming potential, the effects of reduction in each gas are computed to determine its "carbon dioxide equivalent".

The major feature of the Protocol is its mandatory targets for GHG emissions for reductions those leading economies which have ratified it. These targets range from -8 per cent to +10 per cent of the countries' individual 1990 emissions levels "with a view to reducing their overall emissions of such gases by at least 5 per cent below existing 1990 levels in the commitment period 2008 to 2012".

In almost all cases, even those set at +10 per cent of 1990 levels, the limits call for significant reductions in currently projected emissions. Future mandatory targets are expected to be established for "commitment periods" after 2012. These are to be negotiated well in advance of the periods concerned during the Conference of the Parties established through the Convention.

The Kyoto Protocol defined three innovative "flexible mechanisms" to lower the overall costs of achieving its emissions targets: (a) clean development mechanism; (b) joint implementation; and (c) emissions trading. These mechanisms enable Parties to the Protocol to implement cost-effective projects aimed at reducing emissions or to remove carbon from the atmosphere in other countries. While the cost of limiting emissions varies considerably from region to region, the benefit for the atmosphere is the same, wherever the action is taken. However, the emission trading and joint implementation projects are confined to developed countries with defined emission reduction targets; only the CDM offers a new avenue for emission reduction in developing countries which do not have any obligatory emission reduction target.

---

7 A protocol is an international agreement linked to an existing treaty, but standing on its own.

Box I.1: Greenhouse gases and sectors/sector categories

Greenhouse gases

Carbon dioxide (CO_2)
Methane (CH_4)
Nitrous oxide (N_2O)
Hydrofluorocarbons (HFCs)
Perfluoroscarbons (PFCs)
Sulphur hexafluoride (SF_6)

Sectors/source categories

Energy

Fuel combustion

Energy industries
Manufacturing industries and construction
Transport
Other sectors
Other

Fugitive emissions from fuels

Solid fuels
Oil and natural gas
Other

Industrial processes

Mineral products
Chemical industry
Metal production
Other production
Production/consumption of halocarbons and sulphur hexafluoride
Other

Solvent and other product use

Agriculture

Enteric fermentation
Manure management
Rice cultivation
Agricultural solids
Prescribed burning of savannas
Field burning of agricultural residues
Other

Waste

Solid waste disposal on land
Wastewater handling
Waste incineration
Other

Source: Kyoto Protocol to the UNFCCC (Annex A)

4. Clean development mechanism

The clean development mechanism is an economic instrument intended to encourage initiatives aimed at meeting the challenges faced by the impending threat of climate change. It is a mechanism for promoting technology transfer and investment from developed countries to developing countries for projects to reduce GHG emissions. The mechanism allows the Governments of developed countries or private parties in those countries to make investments in emission reduction projects in developing countries and, in turn, benefit from certified emission reductions (CERs) which could be credited against their national emission reduction targets. The proceeds from the transfer of CERs to investors from developed countries

Box I.2: Major events concerning climate change

1988: Intergovernmental Panel on Climate Change (IPCC) constituted.

1990: First report of IPCC published.

1990: World Climate Conference.

1991: Intergovernmental Negotiations Committee set up by the United Nations General Assembly for formulation of an international treaty.

1992: United Nations Framework Convention on Climate Change finalized and placed for signatures of countries at the Earth Summit.

1995: First Conference of Parties, held in Berlin.

1996: Second Conference of Parties, held in Geneva, Switzerland.

1997: Third Conference of Parties, held in Kyoto, Japan, adopted the Kyoto Protocol for implementation of the United Nations Framework Convention on Climate Change and defined the clean development mechanism (CDM).

1998: Fourth Conference of Parties, held in Buenos Aires.

1999: Fifth Conference of Parties, held in Bonn, Germany.

2000: Sixth Conference of Parties, held in The Hague, Netherlands.

2001: Seventh Conference of Parties, held in Marrakech, Morocco, formulated a rulebook (Marrakech Accords) on modalities for implementation of the Convention and its Protocol, including CDM.

2002: Eighth Conference of Parties, held in New Delhi, India, reviewed the status of and made decisions for further action on CDM.

2003: Ninth Conference of Parties, held in Milan, Italy, indicated the modalities and procedures for afforestation and reforestation project activities under CDM.

2004: Tenth Conference of Parties, held in Buenos Aires, highlighted a range of climate-related issues, including the impacts of climate change and adaptation measures, mitigation policies and their impacts, and technology.

2005: Eleventh Conference of Parties, held in Montréal, Canada, was an historic event as the Parties to the United Nations Framework Convention on Climate Change met for the eleventh time, while marking the entry into force of the Kyoto Protocol.

2006: Twelfth Conference of Parties, held in Nairobi, included the second session of the Ad Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol.

will facilitate the implementation of projects that are not possible without CDM. Thus, CDM is intended to serve the dual purpose of assisting developing countries in their pursuit of sustainable development and providing an opportunity for developed countries to contribute to the reduction of global concentrations of GHGs at lesser cost. In essence, CDM has opened a window to suit the interests of both developed and developing countries.

III. CDM Projects: Modalities and Procedures

1. Prerequisites for participation

The Convention and the subsequent negotiations, including the Kyoto Protocol, which laid down the financial mechanisms for combating climate change, recognized the principle of "common but differentiated responsibilities" considering the social and economic capabilities of developing and developed countries. Accordingly, the countries have been grouped into three categories with differentiated responsibilities:

- **Annex I:** consists of the 24 member countries of the Organisation for Economic Co-operation and Development (OECD), the European Union and countries with economies in transition. These countries are committed to limiting their anthropogenic emissions of GHGs, and enhancing their sinks and reservoirs in order to increase the sequestration of GHGs. However, the countries with transitional economies are given certain flexibilities in meeting their targets.

- **Annex II:** consists of the 24 original OECD member countries and the European Union which are also included in Annex I. They are required to provide financial resources to enable developing countries to undertake emissions reduction activities under the Convention and to help them adapt to the adverse effects of climate change. In addition, they have to "take all practicable steps" to promote the development and transfer of environmentally friendly technologies to the economies in transition and developing countries. Funding provided by Annex II Parties is channelled mostly through the financial mechanism of the Convention.

- **Non-Annex I:** comprises mainly developing countries. Certain groups of developing countries are recognized by the Convention as being especially vulnerable to the adverse impacts of climate change, including countries with low-lying coastal areas and those prone to desertification and drought. Others, such as countries that rely heavily on income from fossil fuel production and commerce, may be more vulnerable to the potential economic impacts of measures to mitigate the effects of climate change. The Convention emphasizes activities that address the special needs and concerns of these vulnerable countries, such as investment, insurance and technology transfer.

Countries are required to meet the following prerequisites in order to participate in CDM projects:

- Ratification of the Kyoto Protocol;
- Establishment of a National CDM Authority; and
- Willingness to voluntarily participate in CDM.

In addition to the aforementioned prerequisites, developed countries should also comply with the following requirements as stipulated in the Protocol:

- Establishment of a national system for estimating GHGs emissions;
- Establishment of a national registry and annual inventory;
- Establishment of an accounting system for sale and purchase of emission reductions; and
- Establishment of assigned amount according to emission limitation and reduction commitment to reduce their overall GHGs emission by at least 5 per cent below 1990 levels in the first commitment period of 2008-2012.

However, the developing countries are not required to submit separate yearly inventories of their greenhouse gas emissions; they also have less stringent inventory recording requirements than Annex I countries.

The eligibility criteria for the CDM projects include the following:

- The projects must be approved by all parties involved;
- The projects should promote sustainable development in the host countries;
- The projects should result in real, measurable and long-term benefits towards climate change mitigation; and
- The emission reduction should be additional to what would have otherwise occurred without the project.

2. Institutional structure

The institutional structure created for the implementation of CDM includes three new entities:

- Executive board;
- Designated national authority; and
- Designated operational entity.

2.1. Executive board

To supervise the implementation of CDM, an executive board has been set up and it operates under the authority of the Parties. The executive board consists of 10 members, including one representative from each of the five official United Nations regions (Africa, Asia and the Pacific, Latin America and the Caribbean, Central and Eastern Europe, and Western Europe and others), one representative from the small island developing States and two representatives each from Annex I and non-Annex I Parties. The executive board maintains a CDM registry for issuance of the CERs, for management of fees levied for administrative expenses and an adaptation fund, and for keeping records of CER accounts for developing countries participating in CDM projects. The executive board also accredits the designated operational entities and evaluates/approves the methodologies to be used in order to develop a CDM project.

2.2. Designated national authority

Countries participating in CDM are required to identify a designated national authority, usually a government department, to serve as a focal point for consideration and approval of CDM project proposals (see <http://cdm.unfccc.int/DNA/index.html>).

2.3. Designated operational entity

A designated operational entity under the CDM framework is either a domestic legal entity or an international organization (see <http://cdm.unfccc.int/DOE/list/index.html>) accredited and designated on a provisional basis until confirmed by the Conference of Parties /MOP, by the executive board. The institutions willing to serve as operational entities are required to obtain accreditation from the executive board beforehand. For designation as operational entities, the applicant institutions/agencies should have necessary professional expertise and no conflict of interest with the project participants. The designated operational entity has two key functions:

- It validates and subsequently requests registration of a proposed CDM project activity which will be considered valid after eight weeks if no request for review was made;

- It verifies the emission reduction of a registered CDM project activity, certifies as appropriate and requests the executive board to issue certified emission reductions accordingly. The issuance will be considered final 15 days after the request is made unless a request for review is made.

3. CDM project cycle

The CDM is an innovative market-based instrument which provides, in developing countries, a means to the investors for promoting sustainable development while curbing the GHGs emissions below the "business as usual" levels. It offers opportunities for government as well as private sector investment. Yet, another distinctive feature of the CDM relates to the "bottom-up" approach for project development involving public/stakeholders' scrutiny. The CDM Project cycle entails seven basic stages: project design and formulation, national approval, financial modalities, validation and registration, implementation and monitoring, verification and certification and issuance of certified emission reduction (CERs). In principle, the first four stages are performed prior to the implementation of a project, while the latter three are undertaken during life time of the project. However, in practice, it is also recommended that project developers should first carry out the pre-project screening, see Box III.1. Sequence of the CDM project cycle, on page 11 before they embark on the preparation of a CDM project.

3.1. Project design and formulation

The first step in the CDM project cycle is the preparation of a project design document (PDD) on the candidate CDM project. It is formulated by the project proponents as per the format prescribed by the Secretariat of the United Nations Framework Convention on Climate Change. The document should provide the technical and financial details of project, which include the purpose and the description of the project, the proposed baseline methodology, the estimated operational life time of the project,[8] description of how the additionality requirements are met through the project, documentation on environmental impacts, stakeholders' comments and a monitoring plan.

3.2. National approval

The project design document (PDD) is to be submitted to the designated national authority (DNA) of the host country. In order to seek the approval of the DNA, the project proponents have to ensure that the PDD contains the relevant information and meet the requirements of the design template. The DNA is required to evaluate and, if the project is approved, issue a Letter of Approval (LoA) with the confirmation that the project will help the host country to achieve sustainable development.

3.3. Financial modalities

The financial modalities for CDM projects may have a range of flexible approaches depending on the option chosen by the project proponents and investors. These are described below:

8 The definition of the additionality concept, as defined in United Nations Framework Convention on Climate Change Decision 17/CP.7, paragraph 43, is as follows "A CDM project activity is additional of anthropogenic emissions of greenhouse gases by sources are reduced below those that would have occurred in the absence of the registered CDM projected activity."

3.3.1. Unilateral funding

The project proponents may take sole responsibility for project design and implementation. They may mobilize their own resources for funding the projects and recover the investment with profit accruable from the sale of CERs. Thus, the project proponents will be allowed to own the CERs for sale depending on the market situation.

