GEF/UNDP
Project No. CPR/96/G31

PROMOTING METHANE RECOVERY AND UTILIZATION FROM MIXED MUNICIPAL REFUSE IN CHINA

TERMINAL EVALUATION REPORT

SUBMITTED TO

THE UNITED NATIONS
Development Programme &
Department of Economic and Social Affairs

And

THE PEOPLE'S REPUBLIC OF CHINA
State Environmental Protection Administration

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December 2005

TABLE OF CONTENTS

Section Page

APPENDICES

ACRONYMS:

ACRE – Anshan Coking and Refractory Engineering Company.
ANSHAN – The City of Anshan, China
CDM – Clean Development Mechanism
CDB – China Development Bank
CER – Certified Emission Reduction
CNG – Compressed Natural Gas
ESCO – Energy Service Companies
GEF – Global Environmental Fund
GHG – Greenhouse Gas
FECO – Foreign Economic Cooperation Office of the State Environmental
IRR – Internal Rate of Return
KJ – Kilo Joule
LFG – Landfill Gas
LMOP – Landfill Methane Outreach Program
MAANSHAN – The City of Maanshan, China
MDEA – Methyl Diethanolamine
MIMR – Maanshan Institute of Mining Research – Department of Safety and Environment Protection.
MSW – Municipal Solid Waste
NANJING – The City of Nanjing, China
Protection Administration, China
NAP – National Action Plan
NDRC – National Development and Reform Commission
NPMO – National Project Management Office
ODA – Overseas Development Agency
PMO – Project Management Office at the local city level
SEPA – State Environmental Protection Administration, China
TPR – Tripartite Review
UN – United Nations
UNDDSMS – UN Systems Department for Development Support and Management Services
UNDESA – United Nations Department of Economic & Social Affairs
UNDP – United Nations Development Programme, Beijing Office
USIJI – U.S. Initiative on Joint Implementation
USA – United States of America
WB – World Bank

1.0 EXECUTIVE SUMMARY

The UNDP/GEF Project – Promoting Methane Recovery and Utilization from Mixed Municipal Refuse (The UNDP/GEF Project) in China had a number of goals. These included:

1. Develop a National Action Plan (NAP) to serve as policy for the promotion of landfill gas (LFG) recovery and utilization in China,
2. Mitigate global climate change through the capture and use of methane, a potent greenhouse gas (GHG), released from landfills,
3. Reduce institutional barriers that hinder the development of landfill gas projects,
4. Construct three demonstration landfill gas recovery and utilization projects in each of three cities, namely Nanjing, Maanshan, and Anshan, and
5. Establish a training facility to increase national awareness of LFG to energy projects to help promote development elsewhere in China.

China has accomplished these goals with significant results. By mandating the control of landfill gas and opening the door to outside LFG system developers, China has taken a significant step complying with their environmental regulations and reducing global warming by developing LFG renewable energy projects.

There are several objectives of this report. The first is to review the achievements of The UNDP/GEF Project's immediate objectives and outputs compared to the original UNDP authorization. A second and just as significant goal of this report is to help potential LFG project developers understand the legal and regulatory framework within China established to enhance LFG project development. This will help reduce GHG emissions, reduce the use of other fuels (i.e. coal), and provide a new energy source within China. To accomplish this latter goal, this report has attempted to describe methods of implementing landfill gas to energy projects and provide a convenient source of material by including relevant information in the appendices.

Through the project implementation the following achievements have been observed:

A) Facilitated the preparation and implementation of supporting policies and regulations. With the experiences and lessons learned through this project, the Chinese government has developed and passed the following laws and regulations to support LFG utilization and project financing:

   - Passed the "National Renewable Energy Law" (Appendix A) that requires utilities to purchase energy from LFG projects at a reasonable price.
   - Passed the Interim Regulations for Directing the Foreign Investment in China and the Guiding Index for Foreign Investment in China that allows foreign investors to own 100% of projects in certain sectors like service, environmental protection, and other national priority areas.

- Passed the Law of China on Prevention and Control of Solid Waste Pollution on March 23, 2005 that requires the control of landfill gas emissions from a landfill.

Preferable policies were developed at the city level for the benefit of these projects. For instance, Nanjing tariff, Maanshan medical waste collection fee, etc. were developed. China developed the National Action Plan for Recovery and Utilization of Landfill Gas (Appendix B).

B) Enhanced the awareness of city planners and managers, LFG project developers, and public in general about the benefits of LFG-to-energy projects.

Since project initiation, more than a dozen workshops on waste management and LFG utilization receiving sponsorship from this project were held at the UN sponsored training centre. Additionally, about 3,000 people have visited the three demonstration projects. In 1998 Mayors from Nanjing, Anshan and Maanshan attended a senior-level International Mayor's Conference to promote LFG utilization. In addition, a well received video programme on this UNDP sponsored LFG project was exhibited in the 2004 International Renewable Energy Conference in Germany.

C) Explored and established new management mechanisms and structure for LFG project development.

During the project implementation, Nanjing awarded a contract to Cleanaway – a private company to invest and develop the LFG project; Maanshan and Anshan set up separate companies to execute the projects, which contributed to improve landfill operations.

D) Strengthened the technical capacity of national and local engineers, managers and other professionals.

Before this demonstration project, few people within China specialized in LFG collection or utilization. Project implementation included study tours in the United States of America (USA) and Europe for Chinese professionals to observe LFG projects design and operation and provide specialized training for LFG development, design, operation, and financing.

E) Greatly improved institutional capacity for LFG recovery and utilization in China.

Through this project, a national training centre on LFG utilization was established in Anshan. This centre has held over a dozen training sessions. Furthermore, an additional training centre on LFG was also established in Nanjing due to the success of Nanjing project and local requirements. Thus the two training centres located in the northern and southern parts of China respectively can greatly facilitate the dissemination of LFG utilization knowledge within China.

F) Obtained valuable experience on the financial aspects of project development and operation.

The financial success of the Nanjing project demonstrated the viability of LFG utilization projects. The business approach used on this project, including contract negotiation and project financing provide a successful model for other municipalities interested in developing projects.

With the success of the Nanjing demonstration project, the strengthened technical capacities and awareness of LFG project potential, private Chinese companies also began to pay attention to this new business arena and some have already invested in this sector. Green Energy, for example, is the private company in Nanjing that developed a LFG to electricity project at the Tianjingwa Landfill in Nanjing. Green Energy was successful in obtaining approval from the National Development and Reform Commission for development as a CDM project. The benefit of this approach is providing an alternate project financing mechanism.

The challenges faced by the Maanshan and Anshan projects provide a valuable lesson that not all projects will have the same degree of success.

A key objective of the UNDP project "Promoting Methane Recovery and Utilization from Mixed Municipal Refuse in China" was the construction of three demonstration projects. The three projects (Nanjing, Maanshan and Anshan) have all served their intended purpose of introducing China to LFG energy recovery projects and training national experts.

Each of the three projects have been successful in their own way. The Nanjing project is the most financially successful. The Maanshan project is successful in demonstrating the viability of burning LFG. Anshan chose the most challenging approach converting LFG to compressed vehicle fuel, which is a high value product in China. Because Anshan used a CO_2 removal process that has never been applied to LFG, a number of technical hurdles still have to be overcome. Anshan municipality indicated that additional money has been approved to complete the project and that it should be ready to start shakedown in the spring of 2006. In the mean time, the municipality needs to start the LFG flare and operate the LFG extraction wells to verify the amount of LFG available.

An indirect benefit of The Project was to help China become aware of the need to pass laws favouring the collection and use of LFG. As a result, several policies promoting environmental projects have been issued and more are expected. The tax reduction and exemption for these LFG project is another example. This will help promote LFG projects in the future.

Key Recommendations in this report include:

- Widely disseminate the results and project lessons learned.
- Make a list of landfills in China including current tonnage, future tonnage, fill rate, year landfill opened, and year landfill is expected to close. Prioritise LFG energy recovery projects based on this list.
- Collect LFG operating data from landfills in China for the purpose of developing a LFG collection model that can be used to better predict LFG collection rates.
- Change landfill operating procedures to convert operations from dumps to sanitary landfills. Several landfills visited had Bomag compactors to compact refuse but didn't have scrapers commonly used to haul dirt for daily cover.
- Recommend a procedure to allow local governments to solicit bids from LFG energy recovery developers. Developers can be Chinese companies or companies outside of China.
- Provide guaranteed rates for power and or gas for the expected life of a project (not less than 10 years). This may require government subsidies.
- Consider constructing regional landfills where all environmental issues caused by a landfill can be better managed and landfill gas will be more plentiful for energy recovery. This can go hand in hand with implementing and enforcing State environmental laws for landfills.
- Draft a standard power purchase agreement for use by developers.
- Anshan should take significant and immediate steps to quantify the amount of LFG available from this landfill.
- Determine the expected level of residual contamination in the product CNG following processing by the Anshan CNG plant to make sure that this fuel will not cause problems with truck engines.
- To facilitate LFG project development, it is suggested that a sample contract with a royalty structure be developed for use by municipalities. The royalty structure will describe methods of payment to the landfill owner based on a percent of the gross sales, profits, or some other basis.
- To help local municipalities develop projects within China, SEPA should take the lead in coordinating project funding using the CDM.
- Provide a stable environment for investors of LFG to energy projects. This includes a stable sales price for energy, stable or well established tax rate, and long-term policy that is favourable to private and/or foreign investors.