3.3.2. Bilateral funding

The project proponents may initiate the projects in collaboration with investors from developed countries through credit agreements or equity investment. Under credit agreements, the investors can make an advance payment for the CERs to be accrued from the projects. With equity investment, the investors can take equity shares in the projects, including those of accruable CERs.

3.3.3. Multilateral funding

Investors from developed countries may collectively set up a CDM fund for investment in a number of CDM projects. The CERs credited to the fund and the benefits thereof could be distributed among the investors depending on their contributions to the fund.

3.3.4. Open-ended funding

In the open-ended financing system, a mix of various funding options may be adopted. For instance, the investors and institutions in developing countries may set up a national CDM fund. Alternatively, the developing countries on their own may set up a CDM fund to support the CDM projects and sell shares to investors. Yet another option would be for a CDM fund to tie up with a major investor.

3.4. Validation and registration

3.4.1. Validation

After approval of the DNA, the project design document needs to be validated by designated operational entities who are accredited by the executive board. The role of an operational entity is similar to that of an auditor validating financial statements. The process of validation involves review and assessment of the PDD including the baseline, methods computation for emission reduction and the monitoring plan. The operational entity has to first validate the project and subsequently verify the emission reduction in order to obtain certified emission reductions (CERs). The operational entity also publishes the PDD to elicit comments from stakeholders. During the validation process, the operational entity reviews the PDD with specific reference to the prescribed requirements, which include the following:

- Approval of the designated national authority;
- Eligibility of parties to participate in CDM;
- Eligibility of the project activity under CDM;
- Consideration of comments from stakeholders;
- Environmental impact assessment and results thereof;
- Conformity of the baseline with the principle of the Kyoto Protocol;
- Emissions reduction against the baseline as a result of the project;
- Monitoring plan and methodology.

3.4.2. Registration

Based on the validation report of the operational entity, the project is registered by the CDM executive board. However, the signatory countries may call for a review of the proposed registration.

3.5. Implementation and monitoring

Once the PDD is approved and matters concerning financing modes are finalized, the project proponents can go ahead with the implementation of the project and ensure that performance is periodically monitored, particularly for the assessment of emission reduction as compared to the baseline. The monitoring plan, which is an important component of the PDD, should include the following:

- Information relating to data required for computing emissions from the project;
- Method of data collection, including quality assurance;
- Method of computing emission reductions from the data collected;
- Selection of an independent monitoring system.

3.6. Verification and certification and issuance of CERs

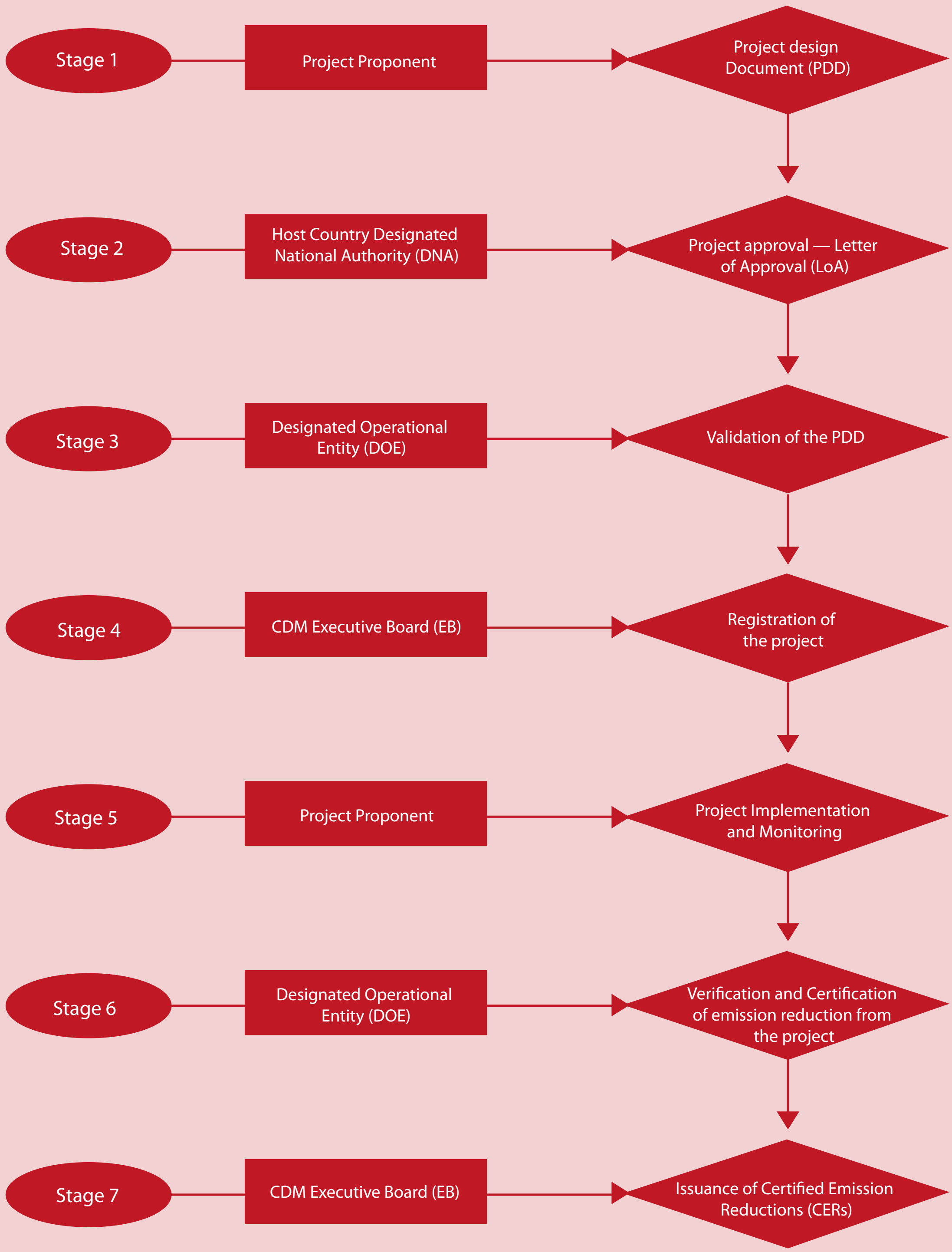
The emission reduction as calculated from monitoring of the project needs to be independently verified by the designated operational entity and compared with reference to the validated project design document. The operational entity is required to submit a verification report and certify the amount of emission reduction generated by the project for issuance of CERs by the CDM executive board (EB): to avoid conflicts of interest and to ensure transparency, two different DOE must be hired to validate the PDD and certify the amount of emission reduction.

3.7. Share of proceeds

As per the Kyoto Protocol, a share of the proceeds from certified project activities is used to cover the administrative expenses as well as to assist developing country parties that are particularly vulnerable to the adverse effects of climate change to meet the costs of adaptation (2 per cent of CERs proceeds for this adaptation fund).

In several countries, it is possible that local DNAs will request a share of the proceeds as well. Since the percentage can vary widely, it is recommended that the local DNA be consulted for further information on this topic. The comprehensive list of DNAs is available on the UNFCCC website: <http://cdm.unfccc.int/DNA/index.html>.

Box III.1: Sequence of the CDM project cycle: actors and activities



IV. Opportunities created by CDM projects for Municipalities and Local Authorities

As presented earlier, CDM allows Governments or other parties in developed countries to invest in emission reduction projects in developing countries and, in turn, receive the benefits in terms of certified emission reductions (CERs), which could be credited against their national emission reduction targets. The proceeds from the transfer of CERs to investors from developed countries will facilitate the implementation of projects in developing countries that are not possible without CDM.

This feature of CDM provides a new opportunity for municipal and local authorities to channel additional investments from developed countries to their sustainable development, projects, which would simultaneously contribute to the reduction of global concentrations of greenhouse gases. Potential areas for such projects would include improved of urban planning, transportation development and energy efficiency, in addition to solid waste management. Municipal and local authorities will recognize that there are a great many beneficial socio-economic impacts that would result from sustainable development projects that could not have been implemented without the additional resources channelled through CDM.

1. Candidate sectors for CDM projects

The important sectors which have potential for CDM projects in developing countries include the following:

- Agriculture
- Buildings (residential, commercial and government buildings)
- Energy generation, distribution and use
- Forestry
- Industry and manufacturing activities
- Mining
- Transport
- Waste management

For the first commitment period (2008-2012), afforestation and reforestation activities have been enlisted for CDM in recognition of the fact that forests can serve as "carbon sinks". Therefore, forestry belongs to a different category, unlike other sectors, which are major GHGs emitters primarily due to fuel consumption. Emission control activities of varied nature in different sectors are the potential candidates for CDM projects. Several technological options are available for GHGs mitigation in different sectors, and an appropriate mix of policy initiatives and cooperative endeavours at different levels would be the best way to make use of those opportunities. Among the potential candidates for CDM projects are the reduction of methane and nitrous oxide emissions in industrial activities, energy efficiency and energy conservation systems, switch-over to cleaner fuels and the development of renewable energy sources.

2. Additional financial possibility – focus on CDM projects related to municipal solid waste management

For the developing countries of Asia and the Pacific, the major priority is to achieve economic growth in order to meet the basic human needs of their populations. While the conventional methods of development have triggered a plethora of environmental problems, including the threat of climate change, the CDM scheme offers an opportunity to adopt a more environmentally compatible mode of

Box IV.1: Potential CDM projects in different sectors

Sectors	Potential projects/activities
Agriculture	• Improvement in cultivation practices to reduce methane emissions. • Reduction of energy use through demand-side management. • Improvement in use of agrochemicals (fertilizers and pesticides).
Buildings (residential, commercial and government	• Energy-efficient design of buildings. • Energy-efficient appliances. • Energy conservation measures. • Fuel switching in households and commercial boilers. • Use of renewable energy sources.
Energy (nuclear energy excluded from CDM)	• Development of renewable energy sources (hydro, solar, wind and biomass). • Clean coal technologies (e.g. coal beneficiation). • Fuel substitution measures. • Improvement in transmission and distribution network. • Reduction of leakage in transport, handling and distribution of oil and gas.
Forests	• Afforestation and reforestation.
Industry and Manufacturing	• Energy conversion and energy-efficiency measures. • Process modifications in order to lower emissions. • Change of feedstock in boilers (e.g. coal to gas).
Mining	• Coal bed methane recovery and reduction of methane emissions. • Control of fires in mines. • Energy-efficient systems.
Transport	• Introduction of alternate fuels (e.g. biofuel). • Switch over to cleaner fuels. • Fuel-efficiency measures. • Improvement in public transport. • Urban planning and traffic management.
Wastes	• Landfill gas recovery and use. • Waste-to-energy conversion activities. • Composting from municipal organic waste.

development. Indeed, CDM holds the promise of environmental, economic/financial and social benefits in developing countries through the attenuation of local environmental concerns. The new paradigm is that GHGs emission diminution activities and economic development actions could cease to be antinomic and become complementary instead.

Usually, lack of financing in Asian and Pacific countries often leads the public and private sectors to select environmentally inefficient but cheaper technologies to sustain their economic growth. Carbon financing, however, improves significantly the internal rate of return (IRR) of projects eligible for the CDM scheme[9]. At the same time, certified emission reductions (CERs) now provide a bankable revenue stream (comparable to a Power Purchase Agreement for example). Moreover, the success and reliability of the CDM system so far encourage lenders, decreasing their risks thanks to the positive impact of carbon financing.

9 It should be borne in mind, however, that the current crediting period for CDM projects is 2008-2012. The Twelfth Conference of Parties to the United Nations Framework Convention on Climate Change, held in Nairobi from 6 to 17 November 2006, decided to discuss, from 2008 onwards, the possible extension of the Kyoto Protocol until 2017.

Therefore, a variety of financial options are available to ease CDM project implementation:

- Full or partial equity: a company finances all or co-finances part of a CDM project in return for full or shared financial returns and CERs;
- Financial contribution: a company financially contributes towards the cost of a CDM project equal to some portion of the incremental cost of the project over and above the baseline technology, or finances the removal of market barriers, in return for CERs;
- Loan: a company provides loan or lease financing at concessional rates in return for CERs;
- Certified emissions reduction purchase agreement: a company agrees to buy CERs as they are produced by the project.

High rates of population growth and urbanization in Asian cities, together with economic growth, accelerate not only the consumption rate, but the generation of waste as well. As more and more waste has been generated in recent years, the management of municipal solid waste has become a day-to-day concern.

Moreover, while the major issue with regard to better MSW management practices in developing countries lies in the lack of financing, the current CDM scheme increases significantly the attractiveness of MSW projects compared with most of other project types (see box IV.2).

For these reasons, the focus here is on CDM projects related to municipal solid waste, as they already represent a significant share of the CDM/JI volume, and more particularly those utilizing landfill gas (LFG).

While waste disposal standards in Asia and the Pacific are slowly improving, some sites still lack bottom liners, leachate treatment systems, active or passive venting wells, etc., and therefore represent a threat to the environment as they continue leaking wastewater and noxious gases even if they are already closed. These sites, classified as "open dump"[10] are the common practice in numerous developing countries in Asia and the Pacific. Concerns over such sites include surface and groundwater pollution, landslides, gas migration and explosions, and land subsidence. To better control this pollution, the landfill must be closed in a safe manner that provides the following:

Box IV.2: Impact of carbon finance on profits in different project types (+ per cent of IRR):

Hydro	0.8 – 2.6
Wind	1.0 – 1.3
Bagasse	0.4 – 3.6
Energy efficiency & district heat	2
Gas flare reduction	2.0 – 4.0
Biomass	2.0 – 7.0
Municipal solid waste	10.0 – 35.0

Source: Finnish Environmental Agency

Box IV.3: Distribution of registered project activities by scope (According to the number of projects)

Energy industries (renewable/ non-renewable sources)	49.7 per cent
Waste handling and disposal	22.2 per cent
Agriculture	9.3 per cent
Fugitive emissions from fuels (solid, oil and gas)	7.9 per cent
Manufacturing industries	6.5 per cent
Others	4.4 per cent

Source: Finnish Environmental Agency

10 See appendix for the classification of the disposal sites according to the United Nations Environment Programme (UNEP).

- Profiling of the landfill;
- Fencing;
- An effluent (LFG and leachate) treatment system;
- Landscaping (often optional in tropical countries).

When it comes to already existing open dumps, such as those described above, emissions are usually reduced by capturing and flaring/utilizing the LFG at a high temperature, converting the methane fraction of the gas into less harmful carbon dioxide and water vapour. Otherwise, LFG emissions into the atmosphere can be reduced through traditional waste reduction measures, such as recycling and composting.

3. Multiple benefits associated with the development of landfill gas projects

In order to better understand these benefits (particularly the environmental benefits), we will define basically the characteristics of the landfill gas (LFG) and the description/design for the utilization of the LFG as a fuel source to generate electricity. Landfill gas to energy (LFGTE) projects represent one of the most widespread types of utilization of LFG (for further information on LFG different end-uses, see subheading 3. LFG utilization technologies on page 30.

3.1. How to turn a liability into a resource

3.1.1. Landfill gas (LFG)

LFG is a by-product of the decomposition of municipal solid waste (MSW), meaning that all landfills emit this gas in amounts that depend on a variety of factors, such as waste composition, weather conditions, humidity and landfill management. Roughly, LFG is made up of the following:

- 50 per cent methane (CH_4);
- 47 per cent carbon dioxide (CO_2);
- 2-3 per cent chlorine, benzene, non-methane organic compounds (NMOCs).

LFG is a serious problem:

- Methane is a potent greenhouse gases (GHGs) contributing to local smog and global climate change. Over a 100-year time horizon, methane is considered to be 21 times more efficient at trapping heat within the atmosphere in comparison with carbon dioxide. This value is currently under review and could potentially be revised upwards in the future (23 times), further increasing the incentive for LFG management projects;
- LFG can migrate below the ground in unsaturated soil zones, especially during the winter and spring months, when the ground may be frozen or saturated with moisture at the surface. LFG can then accumulate in enclosed structures, causing a potential hazard. Methane has no odour and is therefore impossible to detect without proper instrumentation;
- There is a risk of fire and explosion at concentrations between 5 and 15 per cent in the air;
- There are health hazards associated with trace gases (benzenes and family);
- Odour nuisance.

3.1.2. Landfill gas to energy projects

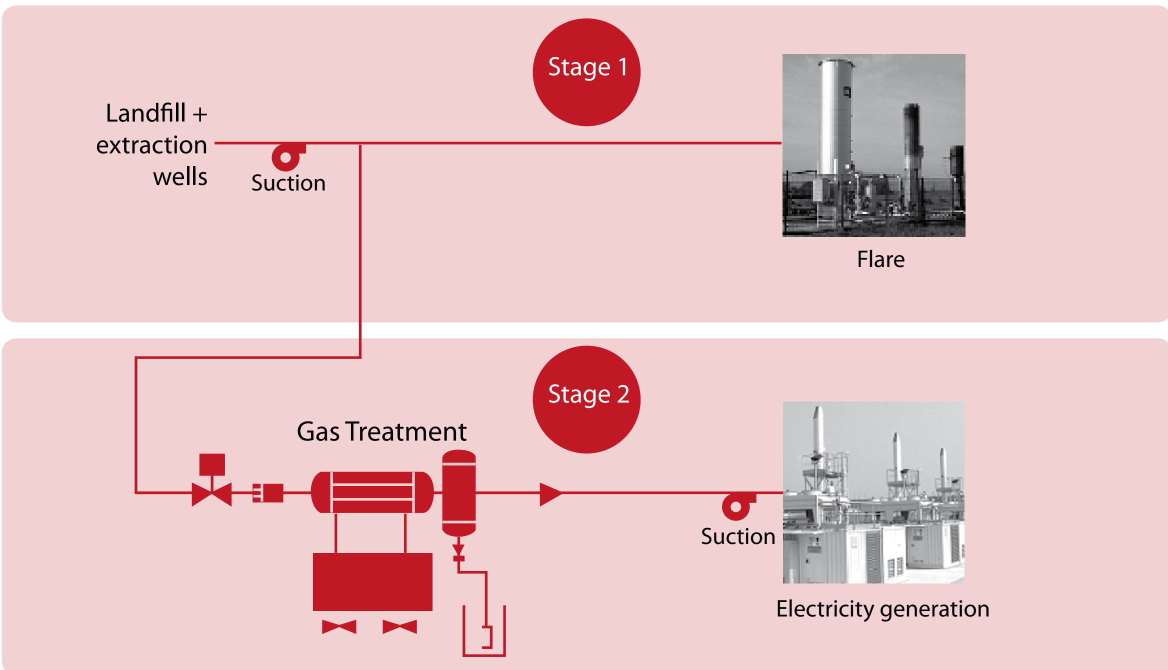
Instead of allowing Landfill gas (LFG) to escape into the air, it can be captured, converted and used as an energy source (i.e., converting a liability into a resource). A typical LFG collection system is comprised of the following components:

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

The basic operating principle is quite simple; a vacuum or pumps are employed to extract the gases from the waste mass. The objective is to establish a neutral pressure/vacuum gradient continuously over the entire surface of the landfill. This system directs the collected gas to a central point, where it will be processed and treated to feed the engine (the adequate level of LFG processing and treatment depends upon the ultimate use of the gas). The revenues provided by such systems create an incentive for better landfill design and management and a contribution towards improvement of the overall waste management system.

However, the ideal conditions usually cannot be achieved at a reasonable cost. Therefore, it is important to balance the costs and benefits of installing supplementary wells in a tighter grid of wells together with a complementary cap system against the additional value of the fuel recovered and flared/utilized. The cost increase to extract LFG up to approximately 80 per cent of the actual LFG being generated is considered relatively linear in nature. However, to achieve such 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 a major capital cost increase.

Figure IV.1: General design of LFGTE facilities



3.2. Multiple benefits of a CDM-related MSW project

3.2.1. Environmental benefits

An LFGTE project will typically reduce landfill gas emissions in the atmosphere by 40-70 per cent (for more information about collection efficiency, see subheading 1.2.2. Collection efficiency on page 25) and leachate production thanks to the landfill cover, which prevents rainfall from streaming into the landfill. Landfill gas is an opportunity because of its significant methane content (high calorific value after adequate processing and treatment). Through networks of pipes in the landfill, the methane can be collected and provided as a fuel source for electricity generation and industrial processes, among other things. Thus, by avoiding the emission of gases through the combustion process as well as the replacement of grids, the project activities will produce major environmental benefits. An LFGTE project may also improve landfill safety, promote good solid waste management (SWM) practices and help in the safe closure of the landfill.

The recovery and combustion of the LFG generated at any landfill site will have significant environmental positive impacts which can be summarized below:

- Reduction, through LFG combustion, of emissions of methane, which is a potent GHGs that contributes to global climate change;
- Reduction of odours that spread naturally in the neighbourhood and local communities due to the presence of several compounds in LFG, which have strong and pungent odours (for example, H_2S or hydrogen sulphide);
- Emissions of volatile organic compounds (VOCs) contribute to ground-level ozone (O_3) formation (smog). Ozone is capable of reducing or damaging vegetation growth as well as causing respiratory problems for humans. Thermal treatment of non-methane organic compounds (NMOCs), including hazardous air pollutants (HAP) and VOCs through flaring and combustion in an engine will reduce the emission of these compounds;
- Reduction of subsurface migration is the underground movement of landfill gas from landfills to other areas within the landfill property or outside the landfill property. Since landfill gas contains approximately 50 per cent methane (a potentially explosive gas), it is possible for landfill gas to accumulate in enclosed structures and ignite when the concentration in the open air reaches 5 to 15 per cent. There have been incidences of subsurface migration causing fires and explosions on both landfill property and private property, especially when there is no bottom liner in the landfill;
- Reduction of GHG emission from grid replacement.

As indicative data, table IV.1 provides reference values of gas engine destruction efficiencies for several gas types.

Table IV.1: Observed landfill gas engine destruction efficiencies for functional groups

Functional group	Minimum (%)	Maximum (%)
Methane	96.0	99.6
Alkanes	70.2	>99.9
Alkenes	50.1	>99.6
Alcohols	84.1	>99.8
Aldehydes	>42.4	95.9
Ketones	>87.4	99.9
Aromatic hydrocarbons	92.0	>99.9
Terpenes	-	>99.9
Halogenated hydrocarbons	>70.1	>99.7
Sulphur compounds	>8.7	>96.6

3.2.2. Social benefits

The social benefits from the LFGTE Facility can be summarized as below:

- The incidence of exposure of landfill workers and local communities to HAP will drop significantly, reducing the health hazards caused by such substances. HAP can cause a variety of health problems, such as cancer, respiratory irritation, and central nervous system damage. In addition, the danger of explosions will be reduced, thereby contributing to safer operations in the part of the landfill area that remains open;
- The odours produced by the landfill area will be abated, which will have a great impact on the quality of life for individuals that live in and around the compound. It will also have a significant economic impact by contributing to higher local property values;
- Finally, the implementation of the project would require the employment of 5 to 20 persons for construction and other duties. Thus, the project will directly and/or indirectly generate net employment opportunities for the local communities.

3.2.3. Economic benefits

Landfill gas use creates jobs associated with the design, construction, and operation of energy recovery systems. Landfill gas projects involve engineers, construction firms, equipment vendors, and utilities or end-users of the power produced. Much of this cost is spent locally for drilling, piping, construction, and operational personnel, helping communities to realize economic benefits from increased employment and local sales. Businesses are also realizing the cost savings associated with using LFG as a replacement for more expensive fossil fuels, such as natural gas and fuel oil. Moreover, landfill gas is a local, renewable energy resource. Because it is generated continuously, it provides a reliable fuel for a range of energy applications, including power generation and direct use. Electric utilities that participate in landfill gas-to-energy projects can benefit by enhancing customer relations, broadening their resource base and gaining valuable experience in renewable energy development. Landfill gas power projects provide important demand-side management benefits, as transmission losses from the point of generation to the point of consumption are negligible.