2.0 INTRODUCTION

A. Original UNDP Objectives:

The UNDP/GEF Project CPR/96/G31 - Promoting Methane Recovery and Utilization from Mixed Municipal Refuse (The UNDP/GEF Project) in China was authorized in May 1997. The project consists of three components: 1) Construct three demonstration landfill gas (LFG) recovery and utilization projects in three cities, namely, Nanjing, Anshan and Maanshan; 2) Develop a National Action Plan to serve as a policy document for the government to promote LFG recovery and utilization in China; and 3) Establish a training facility to teach the principles of LFG recovery. The project was executed by the United Nations Department of Economic & Social Affairs (UNDESA) (formally UN Systems Department for Development Support and Management Services UNDDSMS). The government-implementing agency is the State Environmental Protection Administration (SEPA, formally called NEPA). The project has a Global Environmental Fund (GEF) input of US$5.285 million, financial contributions by the government of US$14.28 million, and private investment estimated at US$6.0 million.

The main objective of the project was to reduce global climate change through the capture and beneficial use of methane gas released from landfills. Methane gas is one of the main greenhouse gases (GHG) that contributes to global warming. By demonstrating the technical and economic feasibility of capturing and using LFG, there will be an incentive to use this technology elsewhere in China. However, the technical and economic success of these projects alone does not guarantee wide spread application within China without the necessary infrastructure and policy to guide relevant agencies in LFG recovery and utilization. The demonstration projects, training centre, and institutional policy changes all assist LFG energy recovery projects by increasing national awareness to convert LFG into energy, thereby encouraging other similar projects elsewhere.

The UNDP/GEF Project had an original anticipated duration of 4 years, but the actual implementation process has been longer for various reasons. Except for the demonstration project in Anshan City, all the components of the project are complete.

The project had a mid-term evaluation in 2002 organized by UNDESA, UNDP and SEPA to review the LFG energy recovery strategy and the approach of each City. The mid-term evaluation focused on the technical design and feasibilities of the demonstration projects in the three cities leading to a number of recommendations. As a scorecard the key recommendations have been repeated in Appendix C of this report along with the action taken.

B. Objectives of the Terminal Evaluation Report:

The objectives of the terminal evaluation are to review the achievements of the project as defined by the original project goals, to review the current institutional setting, and

review project development options. Recommendations include action items to assist the Chinese Government promote future landfill methane recovery and utilization.

C. Report Organization:

The general organization of this report is to review the original project objectives (Chapter 3), project implementation (Chapter 4), project results and consequential benefits including evaluating the project's results with the original objectives (Chapter 5), recommendations (Chapter 6), and lessons learned (Chapter 7). The projects themselves are impressive and photographs showing the accomplishments of what was constructed are included in the photograph section of this report.

The evaluators wish to thank the many people who provided assistance by supplying information and participating at meetings and interviews. Specifically, the evaluators are appreciate of the efforts by Mr. Shaoyi Li of UNDESA, and Mr. Miao Hongjun of UNDP, Mr. Ryuichiro John Hanawa of UNDP, Mr. Gaolai Luo of SEPA, Ms. Rebecca Gunning, Ms. Bin Song, Mr. W. Ji, Mr. Ping Jiang, Mr. Chen, Mr. Fu, Mr. Bin Dai, and Mr. Yang. The evaluators especially appreciate the support provided by Dr. Guangming Zhang who was the principal that assisted during the project interviews and Mr. Gao Hairan for his assistance in compiling reviewer comments.

The preparation of this terminal report was prepared based on a review of documents that were available during the evaluation, UNDP guided document for evaluations, and specific guidance received from the UNDP and SEPA. The evaluators visited all three cities, inspected the demonstration landfill sites and held meetings and interviews with local project officials, technical staff, consultants, and a private developer. Documents reviewed included:

- Initial Project Document, June 1997
- Project Mid Term Report, November 2002
- Case Study for Anshan, March 2005
- Recommendations to the National Action Plan, April 2005
- Annual Project Report (APR), July 2005
- Case Study for Nanjing, August 2005
- Case Study for Maanshan, August 2005
- National Action Plan, August 2005
- Assessment Contents of Gaff's Project for Promoting the Collection and Utilization of China's Municipal Refuse Landfill Gas, October 2005
- Draft reports prepared by IT Power for possible LFG utilization at landfill sites, October 2005
- Specific guidance received from UNDESA, UNDP and SEPA.
- Maanshan financial evaluation
- China training course – Operation of Landfill to Maximize Methane Production, Anshan, May 2001.

3.0 PROJECT CONCEPT AND DESIGN

A. Context of the Project

China's economy is rapidly growing resulting in increased environmental problems associated with urbanization. In the past, uncontrolled refuse dumps have created breeding grounds for rats and other disease spreading vectors, contaminated soils, ground water contamination, and undesirable and possibly toxic air emissions. The Government of China has been aware of the problems associated with uncontrolled solid waste disposal practices and in an effort to combat these problems has passed laws to protect the environment from landfill contamination. Part of the national plan requires municipal refuse to be disposed at sanitary landfills. However, emission of landfill methane, a potent greenhouse gas, remains at a level estimated to be between 3 and 9 million tons per year, contributing to global warming (Calculation 1).

The government of China is committed to combating global warming. To address the absence of LFG collection and control projects, the Chinese Government and United Nations Development Program (UNDP) jointly made an application to GEF for demonstration projects to recover and utilize LFG from municipal mixed refuse in 1993. Three landfills were selected for the demonstration projects. They were Shuige Landfill Site in Nanjing for electric power generation; Xiangshan Landfill Site in Maanshan for medical waste incineration; and Yangeryu Landfill Site in Anshan for vehicle fuel production.

In April 1997, GEF approved the project (CPR/96/G31) with a total grant of US$5.285 million.

The project consists of three major components:

- Demonstrate the technical and economic feasibility of methane recovery and utilization by the construction of demonstration projects at three pilot landfills. These three landfills were strategically selected based on the diversity of LFG energy recovery approach, local economic bases, population, climate and geology.
- Develop a National Action Plan to establish a strategic policy and implementation framework for promoting the widespread adoption of landfill gas recovery and utilization projects in China; and
- Establish a training and information resource centre to provide training and technology development support in China.

Table 1 provided the basic project information

Basic Project Information	
Project Focal Area	Climate Change
International Funding Organization	Global Environmental Facility (GEF)
Total Grant from GEF	US$5,285,000
Chinese Government Input	US$14,280,000
Project Execution Agency	UNDSA
Project Management Office in China	FECO/SEPA
Date Of Entry in WP	4 April 1996
Project Document Signature Date	23 May 1997
Duration (months)	48 months (4 Years)
Completion Date	Original: 31 December 2001
	Revised 1: 31 December 2004
	Revised 2: 31 December 2005

At the end of the project the following outcomes were expected:

- Construct three demonstration plants to capture methane from landfills and use it to generate electricity, direct use as a medium BTU fuel in gas fired burners, and purified methane for vehicle fuel at Nanjing, Maanshan and Anshan respectively.
- Build a training facility to (1) educate, train and assist landfill operators, energy service companies, municipalities and other businesses to build and operate landfill gas energy plants, (2) conduct research to develop more efficient methods for the above purposes, and (3) disseminate information on landfill gas recovery and the use of this technology.
- Establish institutional arrangements to produce and sell gas and/or electricity at each site.
- In at least one location independent companies will have been invited to build, own and operate the LFG collection and energy generating system. As part of the pilot projects, new organizational structures were to be tested, including accessing non-government financing.
- The project would demonstrate approaches to obtain a price of electricity to generate sufficient revenue from electricity sales to make LFG based electrical generation project financially viable.
- Reduce the costs of future energy recovery plants by allowing competitive bidding to establish the value of the energy produced and sold from a project.
- Prepare an action plan to promote widespread replication and adoption of landfill gas recovery technology in China. The action plan would address the issue of capital mobilization, formation of independent companies and their institutional relationship with government. Moreover the action plan would illustrate ways to reduce the cost of landfill energy production.

The actual results of these expected outcomes are discussed in Chapter 5.

B. Project Document

1. The Problem

When the project was initiated in 1997, several barriers to the widespread implementation of LFG recovery and utilization were identified:

Technical Barriers

- China lacked LFG recovery technology and faced high costs for imported technology. The resulting high costs prevented widespread adoption of LFG recovery across China. By implementing demonstration projects within China, citizens of China would gain experience allowing them to carry this effort forward in the future.
- In China, skilled personnel were not readily available for the design, construction and operation of LFG plants. Project development would help Chinese experts interface with international experts allowing them to learn from them.

Institutional Barriers

- China lacked the institutional structure to manage the landfill resources due to a lack of definition of institutional responsibility and resource ownership.
- Local and municipal governments increasingly bear the economic and administrative responsibility to provide urban infrastructure and services including the provision of water and sanitation services. While these governments have attended to develop urban infrastructure and communication, "non-productive" local investments such as water and sewage treatment and waste disposal and management have received lower priorities and fewer resources.

Financial Barriers

- In China, the government predominantly provided capital for the development of landfills. Independent companies require access to domestic or foreign capital markets, which were weak or non-existent.
- The price offered by local power bureaus for electricity was inadequate to cover the cost to construct landfill gas fuelled power plants.

Action Plan Formulation

- The Chinese government did not have an action plan to promote the use of methane recovery at landfills, which has prevented the formulation of a strategy to address the above-mentioned issues in an integrated manner.

2. The Objectives and Technical Approach

The project's long-term objectives are to promote widespread adoption of LFG recovery technology in China based on the technical and organizational experience gained from the three pilot landfill projects, the training centre, and the National Action Plan. Specifically, these long-term objectives include:

1) Reduce the potential adverse social, environmental and economic consequences of global climate change;
2) Improve the health of China's urban dwellers by reducing air, water and land pollution associated with refuse dumping;
3) Promote the development of indigenous enterprises engaged in recovery, cleaning and use of LFG.

With the identification of the barriers that existed in China, the project intended to illustrate the feasibility of technologies to capture LFG and use it directly as fuel. The project would also aim to set up institutional mechanisms for the sale of the energy. In doing so, the project would demonstrate ways to overcome barriers to the use of LFG technology and to the fully competitive sale of methane. In addition, the demonstration and training activities were expected to strengthen the capacity of the implementing agency (SEPA), which would enable it to disseminate the results and undertake similar projects elsewhere in China.

Program Document technical approach provided three immediate objectives:

1. Conduct field trials at three landfills on 2 ha plots to assess the yield and composition of LFG (Immediate Objective 1).
2. Use the data collected in task 1 and waste composition at each site to calibrate a theoretical model of methane gas yield (Immediate Objective 1).
3. Establish institutional arrangements for the construction and operation of the demonstration plants, and the sale of energy at each site (Immediate Object 2).
4. Build and operate a demonstration plant at each site using LFG from an 8 ha area (Immediate Objective 2).
5. Disseminate information, maintain a library and data bases, train all parties engaged in LFG technology, and conduct research on improving the technology and institutional arrangement through a centre located at one of the sites (Immediate Objective 3).
6. Develop an action plan to illustrate ways to reduce costs and/or obtain a price for energy at least equal to the cost of avoided marginal energy supply (Immediate Objective 3). The action plan would focus on (1) technology, (2) the role of independent companies, and (3) the crucial issue of ways to mobilize capital for the widespread adoption of technology.

3. Indicators and Major Assumptions

To evaluate the project results, several key indicators are used.

Climate Change Indicators

- Successful project implementation leading to reductions in methane gas emissions to the atmosphere.
- Clean emissions from the landfill energy recovery project
- Reduced groundwater contamination potential

Project Development Indicators

- Improvements in energy production or installed capacities
- Reduction in technology implementation costs
- Expansion of business and supporting services for renewable energy
- Increase of financing availability and mechanisms
- Development of policies, laws and regulations that support project goals.
- Awareness and understanding of technologies among producers and users

Project Performance Indicator

Outcome 1: Definition of design criteria for the gas collection systems at the Anshan, Maanshan and Nanjing landfills through analysis of the municipal solid waste stream, technical reference centre.

- Characterization of the waste and credible projections of LFG generation for each demonstration project cities by June 2001
- Field trials demonstrate that gas production corresponds to anticipate quantities based on composition and age of the waste by June 2001.
- The quantity of waste input per day is consistent with estimated projection by field trials.
- Field trails demonstrate that LFG production corresponds to anticipated quantities based on the composition and age of the waste
- For new landfills, gas production rates in excess of 5 cubic meters of gas per ton of waste will be considered successful

Outcome 2: Successful demonstration of LFG energy recovery technologies and institutional arrangements for the sale of energy through pilot projects in Anshan, Maanshan, and Nanjing

- Institutional arrangements for the implementation of the demonstration projects;
- Delineating ways to obtain financing for a LFG project by June 2003.
- Production of a technically sound and contractible engineering design for construction and operation of the project on schedule and within budget by June 2003.

- Project costs and revenues by end of project are as projected during the design phase.
- Development of institutional arrangements that can be agreed upon by all parties necessary to implement the demonstration projects.
- Successful sale of power from small LFG based generating plants into power grids and delineating ways to obtain financing for an LFG project.
- Production of a technically sound and constructible engineering design for the construction and operation of the project on schedule and within budget.
- The project operates at the projected thermal efficiency and energy output, with less than 10 percent downtime.
- Costs and revenues are as projected during the design phase.

Outcome 3: A mechanism for rapid dissemination of LFG energy recovery technology set up through preparation of an action plan and establishment of a technical reference centre.

- The National Action Plan (NAP) is useful in establishing LFG energy recovery projects elsewhere in China.
- The capacity building of pilot city have improved and enhanced
- Dissemination of pilot project**.**
- Verification by municipal landfill managers, energy service companies, and financing agencies, that the action plan will be useful in establishing LFG energy recovery projects elsewhere in China
- Development of four courses in fundamental aspects of LFG recovery.
- At least one hundred persons per year trained in fundamentals of LFG recovery
- Maintenance of a technical library and database, with at least 200 library and database accesses by prospective project developers per year

Major assumptions

The primary major assumption was that LFG modeling for landfills in China would be similar to modeling for other parts of the world.

4. Beneficiaries (identification, involvement in the formulation and implementation of the project)

The direct beneficiaries of the project are the municipal governments in Anshan, Maanshan, and Nanjing where the demonstrations were set up. Anshan and Nanjing also benefit from the development of the training centres for methane recovery research and dissemination. All three cities also gain experience in establishing institutional arrangements for the operation of independent companies for the recovery of LFG and energy production, for instance, a number of government officials involved in this project gained knowledge and experience in landfill site management, LFG utilization, and environmental protection during economic development.

Citizens of each of the three cities benefit as the environmental degradation associated with the operation of the landfills have been (or will be) reduced. The technologies

promoted by this project can effectively burn significant amounts of photo reactive organic compounds that contribute to photochemical smog and traces of toxic and carcinogenic organic compounds that contribute to air pollution health risks. Based on AP 42 data available for municipal waste landfills in the United States, the estimated non-methane organic compounds emitted per year in China are 11,000 and 29,000 Mg/yr (Calculation 2).

Chinese environmental professionals also benefit from the project through extensive exposure to LFG recovery and energy production technology and management. Under the project they were able to interact with international experts to formulate the projects. The interactions and exchange between the Chinese environmental professionals and their international counterparts enhanced understanding on both sides.

The indirect beneficiaries would be the municipal governments in other regions and the potential energy service companies who would be able to incorporate the findings disseminated from this project into their own LFG recovery and use efforts.

The ultimate beneficiaries are the citizens of the world who would benefit from the reduced Green House Gas emissions and adverse impacts on natural ecosystems and humankind.

5. Modalities of Execution (selection of the executing agency, the implementing agency and the recipient institution, work plan)

The Executing Agency
The executing agency for this project is UNDESA

The Implementing Agency
The government-implementing agency is State Environmental Protection Administration (SEPA).

Recipient Institution
The recipient institution is Chinese Government, including Anshan, Maanshan, and Nanjing municipalities.

Work Plan
The initial Work Plan was developed and approved during the Inception Mission in May 1997. Additional work plans were developed during the project execution.