3.2.4. Technology transfer

With bilateral or multilateral CDM projects, all parties under the Kyoto Protocol are called upon to cooperate for the effective transfer of technology between foreign and local entities. The local partner would then be able to diffuse a more efficient and less carbon-intensive technology in order to duplicate the intended project when it is economically and technically feasible to do so.

3.2.5. Stakeholder consultation

Under the Kyoto Protocol framework, it is compulsory for the developer to organize some stakeholder consultations so as to ensure that public concerns about the project are taken into consideration. Thus, local authorities are assured that no complaint would continually come up because of the development of such a project. Within the context of the discussions on the proposed projects, there would be explanations about the environmental, economic and social impacts of construction and operation. The comments of local stakeholders would then be obtained through surveys conducted by interview and compiled into three categories: (a) governmental organizations; (b) public and private entities and NGOs; and (c) communities.

V. Specific requirements/challenges for developing landfill gas (LFG) recovery/utilization projects

The landfill owner/operator has to determine whether an LFG recovery/utilization[11] project is likely to succeed at the landfill. Various criteria are used to assess the suitability of a landfill and a number of issues have to be addressed:

- Suitability of a particular landfill for an LFG
- Technical and engineering study
- LFG utilization technologies
- Economic feasibility study
- Risks and barriers

1. Determining if an LFG project is suitable for the landfill

Determining if an LFG recovery/utilization project may be right for a particular landfill is the first phase involved in assessing project options; the process includes the following steps:

- Application of basic screening criteria to determine if the landfill meets the characteristics that apply generally to successful LFG recovery-related CDM projects;
- Estimation of the quantity of LFG that can be collected, as gas quantity is a critical factor in determining whether LFG recovery is a viable option.

1.1. Basic screening criteria

The purpose of basic screening is to quickly identify landfills that are good candidates for LFG recovery/utilization, meetings CDM qualifications. The questions in box V.1. should help guide a landfill owner/operator through the process of evaluating screening criteria, which are identified below. It is likely that the best candidates for such a development will have the following characteristics:

- At least 1 million tons of waste in place;
- Landfill still receiving waste; if closed, not for more than a few years;
- Landfill depth of 10 metres or more;
- Only landfills where flaring/utilizing the LFG is not mandatory (for example, by contract or by law) and those under the CDM scheme.[12]

Landfills that meet these criteria are likely to generate enough LFG to support a gas-to-energy project. However, these characteristics, like the screening criteria, should be only considered as guidelines. Actually, some landfills might be suitable even though they do not meet all the above-mentioned criteria because of important site-specific characteristics. In some cases where the history and composition of solid waste are not well documented, the amount of LFG may be overestimated. Hence, it is important to have good-quality data to make the screening process more effective.

Some additional characteristics may also be indicative of LFG recovery potential.

---

11 "Utilization" also includes the action of simple LFG destruction.

12 For further information on this concept, see subheading 6.3. Regulatory and approval risks on page 36.

Box V.1: Assessment of tool - Is this landfill project feasible?

A. The waste disposed into the landfill must be municipal solid waste; otherwise, additional difficulties will be encountered in the project development process, as the LFG would be made up of many impurities able to prevent the smooth working of the system. In such a case, it would be best to first consult an LFG recovery/utilization expert.

B. Landfill criteria

i. How much waste has been dumped into the disposal site?		Score
Tons	Score	
> 3 million	50	
1-3 million	40	
0.75-1 million	30	
0.5-0.75 million	20	
<0.5 million	10	....
ii. Is the disposal site at least 10 metres deep (considering depth and height)?		
Yes	5	
No	0	+..................
iii. Is the landfill currently in operation? If yes, answer 1. If no, answer 2.		
1. How much waste will be received in the next 10 years? For each 500 000 tons, score 5 points.		+..................
2. If the landfill has been closed for less than 3 years, score 0. If closed for 3 or more years, multiply each year since closure by 5 and subtract that amount from the total.		-..................
iv. Is it mandatory (either by contract or law) to flare/utilize the LFG in the landfill?		
Yes	-10	
No	0	+..................
v. Did any fire occur on the landfill lasting more than one week?		
Yes	-10	
No	0	+..................
Total the answer i-v:		

C. If the score is:

30 or more: The landfill is a good candidate for LFG recovery/utilization;

20-30: The landfill may be a good candidate, especially if the area is limited and the landfill is properly managed ("controlled dump" or "sanitary landfill" [a]);

Less than 20: The landfill may not be a good candidate.

Note:

[a] *See annex for the classification of the disposal sites according to the United Nations Environment Programme.*

These include the following characteristics:

- Climate: moisture is an important medium for the bacteria that break down the waste. In areas with very low rainfall (i.e., less than 65 cm per year), yearly generation of LFG is likely to be relatively low. Therefore, less gas may be available for flaring/utilization each year in arid areas (although gas production may continue for a longer period of time than in a wetter environment). On the other hand, landfills in a tropical area may become saturated if the leachate is not properly managed; such a situation often impedes LFG generation;
- Waste type: methane is generated when organic waste, such as paper and food scraps, decomposes. Therefore, landfills (or cells within landfills) that contain large proportions of synthetic or slowly-decomposing organic waste, such as plastic and construction/demolition waste, may be less attractive candidates;
- Nearby energy use: a smaller landfill may still be a good candidate for LFG recovery if there is a use for the gas at or near the landfill. Such landfills should not be discounted without exploration of direct gas use options.

1.2. Assessment of the LFG potential generated by the landfill

Once the landfill owner/operator has determined that LFG recovery/utilization may be attractive, the next step is to estimate LFG flow. Information on this aspect is of critical importance in determining the technical specifications of the project and later on in assessing its economic feasibility. There are a variety of methods, ranging from very basic desktop estimates to actual field tests, as described below. Because both the cost and the reliability of the estimates increase for more detailed methods, it is recommended that the basic estimation approaches be used first, and the more detailed methods be used (if warranted) as project assessment progresses.

1.2.1. General methods for estimating the LFG flow

Three gas flow estimation methods are presented below. The first method is a relatively simple approach that requires limited site-specific information. Because landfill characteristics and therefore gas generation rates can vary substantially among landfills (even those with the same amount of waste in place), method A will provide only rough gas flow estimates. When using this method, the landfill owner/operator should assume that actual gas flows may be 50 per cent higher or lower. For example, lower gas flows may occur in landfills located in arid areas (i.e. receiving less than 65 cm of rainfall per year) or in landfills containing large amounts of construction/demolition debris. Method B takes into consideration data from the landfill itself; however, the results are only theoretical and depend widely on the model inputs, which are difficult to estimate accurately for a particular landfill. Method C, in contrast, relies on data from the landfill itself, and may provide more accurate estimates.

- Method A: simple approximation

A rough approximation of LFG production can be estimated easily using the amount of waste in place as the only variable. The procedure described below for approximating gas production is derived from the ratio of waste quantity to gas flow observed in the many, often very different, projects already in operation. It reflects the situation at an average landfill which operates an energy recovery project, and may not accurately reflect the details of the type of waste, climate and other characteristics that exist at a specific landfill. Therefore, it should be used primarily as a screening tool to determine if a more detailed assessment is warranted, such as can be developed using methods B and C.

The simple approximation method requires only knowledge of how much waste is in place at the target landfill. Based on their extensive experience at many landfills, industry experts have developed a rule of thumb that landfill gas generation rates range from 3.115 m^3 to over 12.459 m^3 of gas per ton of refuse per year, with the average landfill generating 6.229 m^3 of LFG per ton per year (WMNA, 1992; Walsh, 1994); therefore, the following equation may be used:

Annual landfill gas generation (m^3) = 6.229 m^3/tons x waste-in-place (tons)

- Method B: first order decay model

The second approach — the "first order decay model" — can be used to account for changing gas generation rates over the life of the landfill of a proposed project. Understanding the rate of gas flow over time is critical to evaluating project economics. The first order decay model is more complicated than the rough approximation described previously; it requires that the landfill owner/operator knows or can estimate the variable of the following equation, which is described in the IPCC methodology guidelines:[13]

$$CH_{4\ projected,\ y} = k * L_o * \sum_{t=0,y} WASTE_{contract,\ t} * e^{-k\,(t-y)}$$

Where:

$CH_{4\ projected,\ y}$: the quantity of methane projected to be gerated (m^3)

K : the methane geration rate constant (1/yr) relates to the time taken for the degradable organic carbon in the wase to decay to half its initial mass.

L_O : the methane generation protential (t CH_4 / t waste)

$WASTE_{contract,\ t}$: the waste input at year y

y : the year in which the waste was put into the landfill

t : the year in which methane emission is estimated for the waste deposited in year y

The methane generation rate constant (k) represents the first-order biodegradation rate at which methane is generated following the placement of waste. 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 0.12 for very wet sites.

The methane-generation potential (Lo) represents the total amount of methane that 1 ton of waste is expected to generate over its lifetime (m^3 of methane per ton of waste). The Lo value is dependent on the composition of the waste and in particular the fraction of organic matter present. The estimated Lo value

13 Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories <www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm> and 2006 IPCC Guidelines for National Greenhouse Gas Inventories <www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm>.

Table V.1: Suggested ranges and recommended parameter assignment for the rate constant

Precipitation (mm annually)	Range of k values according to type of waste		
	Relatively inert	Moderately decomposable	Highly decomposable
<250	0.01	0.02	0.03
≥250 to <500	0.01	0.03	0.05
≥500 to <1000	0.02	0.05	0.08
≥1000 to <2000	0.02	0.06	0.09
≥2000	0.03	0.08	0.12

is based on the carbon content of the waste, the biodegradable carbon fraction and a stoichiometric conversion factor. Typical values for this parameter range from 100 m^3 of methane/ton of waste to 310 m^3 of methane/ton of waste. Increased compaction of the waste has no direct effect on the Lo parameter. However, the compaction and the density of the 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 on 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 programmes increase and improve, more organic material, such as food waste and paper, may be diverted from the landfill, thus reducing the quantity of LFG produced. However, recycling initiatives in both developed and developing countries have had more success to date at removing inorganic materials from the waste stream. As a consequence, typical practice has not seen the applicable Lo value decrease significantly. The model user may increase or decrease Lo to reflect specific knowledge of the waste characteristics with either higher or lower organic waste content. In landfills where there are good data, indicating that a significant portion of the waste 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 the data are insufficient to determine the percentage of the waste that is inert. It is recommended that the Lo parameter be reduced or the quantity of contributing waste be decreased if there are clear and concise data quantifying the inert or relatively inert waste stream. As noted previously, the Lo parameter already is well reduced from the theoretical value that would reflect pure organic waste in recognition of the fact that moisture and inorganic materials are present in some portion of any waste stream. If good data exist regarding waste quantities and types, it may be possible to refine the modelling assessment, using the following as guideline parameter assignments for determining 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.

Table V.2: Suggested ranges of methane generation potential

Waste category	Minimum Lo value	Maximum Lo value
Relatively inert	5	25
Moderately decomposable	100	200
Highly decomposable	200	300

The methane generation potential, Lo, represents the total amount of methane that 1 ton of waste is expected to generate over its lifetime. The decay constant, k, represents the rate at which the methane will be released from each ton of waste. If these terms were known with certainty, the first order decay model would predict methane generation relatively accurately; however, the values for Lo and k are thought to vary widely and are difficult to estimate accurately for any landfill.

Box V.2: Typical Asian landfill site – model inputs

Year opened – closed:	1990 - 2003
Average annual precipitation:	2,500 mm
Methane content of LFG adjusted to:	50 per cent
Methane generation rate constant (k):	0.1
Ultimate methane generation potential (Lo):	150

Year	Metric ton disposed in landfill per year	Cumulative metric ton per year	LFG generation rate (m^3/hr)
1990	122 827	122 827	
1991	126 626	249 454	421
1992	130 543	379 996	815
1993	134 580	514 576	1 185
1994	138 742	653 318	1 533
1995	143 033	796 351	1 863
1996	147 457	943 808	2 176
1997	152 017	1 095 826	2 475
1998	156 719	1 252 545	2 760
1999	161 566	1 414 111	3 035
2000	166 563	1 580 673	3 300
2001	171 714	1 752 388	3 557
2002	177 025	1 929 413	3 807
2003	182 500	2 111 913	4 051
2004	0	2 111 913	4 291
2005	0	2 111 913	3 883
2006	0	2 111 913	3 513
2007	0	2 111 913	3 179
2008	0	2 111 913	2 877
2009	0	2 111 913	2 603
2010	0	2 111 913	2 355
2011	0	2 111 913	2 131
2012	0	2 111 913	1 928
2013	0	2 111 913	1 745
2014	0	2 111 913	1 579
2015	0	2 111 913	1 428
2016	0	2 111 913	1 293
2017	0	2 111 913	1 170

- Method C: pump test

According to many experts, the most accurate method for estimating gas quantity, short of installing a full collection system, is to conduct a pump test. A pump test involves sinking test wells and installing pressure-monitoring probes, then measuring the gas collected from the wells under a variety of controlled extraction rates. An obvious benefit of this method is that the collected gas can be tested for quality as well as quantity. The gas should be analysed for Btu content and for impurities such as hydrocarbons, sulphur, particulates and nitrogen. The information obtained in a pump test is important since it is used in the design of the processing and LFG recovery/utilization system, as well as in obtaining project financing.

However, when conducting a pump test, it is critical that the test wells are placed in such a way that they are representative of the waste from which the gas will eventually be drawn, since gas generation rates may vary across the landfill. Unfortunately, this is easier said than done in developing countries, where determining the waste composition is already complex: we are always "surprised" to find used vehicles, household appliances and such a solid waste sites.

As the cost of carrying on a pump test is somewhat prohibitive and the results may not be conclusive, it is often good enough to use method B in developing countries with limited access to reliable landfill data.

1.2.2. Collection efficiency

Before gas generation estimates developed from methods A or B are used to size a LFG recovery/utilization system, it is necessary to correct for LFG collection efficiency (C_e). There are several factors which affect the overall collection efficiency of an LFG extraction system, which can vary widely from about 20 to over 90 per cent. The permeability of the landfill's cover layer will determine how much of the LFG generated will escape into the atmosphere even with the most tightly constructed and controlled collection system. Well spacing and depth, which are determined by economic and other site-specific factors, also affect collection efficiency, as can bottom and side liners, leachate and water levels, and meteorological conditions.

The table below lists the possible different percentage values of C_e depending on the categorization[14] of the landfill. The minimum and maximum values also vary according to (a) the investment granted for the closure of the site and (b) especially the profiling and the final cover.

Multiplying the total LFG generation estimated by methods A or B by the correct assumptions about C_e should yield a reasonable estimate of the LFG available. Even the results of method C may have to be corrected for collection efficiency, since the results of the pump test may not provide an indication of gas flows across the landfill (Kraemer, 1995).

Table V.3: Possible different percentage values of different values of C_e

Landfill category	Minimum C_e	Maximum C_e
Open dump	20 - 30	50 - 60
Controlled dump	40 - 50	60 - 70
Sanitary landfill	60 - 70	70 - 90

14 The landfill owner/operator should keep in mind that C_e values are purely indicative, as the variation from one landfill to another (even in the same geographical area) might be significant.

Box V.3. Case study on landfill gas to energy project assessment

The example of a typical Asian landfill, which had been operational from 1990 to 2003, makes a useful case study. The landfill is sited in a tropical country with precipitation of more than 2,500 mm per year. The landfill may be classified as a controlled landfill; lack of financing impedes the complete safe closure of the site. The following details provide other characteristics of the landfill :

- Profiling of the site has been done, but a soil layer only of 20 cm deep has been laid;
- Fencing of the site has been done in a random;
- Leachate and LFG treatment systems have not been installed;
- Gardening the surface area has not been implemented, but tropical conditions onsite triggered the growth of heavy vegetation only a few months after closure of the landfill.

Fortunately, the landfill has been equipped with a bottom liner, which prevents contamination of the ground soil nearby and bottom landfill gas migration. However, since there is no liquid-effluent treatment system of any kind, it may be expected that the landfill has been completely filled with leachate.

According to the municipality governing, the landfill, it received in its last year of operation 500 tons per day of waste (only municipal solid waste); no further data are available concerning the yearly tonnage received since the landfill's opening. However, the yearly population growth rate since 1990 has been an average of 3 per cent average annually. Therefore, it may be assumed that 2,111,913 tons of waste has been dumped in the landfill during the 13-year period. The average depth of the landfill is more than 10 metres and it covers an area of 12 hectares.

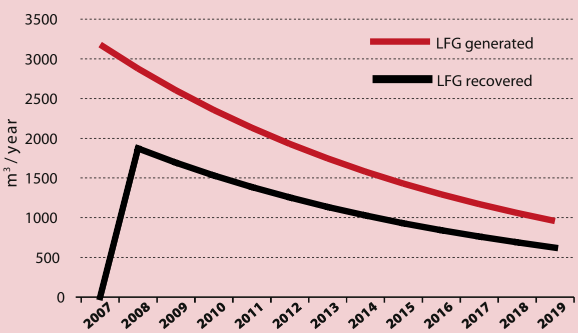
Using the assessment tool described in box IV.1 to determine if the project is feasible, it is found that this landfill meets condition A and scores a total of 40 under criteria B.i.; 5 for B.ii.; -5 for B.iii; and 0 for B.iv. The total of 40 indicates that the landfill is a good candidate for LFG recovery/utilization.

A mathematical model developed by the United States Environmental Protection Agency, called Mexico Landfill Gas Model <www.epa.gov/lmop/international.htm#3>, calculates the maximum expected LFG generation and recovery potential based on factors such as the amount of waste in place, waste acceptance rates, methane generation rate (k) and methane generation potential (Lo). This model reflects the higher levels of organic matter and higher moisture content in refuse found in developing countries such as Mexico and are applicable to most landfills in South-East Asia.

Since LFG generation is one of the most important factors for the successful development of LFG recovery and utilization projects. Because LFG generation can vary widely depending upon the selected values for k and Lo, it is strongly recommended that experts in LFG recovery and utilization be consulted.

As the typical landfill has been classified as a controlled dump and since the project developer chose to afford a soil cover 60 cm deep for the top using a semi-impermeable HDPE sheet for the sides, a collection efficiency of 65 per cent is assumed for this project. The project implementation starts in 2007, with commissioning in January 2008. Therefore, the following table provides data on the LFG actually collected and available:

Year	LFG generation rate (m^3/hr)	LFG recovered (m^3/hr)
2007	3 179	0
2008	2 877	1 870
2009	2 603	1 692
2010	2 355	1 531
2011	2 131	1 385
2012	1 928	1 253
2013	1 745	1 134
2014	1 579	1 026
2015	1 428	929
2016	1 293	840
2017	1 170	760



2. Technical and engineering study

The technical structure is site-specific; more importantly, it depends on the knowledge of and experience in developing LFG projects at the regional and national levels. State-of-the-art conventional technologies to collect LFG is currently being used in many developed countries. However, most developing countries lack knowledge of or experience in implementing these types of projects. Consequently, most often no local companies are able to perform the work needed or more importantly to provide the equipment required for LFG projects.

Therefore, the equipment has to be shipped from Europe or developed countries elsewhere. This transit requirement makes difficult the development of projects because it prolongs delays and creates extra problems in implementation of the projects. Moreover, the design of a gas-collection system and an energy-generation system is a complex undertaking and requires input by an experienced engineering team. The lack of experience in that area in most developing countries implies that the training of local personnel is an indispensable step for LFG projects.

Another difficulty which is met in some countries is the high leachate levels which impede LFG generation and may influence the design of the system.

The present of this guide section has as its objective familiarizing the reader with the different equipment needed to successfully develop an LFG project. They are as follows:

- LFG collection field;
- LFG collection piping system;
- Condensate system;
- Blower system;
- LFG flare;
- LFG processing to achieve different LFG end-uses (electricity generation, heating greenhouses, producing carbon dioxide or vehicle fuel, etc.).

2.1. LFG collection field

A comprehensive network of vertical LFG extraction wells and/or horizontal LFG collection trenches is installed into the waste so as to collect the LFG. Vertical wells are typically installed in a landfill once filling operations have been completed. Using vertical LFG extraction wells offers the following advantages:

- Improved area control of gas emissions;
- The well field may be expanded to reflect the changing landfill site conditions;
- Condensate collection may be minimized.

However, 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 (new section of layer), 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 might also be used when a landfill is drowned with leachate, which is often the norm in Asian landfills (particularly in South-East Asian countries). Indeed, the LFG collection system must be used in concert with good leachate-management practices. Mounding of leachate within the refuse can have a dramatic impact on the rate of LFG recovery because liquid in the extraction wells and collection trenches effectively restricts their ability to collect and convey LFG.

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.

2.2. LFG collection piping system

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 pipes connecting the wells/trenches;
- Subheaders which connect the laterals;
- Headers connecting the subheaders to the extraction plant.

The header system is the central point, where a blower pumps the gas out of the landfill under vacuum. Where possible, the main header is located outside the landfill footprint in order to minimize the effects of settlement. The header system is located primarily above-grade in order to minimize construction costs and allow easy access when maintenance is needed. Some portions of the header system are located below-grade to provide protection from any atmospheric influence. However, there are a several LFG network piping patterns designed to facilitate the drainage of liquids and to minimize the length of pipe required for the collection system. Moreover, the specific characteristics of a landfill site pose many direct implications for the design options and related costs of the piping systems.

2.3. Condensate system

Landfill gas is saturated with vapour. As the gas cools in the piping of the extraction system, the vapour condenses into droplets that become entrained in the gas flow. Eventually, the droplets combine and pool as LFG condensate. The accumulation of condensate in LFG pipelines can obstruct and in some cases completely block the flow of gas. This can lead to surging in the gas lines, making the control and tuning of the extraction system difficult. Therefore, the LFG condensate must be removed in a controlled manner. Condensate control begins at the recovery system, where sloping laterals and headers are used to provide drainage into condensate traps, knockout collectors, barometric drip legs, or tanks. In some cases, the condensate might be drained back into the landfill.

Once separated from the gas, the 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.

2.4. Blower system

The blower system includes all components that are used to generate and apply the vacuum to collect 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. The blower system may be enclosed in a building or it may be mounted on a pad in an exterior installation. A blower system includes the following components:

- 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 per cent of the peak rate of the 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 the construction of an LFG control plant is often beneficial if gradual increases in LFG production are anticipated.

2.5. LFG flare

The gas collected from a site must be disposed of in an environmentally sound manner, such as an enclosed drum flare and/or utilization system. An LFG flare can be used as a backup for the utilization system in the case of lengthy downtimes, both scheduled and unscheduled, for operational and maintenance purposes. The need for a backup flare and equipment redundancy is optional depending upon the reliability and sensitivity of the overall system to short-term loss of LFG extraction and control capability. High-temperature flaring of LFG results in the conversion of methane components of the LFG to carbon dioxide and water. Also, 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 enclosed drum flares.