4.0 PROJECT IMPLEMENTATION

A. Activities

The project implementation was carried out through the following three phases:

Phase I: Landfill gas recovery filed trials
Phase II: Landfill design reviews and establishment of effective management and operation
Phase III: Landfill gas recovery and utilization full-scale demonstration construction, start up, and operation

The detailed activities that were conducted during the project execution included:

- Conducted training courses for the local staff on landfill design and operation practices, LFG recovery and utilization technologies which are necessary for the project implementation, as well as project management skills.
- Organized the field trials to understand LFG characteristics to gain design data for the three demonstration landfill sites.
- Organized study tours comprised of relevant stakeholders, such as project owner, project investor, governmental officials, consulting company, international technological expert, UNDP and SEPA officers to USA and Europe to obtain first hand information and real operating information.
- Organized national and international workshops to exchange information and project experience, discuss the problems encountered during the project and possible solutions.
- Set up a new management and operation mechanism at each of the demonstration cities.
- Conducted full-scale design, procurement, construction, start-up and operation at the three selected landfill sites for the demonstration of LFG to power, LFG as direct fuel, and LFG for vehicle fuel utilizations.
- Developed a National Action Plan
- Developed Anshan LFG Training Centre and Nanjing LFG Training Centre. Provided trainings and information resources to the professionals and public.
- Conducted International Mayors Conference on MSW/LFG, and a mission in China to promote methane recovery and utilization from mixed municipal solid wastes.

B. Quality Monitoring

The project was monitored by the Project Management Office under the Foreign Economic Cooperation Office (FECO) on a daily basis and by frequent visits by Mr. Hardy Wong, the non-resident Chief Technical Advisor and Mr. Gao Hairan, the National Project Coordinator. It was reviewed by the tripartite review (TPR) arrangement, including a representative of the Government, UNDP, and the Executing

Agency, UNDESA, once every 12 months from the start of full implementation. Not all parties have been involved in this project since its inception.

The project mid-term evaluation was conducted in year 2001 and submitted in 2002 after the field trials and institutional arrangements for the demonstration projects had been identified, but before detailed engineering design of the demonstration projects was complete. The evaluation, organized by UNDP, UNDESA and SEPA, looked into the direction and anticipated effectiveness of the projects and made recommendations to the Steering Committee and UNDP/DESA to help make the projects successful. The recommendations of the mid-term evaluation were conveyed to the participating cities and institutions for implementation.

5.0 PROJECT RESULTS

The outline of the project results are taken from the Terms of Reference for the Terminal Evaluation Report provided by the UNDP. The specific tasks included in the Terms of Reference are provided below.

Institutional Results

1) Review of the institutional framework and funding mechanisms for promotion of the LFG recovery and utilization in China as the results of the UNDP/GEF project and other similar projects managed by SEPA:

   A. Policy and regulation setting at the national and local levels for promotion of the LFG recovery and utilization in China.
   B. Institutional arrangement dimension in terms of lead agencies in planning, financing, development, technical expertise, training capacity, etc. in the area.
   C. Existing funding mechanisms in China and elsewhere that have great potential for popularising LFG recovery and utilization.
   D. Opening and involvement by the private sector in both investment and technology transfer.

Applied Technical Results

2) Assessment of outcome of the technologies designed and applied in the three demonstration projects:

   A. The operational managements in supporting the demonstration projects in the three cities.
   B. Technical feasibility of the engineering designs and technology selections applied by each city in recovery and utilization of the methane.
   C. Economic viability and return of the demonstration projects to find out if the price of the LFG (Nanjing and Anshan) and the fee collection (Maanshan) can make the projects sustainable and support possible replication elsewhere.

Project Evaluation

3) Evaluation of the achievements and performance of the project:

   A. Relevance of the project to address to global concerns of the climate change issues and the relevant awareness of the landfill methane.
   B. Assessment of the contribution of the three demonstration projects in the three cities to the GHG reduction in comparison to the original design.
   C. Status of the achievements of the immediate objectives and outputs with the input from the government and GEF.
   D. Capacity building of the project staff in the three cities in design, building and managing the LFG demonstration projects and in provision of services to assist similar projects in other cities.

E. Any major issues and barriers encountered during the project implementation and any useful lessons learned in achievements of the project results.

DISCUSSION OF RESULTS

The discussion of results follows the terms of reference outline.

Institutional Results

1) Review of the institutional framework and funding mechanisms for promotion of the LFG recovery and utilization in China as the results of the UNDP/GEF project and other similar projects managed by SEPA:

China has been progressive in the past 5 years setting policy and law to help promote renewable energy projects in general including LFG projects. China recognizes that LFG projects can be financially and environmentally beneficial. The extremely successful Nanjing project will hopefully lead the way for additional LFG recovery projects. Even though the financial results of the Maanshan and Anshan demonstration project were not as expected, there may have been more learned from these two projects than from the Nanjing project. Projects that struggle provide unique learning opportunities. One of the most valuable lessons from the Anshan project is the need to more accurately quantify LFG availability.

A. Policy and regulation setting at the national and local levels for promotion of the LFG recovery and utilization in China.

In 2002 China published the "National Action Plan for Recovery and Utilization of Landfill Gas". This document was updated in 2005 (Appendix B). The action plan is a forward looking document acknowledging the role landfills play in green house gas emissions and the benefit that can be derived by utilizing the LFG energy. The plan sets the tone for methane development procedures including the need to set a reasonable price for power produced by LFG, and even suggests using the free market to bid projects in China.

A second significant document that will help overcome institutional barriers within China is the "Renewable Energy Law" (Appendix A effective 1 January 2006). The most significant part of this law is that it makes it mandatory for utilities to purchase energy from LFG. This law is the single most significant act to help clear institutional barriers. The implementation of several energy recovery projects should help determine how effective this law will be and how it can be implemented.

The Interim Regulations for Directing the Foreign Investment in China and the Guiding Index for Foreign Investment in China allows foreign companies to own projects in China in the area of service sector, environmental protection and other national priority areas like networks. This makes it possible for International Developers to compete for and build energy recovery projects while reducing their financial risk.

B. Institutional arrangement dimension in terms of lead agencies in planning, financing, development, technical expertise, training capacity, etc. in the area.

There are three primary LFG to energy development options available in China. The first is to use an international developer to own and build the project. In the early years of LFG projects within China, this may be the preferred option. The second is for private enterprise within China to develop the projects and the third is for local municipalities to design, build and own the LFG projects. This third approach will work, however China still lacks significant experience in developing projects. Case in point is the successfulness of the Nanjing project. Cleanaway, an international developer of LFG projects developed Nanjing. To make it more desirable for municipalities to allow developers to design, build and own projects, it is suggested that a royalty be paid to the landfill based on a percent of the energy sales.

C. Existing funding mechanisms in China and elsewhere that have great potential for popularising landfill gas recovery and utilization.

There are a number of potential funding mechanisms for LFG recovery projects. The primary ones include:

- Private investment.
- GEF, WB and other international financial agencies;
- Governmental financial budget, which has been for municipal refuse management;
- Bilateral assistance or Overseas Development Agency (ODA) financial support;
- Government loan from China Development Bank (CDB), which is a state-owned bank providing loans for national priority projects;
- Commercial banks;
- Increasing the disposal fee for refuse, and
- Registering the project as a CDM project and selling Certified Emissions Reduction (CER) Credits to developed countries. Registering projects as CDM projects will also have risks and costs associated with it. The cost of implementation of CDM projects may over-shadow the benefits derived. To verify the cost benefit of this approach it is recommended that a feasibility study be prepared to evaluate the potential costs, benefits, and risks of using a CDM mechanism. If this approach is used, a partial list of funding sources could come from:
    - UK Climate Change Challenge Fund
    - Swiss AIJ Pilot Program
    - Australian International Greenhouse Partnerships Office
    - Netherlands CDM Program SENTER
    - Swedish National Energy Administration
    - U.S. Initiative on Joint Implementation (USIJI)
    - Canadian Office of Joint Implementation and CDM

- Oregon Climate Trust

Determining the most appropriate funding mechanism will be dependant on the project type, the project developer and access to each of the various types of funding. To help municipalities and developers within China, SEPA has established a group that specializes in CDM projects.

D. Opening and involvement by the private sector in both investment and technology transfer.

Private sector investment is perhaps the best way of rapidly expanding the development of LFG to energy projects. Companies throughout the world have the financial capability and the technology to implement these projects, provided institutional barriers and risks can be overcome. Private investors will want to evaluate their risk, especially as it relates potential changes in the price for energy, tax benefits, or the adoption of new laws or regulations that are not favourable to a project or foreign investment. Provided a stable platform can be established, there should be many opportunities to promote LFG recovery with private investors.

To assist private investors evaluate LFG to energy projects, the Government and SEPA should prepare a report describing the stability that can be guaranteed to a project. This should include project ownership guarantees, energy price guarantees (usually as a floor), Tax treatment of profits, long-term government policy concerning foreign investment, and assistance by SEPA and other State organisations to help smooth the way with local governments.

Applied Technical Results

2) Assessment of outcome of the technologies designed and applied in the three demonstration projects:

A. The operational managements in supporting the demonstration projects in the three cities.

The support provided by the management of all three Cities for the demonstration projects was significant. The local authorities and engineers all have a vested interest in making these projects successful. The biggest issue didn't appear to be for lack of "ownership" but lack of an energy user (Maanshan) or capital (Anshan). All parties worked hard to make these projects successful. The management in all three Cities are committed to making these projects work.

B. Technical feasibility of the engineering designs and technology selections applied by each city in recovery and utilization of the methane.

The projects used three substantially different approaches for energy recovery from landfills. The quickest and most efficient use of the LFG was the power plant at the Nanjing landfill.

While Nanjing did not provide information on the engine generator on stream time other than to say it was efficient, it is not uncommon for power plants to experience on stream performance in excess of 95%. Nanjing is the most successful LFG utilization demonstration project because it is able to burn the LFG on a continuous basis and in quantities greater than anticipated.

Power Generation by LFG is a mature industry with hundreds of facilities operating throughout the world. Engines used in this application typically have low exhaust emissions to help protect the environment. Lean burn engines are used at the Nanjing project. Engine manufacturers can package an engine with the generator and all necessary controls and switchgear making this a relatively simple installation.

The Maanshan project selected direct burning of LFG as their use mode. The project demonstrated the ease by which LFG burns in a packaged burner. This system experiences high reliability, however, the plant only operates a few hours per day because of a low medical waste volume. When the incinerator is down, the LFG can be burned in the flare. It is reported that the Maanshan landfill personnel have not yet adjusted the LFG wells because there is surplus LFG available; hence there is no need to optimise the well field operation. Maanshan is still investigating alternate LFG use options including the installation of a small generator, and supply hot water to some recreational centres.

The Maanshan Institute of Mining Research proved to be a capable designer of the sophisticated hazardous waste incinerator plant. They can readily help others design and construct LFG energy recovery facilities. It is reported that they won bids on designing and constructing similar LFG utilization systems in nearby cities.

The Anshan high BTU project has not been able to collect LFG efficiently because of the high leachate level in the landfill. This is a problem with the landfill design. It appears that most of the rain that falls on the landfill percolates into the refuse. Changing the landfill slopes in addition to adding soil cover will help this situation. Furthermore, once the methyl diethanolamine (MDEA) plant construction is finished, it is uncertain if sufficient LFG will be available per plant operation. The technology utilized can work to remove CO_2 from the LFG, but there are other compounds in LFG that can cause engine problems. For instance, siloxane in gas can cause an undesirable build-up in engines. Chlorinated hydrocarbons commonly in LFG can cause hydrochloric acid formation during combustion and can affect the pH of the engine oil. It can also promote corrosion in the exhaust system. The process has not accounted for the removal of these compounds. The LFG dryer on the outlet of the high-pressure compressors is currently operated manually. For the Compressed Natural Gas (CNG) system to operate unattended it will be necessary to automate this dryer. One recommendation is to replace this dryer with a temperature swing dryer that is capable of removing both chlorinated hydrocarbons and siloxane. These compounds can be removed on activated carbon and/ or silica gel commonly used in an air dryer. Additionally, rather than recycle the blow down from the dryer to the compressor suction, the exhaust should be directed to a small flare. This will help reduce odour emissions from this release point.

The amine plant is a technically sound process to remove CO_2 from the LFG. To regenerate the amine and remove the absorbed CO_2, it is necessary to steam strip the Amine. Energy for the stripper reboiler is derived from a coal fired steam boiler that existed at the landfill and was not constructed as part of the amine plant construction. Often times, the energy required for the regeneration process is derived from the gas source that is being processed. The approach used in this process is novel in that the steam is generated by a low value energy source. Amine will also remove H_2S from the LFG. The presence of ammonia in the process gas stream may cause problems with reduced H_2S removal causing the product gas to exceed normal sweet gas limits. Process conditions in the stripper can be changed to help negate the effect of ammonia in the LFG.

The Anshan Coking and Refractory Engineering Company (ACRE) has proven to have significant technical and engineering skills. The MDEA plant is impressive in its execution, creativity of its design, and function. ACRE will be a valuable asset for other systems design and construction within China.

C. Economic viability and return of the demonstration projects to find out if the price of the LFG (Nanjing and Anshan) and the fee collection (Maanshan) can make the projects sustainable and support possible replication elsewhere.

Estimated Nanjing Economics
The estimated Internal Rate of Return (IRR) for the Nanjing project is calculated on Calculation 3 and 4. The IRR for the fully developed 5,000 KW plant for 10, 15, and 20 years of operation are estimated to be 20%, 26%, and 27% respectively. Assumptions are provided on the work sheets. Given the current value of the electricity and favourable tax status, this project has excellent long-term viability. The 10 yr. IRR for the initial engine/generator installation was 12% (Calculation 3).

Maanshan Economics
The revenue for the medical waste incinerator plant is based on a charge of 1 RMB per day per occupied bed in Maanshan. Based on nominally 1,100 beds at 30% occupancy the annual income is US$14,700 (Calculation 5). Because of the low revenue and the difficulty of separating the LFG system cost from the incinerator cost, a financial model was not run.

Anshan Economics
Because the Anshan project has yet to operate, accurately predicting economics is difficult. Calculation 6 was prepared based on performance data obtained during the site visits and a sales gas price of 2.7 RMB per cubic meter of gas with 96 percent methane. The IRR for 10, 15, and 20 years of operation are estimated to be 3%, 8%, and 10% respectively. Assumptions are provided on the work sheet.

The effect of inflation was not considered on any of the worksheets.

Project Evaluation

3) Evaluation of the achievements and performance of the project:

A. Relevance of the project to address global concerns of the climate change issues and the relevant awareness of the landfill methane.

There are two parts to the issues addressed in this section. The first is recognition that methane emissions are a potential problem. The difficulty within China is that many of the municipalities are financially strapped so it is difficult to construct LFG collection systems and flares to accommodate GHG reduction goals. The relevance of these demonstration projects is that they provide a mechanism whereby the LFG collection project can be financially viable and GHG reduction is a natural consequence of the development. All three cities were aware of the need to collect LFG to reduce GHG.

B. Assessment of the contribution of the three demonstration projects in the three cities to the GHG reduction in comparison to the original design.

The three projects had the following GHG reduction performance goals.

TABLE 1

Landfill	Target Methane Collection	Actual 2005 Methane Collection
Anshan	10,000 nM3/Day	0 nM3/Day
Maanshan (reported)	Not Available	1200 nM3/Day
Nanjing (2005 estimated)	Not Available	15,500 nM3/Day

C. Status of the achievements of the immediate objectives and outputs with the input from the government and GEF.

1. Immediate Objective 1 was to develop a theoretical model of methane gas yield. The problem with the results of this task is that Chinese landfills do not seem to generate as much gas as other landfills in the world. Further, there did not seem to be any relationship between methane collection rate and landfill tonnage from these three sites.
2. Immediate Objective 2 was to collect LFG from 8 ha parcels. Each city chose to maximize LFG system by designing and constructing comprehensive LFG collection systems.
3. Immediate Objective 3 was to develop a training centre to help disseminate information and to develop an action plan for LFG projects. There were two training centres developed, one at Nanjing and one at Anshan. Furthermore, curriculum was developed providing a broad overview of sanitary landfill design including LFG collection system design. It is reported that in excess of 3,000 people have been introduced to modern landfill design and gas collection through these training centres.

In 2002 a National Action Plan promoting the use of landfill methane was published providing methodology and recommendations. This plan was updated and re-released in August 2005. It lays out the fundamentals of LFG recovery and discusses funding mechanisms.

All of the immediate objectives have and will contribute to successful project implementation that will lead to reductions in methane gas emissions to the atmosphere and reduced groundwater contamination potential.

Project Development Indicators

- The development of the National Renewal Energy Law and the National Action Plan will help guide municipalities with LFG energy recovery projects. Each of these is attached as appendices to this report.
- Nanjing is the best project as it relates to project development indicators. First, Cleanaway has been able to progressively collection more gas by the installation of additional engines.
- Cleanaway purchased pre-packaged engine generators to reduce initial investment costs and expedite construction.
- Cleanaway is expanding their energy development business within China by signing contracts for other landfill gas energy recovery projects.

Project Performance indicator

Outcome 1: Definition of design criteria for the gas collection systems at the Anshan, Maanshan and Nanjing landfills through analysis of the municipal solid waste stream, technical reference centre.

- *Characterization of the waste and credible alternative projections of LFG generation for each demonstration project cities by June 2001*

While the waste was characterized and testing performed to quantify LFG collection potential, it appears that the modeling coefficients are poorly. A variable that makes it difficult to predict LFG generation is caused by the differences in landfill operation. Most landfills are operated as dumps with no daily cover and extensive water infiltration while others are operated as sanitary landfills. This difference alone can have a significant impact on gas generation and the resulting modelling coefficients. These differences are not well understood at this time.

LFG model results were not provided by any of the projects so the evaluation team was unable to determine the credibility of the LFG model results.