2.6. LFG processing systems

To employ most of the LFG utilization technologies described under subheading 3. LFG utilization technologies on page 30, the gas needs to be processed, at least to some extent. The primary form of treatment of LFG is to remove some portion of the water vapour from the saturated LFG. Reducing the moisture content of the LFG and the quantity of impurities (trace constituents and particulates) reduces the corrosive nature of LFG, which lowers 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; project-specific costing is necessary to assess the application of these technologies to a site:

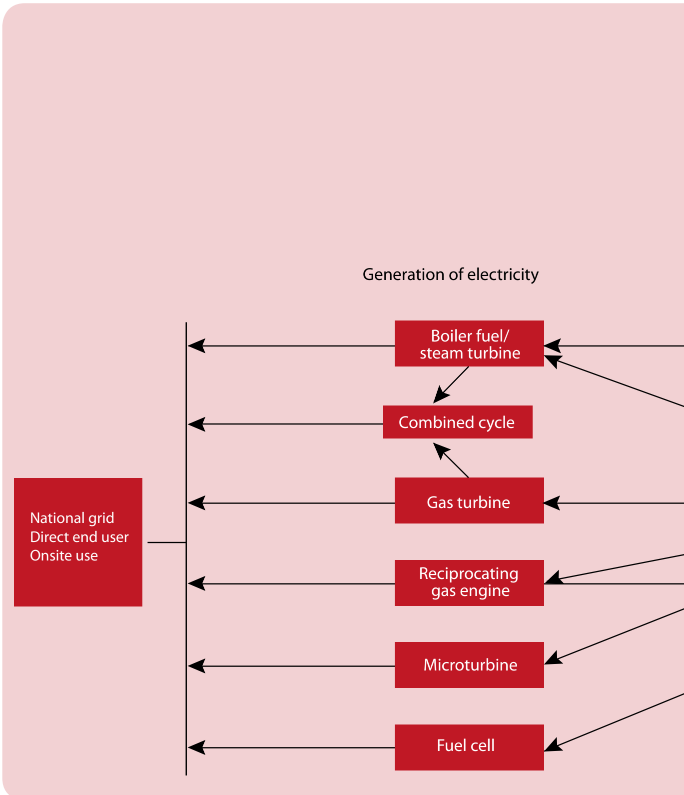
- **Moisture removal:** the degradation of organic waste is an exothermic process and therefore LFG is warm and essentially saturated with water vapour. High moisture content, in combination with carbon dioxide, hydrogen sulphide and volatile organic compounds, creates a potentially corrosive gas. The 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 the gas velocity and enabling 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 LFG passes. Mist eliminators also intercept particulate matter entrained within the water droplets. Cooling and compression of the gas decreases the ability of 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 a view to the end utilization of the gas. Absorption uses a liquid with a high affinity for water. The LFG to be absorbed is either introduced into the bottom of a column of an 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 used and the characteristics of the LFG. Absorption 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. This technique is sometimes used in conjunction with absorption in systems such as packed towers, plate columns, spray towers and venturi scrubbers. Because contamination of the specialized media employed in these systems causes reduced efficiency over time, replacement is required;

- **Particulate removal:** the solid particles carried within the LFG stream must be removed in applications for the use of medium-to high-grade fuel in order 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 the 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 sulphur compounds, non-methane organic compounds, and volatile organic compounds. These can be removed through the use of granular activated carbon (GAC), selective solvents, or iron sponge. GAC is the most commonly used substance for treating hydrocarbons and volatile organic compounds. One significant disadvantage of using GAC for LFG polishing applications is its high affinity for moisture. However, 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 sulphide from LFG. The system uses hydrated iron oxide supported on wood shavings in order to react with the iron oxide and produce iron sulphide;
- **Carbon dioxide stripping:** carbon dioxide has no caloric value, and it creates a corrosive liquid when combined with water vapour. By using extraction, adsorption and membrane separation methods, carbon dioxide can be removed from LFG, thus 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 LFGTE projects unless there is a very high market value for the fuel products.

3. LFG utilization technologies

The collection and flaring of LFG is by itself an effective means of LFG management by reducing odour, the potential for producing greenhouse gas (conversion of methane in carbon dioxide), migration problems. The development of an international carbon market is discussed further under the heading Opportunities created by CDM projects for municipalities and local authorities on page 12.

However, flaring LFG does not enable the recover of any of the energy from the gas. Consequently, this section details different technologies that are available for recovering some of the energy from LFG, which potentially could provide a supplementary source of income to the landfill owner/operator through the sale of LFG-related products.

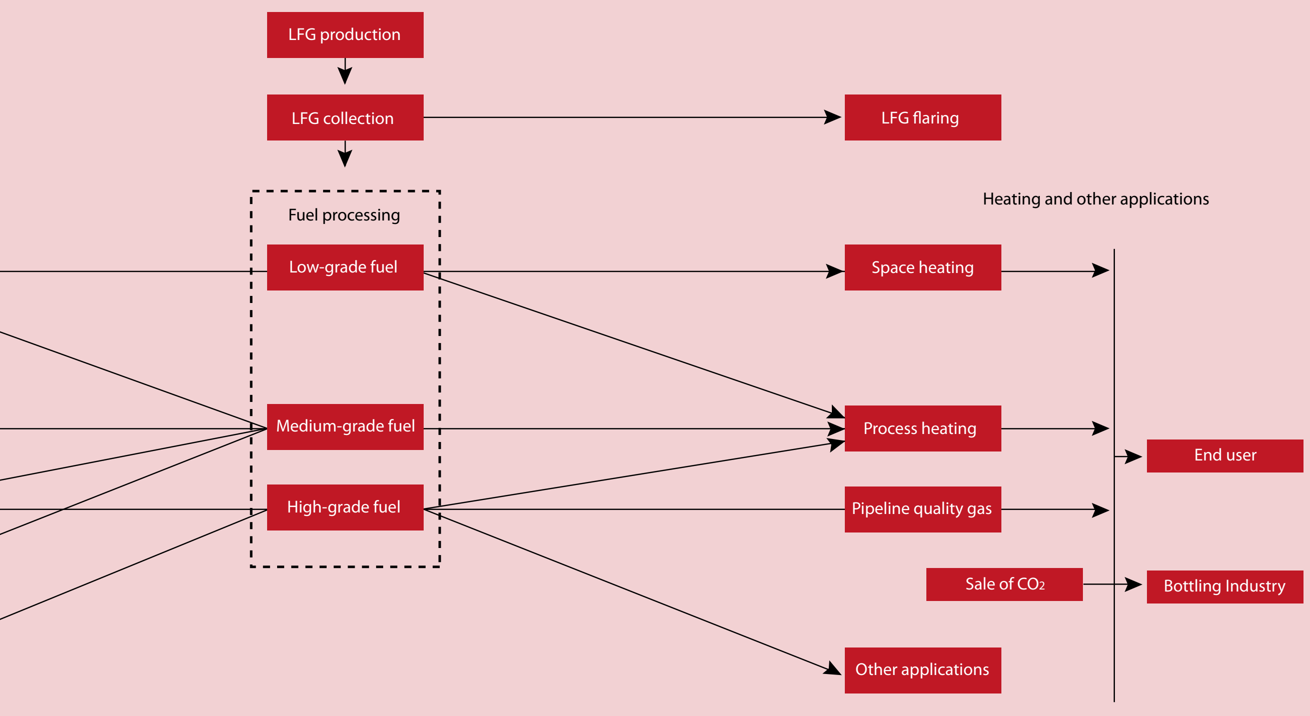


As mentioned under the subheading 2.6. LFG processing systems on page 29, depending upon the application, raw LFG may require some level of processing prior to being utilized in order to reduce the high moisture content of the gas and remove the numerous impurities it contains, as these can prevent the entire system from working efficiently. To ease this situation, LFG has been classified into three categories, based on the level of pre-treatment/processing required prior to utilization:

- **Low-grade LFG fuel:** utilization of LFG as a low-grade fuel usually 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 LFG fuel:** additional gas treatment devices are used to extract more moisture (with contaminants) and finer particulate matter. The process involves compression and refrigeration of LFG and/or chemical treatment or scrubbing in order to remove additional moisture and trace gas compounds, such as mercaptans, sulphur compounds, siloxanes and volatile organic compounds;
- **High-grade LFG fuel:** utilization of LFG as a high-grade fuel involves (a) extensive gas pre-treatment in order to separate the carbon dioxide and other major constituent gases from the methane and to remove impurities, including mercaptans, sulphur compounds, hydrogen sulphide and volatile organic compounds and (b) compression of the gas to dehydrate it.

The difference between the various types of fuel is in the heating value. Low- and medium-grade fuels produced from LFG have a heating value of approximately 16.8 MJ/m^3 (or roughly half the heating value of natural gas), while high-grade fuel has a higher heating value (37.3 MJ/m^3) and can be substituted directly for natural gas in pipeline applications (CRA, 1996). Figure V.1. illustrates the increasing degree of processing that is required to transform LFG from a low-grade fuel into a more refined fuel source.

Figure V.1: Required processing so that LFG can be utilized.



4. Utilization selection factors: The LFGTE example

As mentioned previously, 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 the following:

- Projected LFG availability;
- Presence and location of suitable markets;
- Market price for end products;
- Environmental and regulatory factors;
- Capital and operating costs of utilization system options, including processing and transport issues/ costs.

The viability of an LFGTE project is largely influenced by the quality and quantity of the LFG (especially its methane content) and the electricity off-take tariff in the particular country that is considering the significant capital and operating/maintenance costs involved.

Several factors must be evaluated when considering generating electricity with LFG: whether or not 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 minimum methane content of LFG also varies with each technology. The net power fed into the grid is equal to the total output from the generator less any "plant parasitic losses", which include the energy spent on gas compressors, jacket water pumps, lubricant oil pumps, radiator fans, generator fans, station transformers, and other station auxiliaries.

Other important factors that must be considered when deciding on whether or not to utilize LFG for electrical generation include availability and emissions. Availability is the actual time of power generation divided by the hours available annually. This is mainly a measure of the reliability of the power-generation equipment and the supply of the fuel to the facility. The emissions from exhausts of an LFG flare or a piece of generation equipment must be controlled within acceptable limits set by governmental agencies. The emissions of concern include nitrogen oxides, carbon dioxide, carbon monoxide, non-methane hydrocarbons, volatile organic compounds and products of incomplete combustion.

Financial summary (United Sates dollars)		
Capital cost	5 630 064	
LFG collection system	1 164 000	
LFG utilization system	3 001 200	
Average annual operating cost	628 254	
Year		2007
LFG generation potential (m³/y)		27 849 242
LFG recovery (m³/y)		0
Electrical generation potential (kWh)		0
Number of engines		0
Net electrical generation (kWh)		0
CO_2 Equivalent from LFG (CERs)		0
CO_2 Displaced by power generation		0
Costs		
Capital cost		5 630 064
Annual operating cost		
Revenues		
CERs		0
Electricity sales		0
Project cash-flow (prior to taxes…)		-5 630 064
IRR		30 per cent

5. Economic feasibility study

The previous sections have focused on understanding the LFG fuel resource, how to collect and use it. The second area of key input data needed to undertake an economic feasibility study is an extensive understanding of the market-specific conditions applicable to the site and the country in which the project is to be located. Sections 3 and 4 outlined the technologies and energy market issues that must be considered in order to develop the cost component for the utilization options, which, along with the market/revenues that may potentially be available to the project, will enable the making of a final decision on whether or not an LFG project is suitable for a specific landfill.