- *Field trials demonstrate that gas production corresponds to anticipate quantities based on composition and age of the waste by June 2001.*

Field trials appear to have underestimated gas availability from the Nanjing landfill and over predicted gas availability at the Anshan landfill. No information was available on gas collection potential from the Maanshan landfill.

- *The quantity of waste input per day is consistent with estimated projection by field trials.*

It is reported that waste input to the landfills is increasing at the rate of about 8% per year in Nanjing and Maanshan. However, obtaining historic waste fill rates from the landfills was not possible because records do not appear to exist.

- *Field trials demonstrate that landfill gas production corresponds to anticipated quantities based on the composition and age of the waste*

The actual LFG collection rates did not correspond well with the results of the field trials.

- *For new landfills, gas production rates in excess of 5 cubic meters of gas per ton of waste will be considered successful*

It is difficult to quantify the methane yield based on the criteria provided in this objective because generation is typically considered to follow an exponential decay curve. This criteria did not provide the years for LFG collection hence it is not impossible to estimate the ultimate methane yield per ton of waste.

<u>Outcome 2:</u> Successful demonstration of LFG energy recovery technologies and institutional arrangements for the sale of energy through pilot projects in Anshan, Maanshan, and Nanjing

Briefly, the status of the three projects is as follows:

- The Nanjing power generation project is thriving and far exceeded its initial design by installing two additional 1250 kW generators. Photographs of this and other projects are included in the photographs section of this report.
- The Maanshan project, while successfully implemented struggles because the medical waste incinerator does not require very much LFG to operate, as a result it only burns LFG a few hours per day.
- The Anshan vehicle fuel project ran out of funding. With new funding provided by the municipality, it is expected to be completed in Spring 2006.
- Institutional arrangements for the implementation of the demonstration projects; the local municipalities each worked hard to clear institutional barriers for the demonstration projects and issued favourable policies to facilitate the LFG projects.

All projects had what appeared to be technically sound engineering plans prepared for them. The biggest difference was LFG availability or lack thereof, inadequate LFG use, or inadequate capital available.

1) Budget control: The Anshan project ran out of money before the project could be competed. They reported that another 3,000,000 RMB, which is allocated by the municipality, is required to complete the project.
2) Maanshan Revenue: The Maanshan project was technically sound in its construction, however it only burns LFG 2-3 hours per day. There is a need for other LFG use options. Possibly once the Renewable Energy Law takes effect, this will allow the City to move forward with the installation of an engine generator.

- *Project costs and revenues by end of project are as projected during the design phase.*

1) Maanshan Revenue: The Maanshan project burns LFG 2-3 hours per day. Unfortunately, the current revenue for this project is not tied to the amount of LFG burned but to the per bed fee collected from the hospitals. Revenue by this method is only US$14,700/Year. If the fee were based on the value of the methane gas burned in the incinerator, the fee would be about US$89,000/Year. This fee is based on a methane gas value of 2.7 RMB/ Cu M (Calculation 5).

2) Anshan Revenue: Because this project has yet to start, there is no revenue. Calculation 6 does have estimated revenue based on plant operation at maximum capacity.

3) Nanjing Revenue: The current revenue for the Nanjing project is estimated at US$1,337,000/yr.

- *Development of institutional arrangements that can be agreed upon by all parties necessary to implement the demonstration projects.*

National Policies

In 1994, the Ministry of Finance and State Administration of Taxation issued the Notice on Several Preferential Policies about Enterprises' Income Tax. The notice show the preferential policy on the income tax of integrated resources utilization project and new energy project etc. According to this policy, GEF Nanjing project received a 2-year exemption of income tax, a 50% income tax reduction in years 3-5, and a 30 percent reduction in years 6-10.

In 1999, the National Development and Reform Commission (NDRC), the Ministry of Science and Technology jointly issued the Notice of Further Support for Renewable Energy Development. The notice states that the electric generation project by garbage incineration could get a two percent financial interest subsidy on a Bank loans. Also, the

notice provided preferential policies on electrical generation by garbage incineration, allowing connection to the power grid and the purchase of electrical power. For LFG power projects, selling power to the grid is very important. The electric price was and continues to be a key issue for the Nanjing project. At this time, the price for the Nanjing Project is 0.527 RMB per kWh, which is significantly higher than the price of RMB 0.2 per kWh paid for power generated by conventional technologies. In other cities in Guangdong Province, the price even goes higher than 0.60 RMB per kWh. The local economic condition is the determinant for the price. In some very poor cities in the western part of China, the local government/grid company even cannot afford RMB 0.3 per kWh for green electricity generated from LFG.

In 2000, the Ministry of Construction, SEPA and the Ministry of Science and Technology jointly issued the "National Technical Policy for City Garbage Disposal & Pollution Prevention".

In 2001, the Ministry of Finance and State Administration jointly issue the "Notice on Integrated Utilization of Some Resources and Other Products' Value -added Tax". This notice states that value added tax could be exempted if generating electricity by city garbage since January 1, 2001. The LFG electric generation project enjoyed the benefits of this preferential policy and promoted the participation of private sectors.

In 2002, the NDRC, the Ministry of Construction and SEPA jointly issued "Suggestions on Promoting Industrial Development of City sewage and Garbage Disposal".

In 2002, the NDRC, the Ministry of Finance, the Ministry of Construction and SEPA jointly issued the "Charge Regulation of City Garbage Disposal to Accelerate the Industrial Development". The goals of this notice are to take advantage of market's resources situation, expand co-financing channels, improve investment environment and encourage national and international funding, including private sectors. Furthermore, the regulations were intended to set up reasonable garbage disposal mechanisms and solve environmental pollution issues caused by lack of proper garbage disposal facilities. This policy encouraged Nanjing to engage foreign enterprises for the GEF Nanjing Project.

The NDRC and State Economic and Trade Commission issued the "Guidance Catalogue of Nationally Encouraged Products in the Field of Prior Technical Development".

All these regulations and policies greatly promoted the implementation of GEF Nanjing, Maanshan, and Anshan projects, especially the subsidy policy on renewable energy sources and clean energy sources,

It is expected that similar projects in China would also benefit from these preferential national policies and incentives in addition to the National Renewable Energy Law that becomes effective January 1, 2006.

<u>Local Policies, Nanjing Project</u>

Nanjing government also supported the Nanjing LFG recovery and utilization project and facilitated the project implementation process, such as landfill site reconstruction, resident resettlement and loan subsidy etc. Nanjing government strengthened the municipal waste management based on national policies and provided the necessary prerequisite of Shui Ge landfill site reconstruction.

In order to promote industrial development of municipal waste management, the Nanjing government set up relevant implementation rules and garbage disposal charge system which attracted investment of a private investor. Cleanaway Company won the tender and designed, constructed and financed the GEF Nanjing Project at the Shui Ge landfill site.

Local Policies, Maanshan Project

As a key project of the Maanshan Municipal Government, Maanshan GEF Project directly benefited from the preferential policies and measures of local government on land requisition, investment and taxation. First, the Maanshan Municipal Government granted preferential policies to accelerate land requisition for this Project; second, the Maanshan Municipal Government has given full support to this Project by making sure that it was fully funded.

In accordance with relevant national polices like *Opinions on Promotion of Development of Industrialization of Urban Sewage and Waste Treatment* and *Policies on Urban Domestic Refuse Disposal and Pollution Prevention Technologies,* Maanshan Municipal Government started the progress of industrialized refuse disposal and has established Maanshan Huanjia Energy Co. Ltd. as they gradual move towards an independent enterprise-like operation.

Local policies, (Anshan project)

The municipal government of Anshan City placed great importance on the Anshan demonstration project throughout its ten years of implementation. The project was even included in the City's tenth 5-year plan. Based on national regulations, the Anshan municipal government formulated policies to stimulate commercialization of waste disposal and implemented a waste treatment fee collection system. This allowed the Anshan City Waste Disposal Centre to function as a commercial enterprise. It was found that waste disposal and treatment is still suffering from a shortage in funding. The further development of an effective waste disposal fee is important for the future success of the Anshan project.

The City also stimulated the commercialization of the project by improving and implementing policy measures such as low interest loans and tax reduction and exemption measures for organizations operating in the way of enterprises. However, full commercialization of the project was not achieved and further support in the form of credit and tax benefits remains necessary. The project has shown the importance of

stimulation of organizations that operate as commercial enterprises through policy measures such as low interest loans and tax benefits.

- *Successful sale of power from small landfill-gas-based generating plants into power grids and delineating ways to obtain financing for a LFG project.*

The success of the Nanjing project is based on several factors. First, the price of power sold to the grid is much higher than coal based power reflecting the increased value of renewable power. The biggest hurdle for this type of project is obtaining sufficient revenue from the grid. One way of supporting this type of project is to develop it as a CDM project to take advantage of CER credits. Because this is a methane gas recovery project, it should be possible for these projects to qualify as a CDM project. This will help reduce the selling price of electricity to the grid while still allowing the project to make a profit.

- *Production of a technically sound and constructible engineering design for the construction and operation of the project on schedule and within budget*

Whenever developing new technology, it is not uncommon to have unexpected delays or costs. Anshan was the only project that appeared to face unexpected costs and delays. Anshan reports that they need 3,000,000 RMB more to complete the project.

- *The project operates at the projected thermal efficiency and energy output, with less than 10 percent downtime.*

Downtime for the Nanjing was not quantified, however other power projects rarely have in excess of 10% downtime without some overriding problem with the LFG (i.e. excess siloxane or chlorinated hydrocarbons in the LFG causing unusual engine wear or engine problems).

The Maanshan project has very little unscheduled downtime, however, because of the low incoming waste stream, it only operates 2-3 hours per day.

- *Costs and revenues are as projected during the design phase*

Revenue from the Maanshan project is significantly lower than required for this plant to have long-term profitability. One way to help this project is to install an engine generator to burn surplus gas.

Costs for the Anshan project were higher than expected. This led to the additional financing required to complete this project.

Nanjing demonstration project has achieved excellent institutional arrangements for the recovery and utilization of LFG and the subsequent sale of electrical energy to the grid. Approximate costs are shown on Calculations 3 and 4.

<u>Outcome 3:</u> A mechanism for rapid dissemination of landfill gas energy recovery technology set up through preparation of an action plan and establishment of a technical reference centre.

The NAP is useful in establishing LFG energy recovery projects elsewhere in China. This guidance document along with the Renewable Energy Law provides an effective tool to aid municipalities and developers of LFG to energy projects.

The training centres at Nanjing and Anshan also help to publicize the viability of the LFG to energy projects. This coupled with solicitation by Cleanaway, Onyx and other LFG system developers is generating interest in LFG development within China.

- *Dissemination of pilot project.*

The best method of disseminating the pilot project information is through the training centres. An alternate method that China should consider is the implementation of a national organization whose goal is the promotion of LFG. In the USA, for example, an organization established by the US Government is the Solid Waste Association of North America. The purpose of this organization is the technical exchange between landfill professionals. An organization of this type with annual meetings could greatly improve the dissemination of information. The Landfill Methane Outreach Program (LMOP) is another program designed to promote LFG recovery in the USA.

- *Development of four courses in fundamental aspects of LFG recovery.*

Because the training manual was in Chinese, it was not reviewed.

- *At least one hundred persons per year are trained in fundamental of LFG recovery*

Based on reports from the training centres, it appears that this goal is being met. While the exact number of students trained per year is not known, training centres have indicated that they have trained several thousand students.

- *Maintenance of a technical library and database, with at least 200 library and database accesses by prospective project developers per year*

It is recommended that SEPA collect data for a national data base of landfills, LFG system developers, bankers and financial institutions, consultants, engineers, constructors, operators, attorneys, and the like to assist in the development of LFG projects. This is the same as the LMOP model established in the United States.

D. Capacity building of the project staff in the three cities in design, building and managing the LFG demonstration projects and in provision of services to assist similar projects in other cities.

The technical staff in both Maanshan and Anshan have developed considerable skills in developing LFG projects. The education of technical staff through the implementation of the demonstration projects is invaluable and will benefit China with future development. Part of any development of new technologies involves some failures or problems so the challenges faced by the Maanshan and Anshan projects are not looked upon negatively. Rather, learning from these projects could significantly help future LFG energy recovery projects.

E. Any major issues and barriers encountered during the project implementation and any useful lessons learned in achievements of the project results.

The current institutional climate in China is not the same as it was when the demonstration projects were developed. With the implementation of the National Renewable Energy Law and the revised National Action Plan there is considerable support given to potential project developers. The biggest hurdle that needs to be overcome is coming to an equitable value of the energy from LFG to make a project viable.

6.0 FUTURE DEVELOPMENT

LFG to energy projects in China is a new technology. There is a significant learning curve that is required to allow projects to have long-term profitability. Companies throughout the world have significant experience with these types of plants. Until China is in a position to finance projects and take the financial risk associated with them it is suggested that landfills solicit proposals from international companies that are routinely engaged in LFG to energy projects. Once China is comfortable with the technology, LFG testing, modeling and operation and maintenance, then a transition can be made to local development.

If a municipality wants to develop a project independently, it is recommended that at a minimum they use the services of an international expert to review all work and help guide them through the development process. This at a bare minimum will help reduce their risk. Financing a project can be expensive. If projects can be developed through the CDM mechanism, this should help a project's viability. SEPA has a branch that specializes in CDM projects and they should be contacted for support.

China needs to select a lead agency to compile a list of potential Landfills interested in energy recovery. This agency can also become a clearinghouse for LFG information. One of the functions of the lead agency could be the compilation of LFG collection data from landfills and the commissioning of a study to evaluate the methane generation potential and generation rate from landfills. This effort will greatly aid in making quick predictions of LFG availability from a site.

There is also a strong need to improve landfill operations by covering them with soil cover to inhibit water infiltration. This will help to shed water and also provide a better anaerobic environment for methane gas generation. One of the best ways to comply with environmental regulations is to build large regional landfills. There are several cost benefits of this approach. First, the landfill will have a greater revenue source with which to comply with environmental laws and regulations. Second, LFG recovery at regional sites will provide a greater gas source making it more economically viable for LFG to energy projects. Creating regional landfills is a common practice once strict environmental laws were passed and enforced in the USA.

Anshan must immediately start quantifying the amount of LFG available for the plant. This is actually a common recommendation for all landfills. Prior to installing gas use equipment, a full landfill gas collection system installation will provide the best data possible on LFG collection. This will reduce the risk of failures caused by a lack of LFG availability.

Anshan also has significant water infiltration that makes it difficult to collect LFG. There is a concern that the landfill will continue to flood with infiltrating water. If gas cannot be collected with vertical gas wells, horizontal wells covered with plastic sheeting can be used to collect gas above the water level while this system can work, it tends to be expensive.

7.0 LESSON LEARNED

The entire project has been an excellent learning experience for China. It is obvious that there are now qualified engineers that can take the lead in complicated LFG recovery system design in both Maanshan and Anshan. However simple systems can have significant benefit as evidenced by the Nanjing project. The use of a private developer can significantly reduce the risk to financially strapped municipalities. This can even provide a revenue stream to the landfill if the contract is negotiated in this manner.

Future landfills should be engineered using modern design standards to improve landfill operations and LFG collection. This will help future sites to more accurately predict the rate of LFG collection.

It cannot be overstated the need to have cooperation of the local agencies and the gas or electric utilities. This is essential for a project to move forward successfully. The demonstration projects all prove that projects can be built when the municipality takes a lead roll in the development to clear institutional hurdles.

Whenever undertaking new development such as at the Anshan landfill, it is not merely necessary to have the funds required, but to have extra money available to account for project changes that may be required after commissioning. There are hundreds of successful landfill projects throughout the world and there is no reason that China cannot join the ranks of environmentally sophisticated nations while providing benefits to the country through LFG project development.

CALCULATIONS

CALCULATION 1

Calculated Steady State Annual Methane Generation in 2005

Refuse from 662 Cities in 2003 (1)	175,000,000	Mg
Annual Refuse Growth Rate (1)	8%	
Max Estimated Methane Yield (2)	62.5	cu m/Mg
Min Estimated Methane Yield (2)	25	cu m/Mg
CALCULATIONS		
Max Methane yield in 2003	10,937,500,000	cu m
Min Methane yield in 2003	4,375,000,000	cu m
Max Methane Yield in 2005	12,757,500,000	cu m
Min Methane Yield in 2005	5,103,000,000	cu m
Max Tons methane in 2005	**9,112,500**	**Mg**
Min Tons methane in 2005	**3,645,000**	**Mg**

(1) Source, National Action Plan
(2) GC Environmental Experience and limited information on China Landfills

CALCULATION 2

Calculated Annual Steady State NMOC Emissions in 2005

Refuse from 662 Cities in 2003 (1)	175,000,000	Mg
Annual Refuse Growth Rate (1)	8%	
Max Estimated Methane Yield (2)	62.5	cu m/Mg
Min Estimated Methane Yield (2)	25	cu m/Mg
NMOCs in LFG (3)	595	PPMv as hexane
Molecular Weight of Hexane	86	g/g mole
CALCULATIONS		
Max Methane yield in 2003	10,937,500,000	cu m
Min Methane yield in 2003	4,375,000,000	cu m
Max Methane Yield in 2005	12,757,500,000	cu m
Min Methane Yield in 2005	5,103,000,000	cu m
Max Tons hexane in 2005	**29,143**	**Mg**
Min Tons hexane in 2005	**11,657**	**Mg**