Therefore, 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

Table V.4: A typical example of the financial summary for an LFGTE project

Annual financing cost	
Financing	Equity
Inflation rate	2 per cent
Power sales royalties	0 per cent
CERs royalties	0 per cent

Electrical production assumptions	
Each reciprocating engine (kWh)	900
Availability	90 per cent
Conversion efficiency	35 per cent
Electricity off-take tariff (US$/kWh)	0 08

CERs value (US$/ $TeqCO_2$)
10

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	25 199 037	22 801 031	20 631 226	18 667 905	16 891 419	15 283 988	13 829 524	12 513 471	11 322 657	10 245 164
	16 379 374	14 820 670	13 410 297	12 134 139	10 979 423	9 934 592	8 989 191	8 133 756	7 359 727	6 659 356
	28 917 572	26 165 702	23 675 706	21 422 665	19 384 029	17 539 394	15 870 300	14 360 042	12 993 503	11 757 008
	3	3	3	2	2	2	2	1	1	1
	21 200 000	21 200 000	21 200 000	14 080 000	14 080 000	14 080 000	14 080 000	6 960 000	6 960 000	6 960 000
	113 604	103 621	94 589	83 514	76 119	69 428	63 373	54 993	50 036	45 550
	18 256	18 256	18 256	12 125	12 125	12 125	12 125	5 994	5 994	5 994
	628 254	628 254	628 254	628 254	628 254	628 254	628 254	628 254	628 254	628 254
	1 318 602	1 218 779	1 128 455	956 392	882 441	815 527	754 981	609 863	560 292	515 439
	1 696 000	1 696 000	1 696 000	1 126 400	1 126 400	1 126 400	1 126 400	556 800	556 800	556 800
	2 386 348	2 286 524	2 196 200	1 454 538	1 380 587	1 313 673	1 253 127	538 409	488 838	443 985

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. Typically, an LFGTE project could not bear the costs of any extensive infrastructure needed 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 aspect makes most of these potential projects reliant upon the infrastructure that currently exists. Often the geographic or political region where the candidate site is located may have very specific rules and limitations with respect to the sale, access to and distribution of the energy products. The LFGTE projects are typically considered small projects from a national energy perspective; however, 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 severe regulatory constraints or prohibitive cost limitation hinder access to non-utility generators or suppliers, these types of projects should be treated as a separate category of generator.

To proceed with the economic feasibility study, it is 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 CERs (dollar per ton of ton equivalent of CO_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 CERs sales.

As mentioned previously, it is strongly recommended that experts in LFG recovery and utilization be consulted before implementing this kind of project that particularly because LFG generation is one of the most important factors for the successful development of an LFG recovery and utilization project. Gas generation can vary widely according to the selected values for k and Lo. It can also vary depending on the characteristics of each specific site. Not only can the investment required vary widely, but also the revenues can according to the assumptions used.

6. Risk factors – barriers to the development of LFG project

The increasing development of LFGTE projects in North America and Europe over the past decade has increased investor confidence in this technology; however, energy recovery from LFG is still not considered as a mature industry. Therefore the landfill owner/operator must understand well the risks associated with LFGTE projects as these factors will lead potential end users and financiers to perceive them as highly risky.

In the context of this guide, risk refers 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 an LFGTE project. This includes risks or uncertainties that relate to the following:

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

LFGTE technology has been proven; it has real potential for sites where 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 under development throughout the Asian and Pacific region. Although such policies and regulations have the potential to be shaped in favour of the development of such projects, their current uncertain status represents a risk and a concern to prospective developers and financing institutions.

6.1. LFG availability risks

Underperformance with regard to the amount of LFG available will have a severe impact on the success of any LFGTE project. There are three areas where LFG availability risks exist: the quantity of waste that may be available to produce LFG fuel; the characteristics of the waste that would be used to produce the LFG fuel; and the insitu environment that controls the process of anaerobic decomposition that produces the LFG fuel.

As previously mentioned under subheading 1.2.1. General methods for estimating the LFG flow on page 21, the first and second sources of risk are likely to occur in developing countries with limited access to reliable landfill data. The third source of risk is uncertainty about the conditions under which the waste is decomposing. This is represented in the model by a range of k values, based on the conditions at the site. As mentioned under method C, some of the risk or uncertainty can be alleviated by pumping test data used in conjunction with LFG modelling in order to demonstrate current LFG quality and quantities and help to refine the parameters input into the model. However, this does not alleviate all the risk, as pumping tests can indicate only the resources for the period of the field test and cannot provide any indication of future gas resources. Typically, in order to obtain financing for a utilization project, a private company would require a reasonable level of assurance that the LFG production and collection rate models were representative of actual conditions. The availability risk can be reduced and managed in a number of ways, as shown below:

- By applying a conservative (low) multiplier against the modelled LFG recovery curve in order to protect against any underperformance in the LFG fuel available;
- By undertaking to construct and operate the LFG collection system for a minimum agreed period in order to verify the presence and quantity of the LFG resource;
- By staging the development in phases in order to minimize the capital risks associated with oversizing the LFG utilization system, which is the major cost component of a project;
- By utilizing any or all of the above in some combination.

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

6.2. LFG technology risks

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

As mentioned under subheading 1.2.2. Collection efficiency, on page 25, all the LFG that is being generated cannot be collected. A well-designed and operated LFG collection system can typically collect 60 per cent or more of the total quantity of LFG that is generated. However, the additional risk associated with the LFG collection rate is associated with the operation and maintenance of the LFG collection system. Poor or improper operation and maintenance may result in deterioration of that system and a reduction in LFG quantity and quality. Such an outcome could have a significant impact on 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 operation and maintenance programme be proactive and able to adapt and change adequately.

Potentially serious implications, such as landfill fires, are related to the improper operation of gas recovery systems or overdrawing on a system. Overpumping from an LFG extraction well holds serious implications for safety and can also negatively affect the fuel supply by diluting and reducing its heating value (ideally the collected LFG is approximately 50 per cent methane by volume). It must always be remembered that a well-designed and well-operated LFG extraction system can still have widely varying rates of collection from individual wells because of the extreme heterogeneity of the waste mass.

The potential for conflict between the operating landfill, and the LFG collection and utilization system is another major risk. The design and the operation of the LFG system must not interfere with the purpose of the primary site: the dumping of wastes into the landfill. This includes resolving conflicts between both those responsible for the operations and the various systems, such as leachate collection system, of the working landfill, or directly developing already closed landfills. The most important issue to consider are the activities on site. Therefore, if a cell is still operational, the developer and the operator should define conjointly a suitable itinerary for the lorries and machines on site in order to protect the LFG recovery system.

6.3. Regulatory and approval risks

The coming into force of regulations that would require the flaring/utilization of LFG may prove to be a hindrance to the development of several LFG management projects, because the creation of emission reduction credits (carbon credits) can be achieved only through voluntary action. Therefore, policymakers must be aware of all the potential implications of legislation created to deal with LFG collection and utilization.

As mentioned in under subheading 3.1. Project design and formulation on page 8, the project developer must show how the "additionality" requirements would be met by the project. 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 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 proposed project has become operational. This concept necessitates the establishment of a baseline scenario for emissions that would occur if the project did not take place and carefully monitoring the emissions throughout the life of the project in order to quantify and to verify the emission reductions resulting from the project.

The following four examples outline the baseline scenario and additionality concepts:

- Landfill where there is no obligation to flare/utilize the LFG: the baseline scenario of emissions establishes that all emission reductions throughout the lifetime of the project will be additional;
- Landfill where there is no obligation to flare/utilize the LFG, but the landfill owner, for safety/environmental reasons, has installed a system to recover/flare part of the LFG: only the emission reductions throughout the project's lifetime subtracted from the part already flared on site will be considered additional;
- Landfill where there is an obligation to flare/utilize the LFG (either by law or under contract) and when the project has been implemented:[15] only the emission reductions achieved throughout the period when the collection/flaring efficiency of the system has been improved will be considered additional;

15 When there is an obligation to flare/utilize the LFG, but nothing has been done because of a lack of law enforcement owing to local development constraints, it might be possible to prove that the emission reductions achieved by the operational project will be additional, since the current practice is to release the total amount of LFG into the atmosphere.

- Landfill where there is no obligation to flare/utilize the LFG and no system installed on site but many projects of LFG recovery/utilization have come up because of some specific incentives, such as the electricity off-take price, for example: common practices are also taken into account in the CDM accreditation; therefore, only the emission reductions achieved throughout the period when the collection/flaring efficiency of the system has been improved will be additional.

7. Typical LFG projects implemented in the Asian and Pacific region

Seven municipal solid waste-related CDM projects were registered in Asia, five of which were LFGTE projects (71.4 per cent of the total), while five were seeking registration, all of which were LFGTE projects. In comparison, there were 43 registered municipal solid waste-related CDM projects worldwide and 13 seeking registration. Therefore, the Asian and Pacific region accounts for only 16.2 per cent of the registered municipal solid waste-related CDM projects and 38.4 per cent of the projects seeking registration.

Why is the share of Asia and the Pacific so low with regard to this technology, even though the population of the region represents approximately 60 per cent of the global population? Several factors explain this situation, although they are not exhaustive. Some of the following factors are related to the technology and others to the CDM scheme itself:

- There are more potential industry-related CDM projects in Asia and the Pacific, with expected revenues considered to be far more interesting than those that would be generated by LFG projects, even though the internal rate of return after would be lower. Thus, project developers have focused their energy and resources on developing such projects;
- The region is characterized by the great heterogeneity of languages, landfill regulations (ownership in particular), state of doing business compared with Latin America, for example. In general, there are also more protectionist measures in Asia and the Pacific that limit market access by foreign investors;
- Since the development of CDM projects attracts considerably amounts of money, some countries, following the example of China, are considering levying taxes on project revenues, which usually result in CERs. Such measure reduce only the overall internal rate of return of large-scale projects which hence are still attractive. However, small and medium-scale projects are often phased out from actual implementation. This is in opposition to the efforts of the United Nations Framework Convention on Climate Change;[16] the notion is that the implementation of such projects would drain benefits from nearby communities;
- Governments in Asia and the Pacific in general (China and India must be considered differently) have been less enthusiastic and proactive in establishing dedicated national authorities and the criteria for national validation, which is required in order to get a letter of approval from the host country. Thus, Asian and Pacific countries have not been so effective with regard to CDM projects, especially if proactive China and India are removed from the picture. Fortunately, several countries in the region have understood the potential benefits and are nowadays encouraging the development of CDM projects: Indonesia, Malaysia, Philippines, Republic of Korea and Viet Nam;
- There are also significant issues regarding the project design and the technologies to use as most of the landfills in South-East Asian countries are virtually drowned in leachate. Moreover, the municipal solid waste practices in several countries may also act as an impediment to LFGTE project development. For

16 A project which is eligible to be considered as a small-scale CDM project activity can benefit from the simplified modalities and procedures in order to reduce transaction costs associated with preparing and implementing a CDM project activity.

example, landfills in Indonesia, even though they receive significant quantities of waste, are too shallow and wide to be efficient.

Annex 2 provides some worldwide experiences. Please be advised that the case studies, sited in countries such as Canada, Latvia, Poland and Turkey, have not been developed through CDM scheme and hence, not resulted in CERs revenues. However, readers may learn from their experiences in overcoming barriers during the implementation phrase.

Table V.5. A list of typical LFG projects in the Asian and Pacific region (as of 1st April 2007)

Title	Host country	Status	Subtype	Metho-dology	Kilotons of CO_2/year	years	Mega-watts
Landfill gas extraction and utilization at Matuail landfill, Dhaka	Bangladesh	Registered	Landfill power	ACM1+ ACM2	187	7	3.0
Composting of organic waste, Dhaka	Bangladesh	Registered	Composting	AM25	89	7	
Shenzhen Xiaping landfill gas collection and utilization project	China	Request review	Landfill power	ACM1	472	10	8.0
Anding landfill gas recovery and utilization project	China	Registered	Landfill flaring	ACM1	75.6	10	0.0
Nanjing Tianjingwa landfill gas to electricity project	China	Registered	Landfill power	ACM1+ AMS-I.D.	214	7	6.0
Meizhou landfills gas recovery and utilization as energy	China	Registered	Landfill power	ACM1	287	7	2.0
Wuxi Taohuashan landfill gas-to-electricity project	China	Register requested	Landfill power	ACM1+ AMS-I.D.	75	10	2.1
Jinan landfill gas-to-energy project	China	Register requested	Landfill power	ACM1+ AMS-I.D.	113	7	3.0
Methane avoidance by municipal solid waste processing, in Chandigarh.	India	Registered	Landfill power	AMS-III.E.	40	10	0.0
PT Navigat Organic Energy Indonesia integrated solid waste management GALFAD project, Bali	Indonesia	Register requested	landfill power	ACM1+AM25 +AMS-I.D.	123	7	9.6
Krubong Melaka LFG collection & energy recovery CDM project	Malaysia	Registered	Landfill power	ACM1	58	10	2.0
Landfill gas utilization at Seelong sanitary landfill,	Malaysia	Register requested	Landfill power	ACM1	108	7	3.0
Sudokwon landfill gas electricity generation project	Republic of Korea	Register requested	Landfill power	ACM1+ ACM2	1 210	10	50.0

VI. Annexes

Annex 1: Landfill classification according to the United Nations Environment Programme

Key characteristics of municipal solid waste landfill

Type	Characteristics	Advantages	Disadvantages
Open dump	Poorly sited	Easy access	Environmental contamination
	Unknown capacity	"Extended" lifetime	Overuse, many noxious sites
	No cell planning	Low initial cost	Environmental contamination
	Little or no site preparation	Low initial cost	Unsightly, needs remediation
	No leachate management	Low initial cost	Ground water and surface water contamination
	No gas management	Low initial cost	Risk of explosion, greenhouse gases
	Only occasional cover	Low initial cost, aerobic decomposition	Vectors/disease, unsightly
	No compaction of waste	Low initial cost, aerobic decomposition	Shorter lifetime
	No fence	Low cost, access to waste pickers	Indiscriminate use, vermin
	No record keeping	Low initial cost	No record of landfill content
	Waste picking and trading	Materials recovery, income	Least efficient for materials recovery
Controlled dump	Sited with respect to hydro-geology	Less risk of environmental contamination	Perhaps less accessible
	Planed capacity	Permits long-term planning	(none)
	No cell planning	Low initial cost	Environmental contamination
	Grading, drainage in site preparation	Easier rainfall runoff, reduced risk	Cost
	Partial leachate management	Moderate cost, reduced risk	Cost
	Partial or no gas management	Moderate cost, reduced risk	Cost
	Regular (not usually daily) cover	Moderate cost, reduced risk	Cost, slower decomposition
	Compaction in some cases	Extended lifetime	Cost
	Fence	Controlled access and use	Cost, maintenance
	Basic record keeping	Valuable information	Cost
	Controlled waste picking and trading	Materials recovery, income, lower risk to pickers	Harassment, possible displacement of pickers and buyers, loss of recyclable resources
Sanitary landfill	Site based on Environmental risk assessment	Minimized environmental risk	Access, longer sitting process
	Planed capacity	Permits long-term planning	(none)
	Designed cell development	Minimize environmental risk	Cost
	Extensive site preparation	Reduced risk at and from site	Cost, preparation time
	Full leachate management	Reduced risk from leachate	Cost
	Full gas management	Reduced risk from gas	Cost
	Daily and final cover	Vector control, aesthetics	Cost, slower decomposition
	Compaction	Extended lifetime	Cost
	Fence and gate	Secure access, gate records	Cost, maintenance, staff
	Record volume, type, source	Valuable information	Cost, equipment
	No waste picking	Eliminate risk to pickers	Displacement of pickers and buyers, loss of recyclable resources

Adapted from G. Tchobanoglous, H. Theisen and R. Eliassen. Solid Wastes: Engineering Principles and Management Issues. (New York: McGraw-Hill, 1977) and D. R. Brunner and D. J. Keller Sanitary Landfill Design and Operations. (Washington, D.C., US EPA, Publication SW-65ts, 1972).

Source: <www.unep.or.jp/ietc/ESTdir/Pub/MSW/SP/SP6/SP6_3.asp>

Annex 2: Exemplar analysis on some World Bank case studies[17]

1. Waterloo LFGTE Project (Canada)

The waterloo project has been operational for approximately eight years and is working well. It is the only case study that can be categorized as being in a relatively steady operating mode. There are two key lessons to be 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 experience serves to reinforce the need to establish market access as an important issue and to prevent it from becoming an impediment to developing LFGTE projects in Asia and the Pacific. Second, the 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 US$ 300,000 per megawatt (MW) of electricity-generating capacity. This cost is variable and subject to site-specific conditions and the configuration of the site.

The cost of Waterloo plant was less than US$ 1.5 million per installed MW of generating capacity. The plant incorporates a number of systems to facilitate future expansion. The project received no grant funding or other financial support, yet has been a financial success for the participants, with the base revenue for electrical power being approximately US$ 0.045/kWh. Since the project is located in Canada (an annex 1 country), the project developer could not claim carbon credits.

2. The El Molle, Lo Errazuriz, Lepanto and La Feria LFGTE Projects (Chile)

The case studies in Chile were the only ones 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 to the city of Santiago. In another case, the LFG was utilized by a large, nearby agro-industry. A third project initially flared the LFG but 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 aspect in mind.

3. Getlini LFG-to-energy Project (Latvia)

Of the projects being developed in Latvia, two are LFG-to-energy projects: the Getlini project and the Liepaja project. Prior to construction, the Leipaja project became stalled because of the differing approval requirements of the large number of investors involved. Although the Getlini project has been commissioned, it has experienced difficulty vis-à-vis market access and market pricing as well as technical difficulties in the collection of LFG owing to the high leachate level at the site. This case study project serves to reinforce a number of key elements, including the following:

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

The actual cost for the Getlini plant in Riga is less than US$ 1.5 million per installed MW of electricity-generating capacity. The total capital and development cost for the waste management system at this site

17 <http://wbln0018.worldbank.org/esmap/site.nsf/files/SWANA_Keynote2004.pdf/$FILE/SWANA_Keynote2004.pdf>

included the cost of constructing the LFGTE plant; the cost was covered by a Global Environment Facility grant and other supporting funds, which make it difficult to fully identify the costs related to the LFGTE plant and gas collection.

4. Monterrey LFGTE Project (Mexico)

The Monterrey project has just recently been commissioned; it could be characterized as being in the initial start up and optimization phase. The project has been well supported in order to obtain access to the electrical power market and realize a reasonable rate of return on the electricity sold. This case study illustrates that successful LFGTE projects can be developed and operated if there is a well-developed business plan and cooperation exists between the various levels of government, industry and the finance and resources sectors. While the cost of developing the project may be considered high, the overall revenue structure is adequate to support a reasonable rate of return on the investment for the developers. Future values for CERs are expected to further enhance the value of the project.

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

The actual cost of the 7 MW plant and preliminary associated studies was US$ 13,250,000 or approximately US$ 1.9 million per installed MW of generating capacity. GEF contributed approximately US$ 6million of the total capital and development costs.

5. The Torun, Gdansk, Krakow and Olsztyn LFGTE Projects (Poland)

The Torun project was commissioned in 1997 and the Gdansk project the following year. The Krakow project was commissioned with one engine in 1998, with second engine having been added in 1999 and a third engine in 2002. The Olsztyn boiler plant project was commissioned in 1999. These are all 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 Poland.

Problems were encountered in determining the full extent of the information required for applications and approvals. In one case, permission to start construction was given by an authority outside its jurisdiction, sparking a protest from the both the public and other authorities. Another problem that has plagued all four sites is limited fuel recovery of the LFG collection system, which was likely a result of condensate blockage. In many cases, parts of the LFG collection systems were flooded and no longer collecting LFG efficiently, if at all.

The electricity-generating plants at these sites are all less than 1 MW each in size. The actual cost of these plants ranged from slightly less than US$ 1.5 million to more than US$ 2.2 million per installed MW of generating capacity.

6. Kemerburgaz LFGTE Project (Turkey)

The Kemerburgaz LFGTE project, located near Istanbul, was an offshoot of a rehabilitation project that resulted from a catastrophic waste slide. The plant was commissioned in late 2002. Turkey charges a relatively high price for both industrial and domestic energy, at approximately US$ 0.09/kWh, making this a promising project. Although it was not possible to obtain all of the capital and operating costs, it has been estimated that this facility would provide an adequate return on investment in order to encourage developers and the site owner/operator.

The project ran into several problems during its development, as a result of poorly written specifications and differences in cross-cultural interpretation. In addition, the lack of a clear project leader led to considerable role confusion, which initially stalled construction. There were also issues related to conflict of interest, which increased the cost of the overall project, although they were subsequently resolved. The facility is currently in operation.

7. Case study summation

In summary, the case studies consistently reinforce the need to understand the LFG resources and site-specific applications. From a technical perspective, the technology to utilize LFG is generally well developed. The technical issues were very much concerned with 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 the following: access to energy markets; market price for energy products and CERs; project team organization and coordination; and the difficulties encountered in obtaining permits and approvals.

Annex 3. Further references

Although some essential references and URLs are already in the text of this publication, the following are some additional sources:

- **Introduction to CDM and CDM projects**
  <www.unescap.org/esd/publications/CDM.pdf>
  <http://cdm.unfccc.int/index.html>
- **Landfill classification according to UNEP**
  <www.unep.or.jp/ietc/ESTdir/Pub/MSW/SP/SP6/SP6_3.asp>
- **Word Bank case studies**
  <http://wbln0018.worldbank.org/esmap/site.nsf/files/SWANA_Keynote2004.pdf/$FILE/SWANA_Keynote2004.pdf>
- **CDM projects pipeline – CDM news**
  <http://cd4cdm.org/>
  <http://cdm.unfccc.int/Projects/projsearch.html>
  <www.pointcarbon.com/>
- **Technical references**
  <www.epa.gov/landfill/index.htm>
  <http://wbln0018.worldbank.org/esmap/site.nsf/files/318-06% 20FINAL.pdf/$FILE/318-06%20FINAL.pdf>

Readers may also view the project design documents prepared by the developers in the course of CDM certification at the following URL: <http://cdm.unfccc.int/Projects/index.html>.

كيفية الحصول على منشورات الامم المتحدة

يمكن الحصول على منشورات الامم المتحدة من المكتبات ودور التوزيع في جميع انحاء العالم . استعلم عنها من المكتبة التي تتعامل معها أو اكتب الى : الامم المتحدة ، قسم البيع في نيويورك او في جنيف .

如何购取联合国出版物

联合国出版物在全世界各地的书店和经售处均有发售。请向书店询问或写信到纽约或日内瓦的联合国销售组。

HOW TO OBTAIN UNITED NATIONS PUBLICATIONS

United Nations publications may be obtained from bookstores and distributors throughout the world. Consult your bookstore or write to: United Nations, Sales Section, New York or Geneva.

COMMENT SE PROCURER LES PUBLICATIONS DES NATIONS UNIES

Les publications des Nations Unies sont en vente dans les librairies et les agences dépositaires du monde entier. Informez-vous auprès de votre libraire ou adressez-vous à : Nations Unies, Section des ventes, New York ou Genève.

КАК ПОЛУЧИТЬ ИЗДАНИЯ ОРГАНИЗАЦИИ ОБЪЕДИНЕННЫХ НАЦИЙ

Издания Организации Объединенных Наций можно купить в книжных магазинах и агентствах во всех районах мира. Наводите справки об изданиях в вашем книжном магазине или пишите по адресу: Организация Объединенных Наций, Секция по продаже изданий, Нью-Йорк или Женева.

COMO CONSEGUIR PUBLICACIONES DE LAS NACIONES UNIDAS

Las publicaciones de las Naciones Unidas están en venta en librerías y casas distribuidoras en todas partes del mundo. Consulte a su librero o diríjase a: Naciones Unidas, Sección de Ventas, Nueva York o Ginebra.

Printed in Bangkok

August 2007

United Nations publication

Sales No. xxxxxxxx

ISBN: xxxxxxxxxxx