(1) Source, National Action Plan
(2) GC Environmental Experience and limited information on China Landfills
(3) EPA AP42 for normal landfills

CALCULATION 3

Nanjing - Small Scale Electrical Generation

Term of Loan (yrs)	10		
Sale Price per Kwh	$0.064	0.527	
Maintenance Cost per Kwh	$0.020	0.164	RMB
Capital Cost per Kw Future generators	$1,250.00	10,250	RMB
On stream time %	90.00%		
Assumed Exchange Rate RMB/US$	8.20		

10 yrs	15 yrs	20 yrs
IRR	**IRR**	**IRR**
12%	**16%**	**17%**

	Capital Cost for elect gen equip and LF improvements	Generation Increment	Total kW generation	Generated Kwh/yr	Maintenance Cost/yr	Gross Income/yr	Net Income/yr	Capital Improvements	Annual Income	Sum of Capital and annual income
Year								-$2,439,024		-$2,439,024
2002	$2,439,024	1250	1250	9855000	$197,100	$633,364	$436,264	$0	$436,264	$436,264
2003	$0		1250	9855000	$197,100	$633,364	$436,264	$0	$436,264	$436,264
2004	$0		1250	9855000	$197,100	$633,364	$436,264	$0	$436,264	$436,264
2005	$0		1250	9855000	$197,100	$633,364	$436,264	$0	$436,264	$436,264
2006	$0		1250	9855000	$197,100	$633,364	$436,264	$0	$436,264	$436,264
2007	$0		1250	9855000	$197,100	$633,364	$436,264	$0	$436,264	$436,264
2008	$0		1250	9855000	$197,100	$633,364	$436,264	$0	$436,264	$436,264
2009	$0		1250	9855000	$197,100	$633,364	$436,264	$0	$436,264	$436,264
2010	$0		1250	9855000	$197,100	$633,364	$436,264	$0	$436,264	$436,264
2011	$0		1250	9855000	$197,100	$633,364	$436,264	$0	$436,264	$436,264
2012	$0		1250	9855000	$197,100	$633,364	$436,264	$0	$436,264	$436,264
2013	$0		1250	9855000	$197,100	$633,364	$436,264	$0	$436,264	$436,264
2014	$0		1250	9855000	$197,100	$633,364	$436,264	$0	$436,264	$436,264
2015	$0		1250	9855000	$197,100	$633,364	$436,264	$0	$436,264	$436,264
2016	$0		1250	9855000	$197,100	$633,364	$436,264	$0	$436,264	$436,264
2017	$0		1250	9855000	$197,100	$633,364	$436,264	$0	$436,264	$436,264
2018	$0		1250	9855000	$197,100	$633,364	$436,264	$0	$436,264	$436,264
2019	$0		1250	9855000	$197,100	$633,364	$436,264	$0	$436,264	$436,264
2020	$0		1250	9855000	$197,100	$633,364	$436,264	$0	$436,264	$436,264
2021	$0		1250	9855000	$197,100	$633,364	$436,264	$0	$436,264	$436,264

Capital does not include initial LFG system installation
Assumes capital is spent 1 year before equipment operation
Assumes capital cost also includes landfill gas system improvements needed to support the new engine/generator
O&M costs include engine and LFG system Maintenance.
Assumes no salvage value of equipment
No LFG Model was run for this project, actual gas generation rates are unknown
Assumes no inflation for sales price of power or cost of operation.
IRR are before taxes
No inflation

CALCULATION 4

Nanjing - Small Scale Electrical Generation

Term of Loan (yrs)	10
Sale Price per Kwh	$0.064
Maintenance Cost per Kwh	$0.020
Capital Cost per Kw future generators	$1,250.00
On stream time %	95.00%
Assumed Exchange Rate RMB/US$	8.20

0.527
0.164 RMB
10,250 RMB

10 yrs	15 yrs	20 yrs
IRR	**IRR**	**IRR**
16%	**22%**	**23%**

	Capital Cost for elect gen equip and LF improvements	Generation Increment	Total kW generation	Generated Kwh/yr	Maintenance Cost/yr	Gross Income/yr	Net Income/yr	Capital Improvements	Annual Income	Sum of Capital and annual income
Year								-$2,439,024		-$2,439,024
2002	$2,439,024	1250	1250	10402500	$208,050	$668,551	$460,501	$0	$460,501	$460,501
2003	$0		1250	10402500	$208,050	$668,551	$460,501	-$1,562,500	$460,501	-$1,101,999
2004	$1,562,500	1250	2500	20805000	$416,100	$1,337,102	$921,002	$0	$921,002	$921,002
2005	$0		2500	20805000	$416,100	$1,337,102	$921,002	-$1,562,500	$921,002	-$641,498
2006	$1,562,500	1250	3750	31207500	$624,150	$2,005,653	$1,381,503	$0	$1,381,503	$1,381,503
2007	$0		3750	31207500	$624,150	$2,005,653	$1,381,503	-$1,562,500	$1,381,503	-$180,997
2008	$1,562,500	1250	5000	41610000	$832,200	$2,674,204	$1,842,004	$0	$1,842,004	$1,842,004
2009	$0		5000	41610000	$832,200	$2,674,204	$1,842,004	$0	$1,842,004	$1,842,004
2010	$0		5000	41610000	$832,200	$2,674,204	$1,842,004	$0	$1,842,004	$1,842,004
2011	$0		5000	41610000	$832,200	$2,674,204	$1,842,004	$0	$1,842,004	$1,842,004
2012	$0		5000	41610000	$832,200	$2,674,204	$1,842,004	$0	$1,842,004	$1,842,004
2013	$0		5000	41610000	$832,200	$2,674,204	$1,842,004	$0	$1,842,004	$1,842,004
2014	$0		5000	41610000	$832,200	$2,674,204	$1,842,004	$0	$1,842,004	$1,842,004
2015	$0		5000	41610000	$832,200	$2,674,204	$1,842,004	$0	$1,842,004	$1,842,004
2016	$0		5000	41610000	$832,200	$2,674,204	$1,842,004	$0	$1,842,004	$1,842,004
2017	$0		5000	41610000	$832,200	$2,674,204	$1,842,004	$0	$1,842,004	$1,842,004
2018	$0		5000	41610000	$832,200	$2,674,204	$1,842,004	$0	$1,842,004	$1,842,004
2019	$0		5000	41610000	$832,200	$2,674,204	$1,842,004	$0	$1,842,004	$1,842,004
2020	$0		5000	41610000	$832,200	$2,674,204	$1,842,004	$0	$1,842,004	$1,842,004
2021	$0		5000	41610000	$832,200	$2,674,204	$1,842,004	$0	$1,842,004	$1,842,004

Capital does not include initial LFG system installation
Assumes capital is spent 1 year before equipment operation
Assumes capital cost also includes landfill gas system improvements needed to support the new engine/generator
O&M costs include engine and LFG system Maintenance.
Assumes no salvage value of equipment
No LFG Model was run for this project, actual gas generation rates are unknown
IRR are before taxes
No inflation

CALCULATION 5

ANNUAL REVENUE, MAANSHAN ENERGY RECOVERY PLANT

Fee Calculation

Number of Beds	1100	
Average Occupancy	30%	
Charge per day for medical waste disposal per bed	1	RMB
Annual income	120450	RMB
Exchange Rate RMB/ US$	8.2	
Annual Income in US$	**$14,689.02**	**US$/Yr**

Alternate Fee Calculation based on the Value of LFG Burned

Landfill Gas Burned Per Day	1200	nM3/day
Percent methane in LFG	62%	
Methane Gas Value RMB/Cu M	2.7	RMB/Cu M
Value of LFG Burned Per Year	733212	RMB/Yr
Value of LFG Burned Per Year	**$89,416.10**	**US$/Yr**

Estimaed LFG Available	6000	nM3/day
Operating hours per day	3	Hours

CALCULATION 6

Anshan - CNG Plant

Term of Loan (yrs)	10	
Sale Price per Cu M Methane	$0.329	2.70 RMB
Plant Maint Cost $/Cu M produced	$0.171	1.40 RMB
Capital Cost per Kw	$1,250.00	10,250 RMB
On stream time %	95.00%	
Assumed Exchange Rate RMB/US$	8.20	
LFG Collection Rate Cu M/Day	10,000	
Methane Conversion Efficiency	96%	
Methane Content of LFG	62%	
Calculated Gas Value in $/mmBTUs	$9.712	Assumes 960 BTU/Cu Ft gas

10 yrs	15 yrs	20 yrs
IRR	**IRR**	**IRR**
3%	**8%**	**10%**

	Capital Cost for elect gen equip and LF improvements	CNG Production Cu M/Hr	Cu M methane/ Hr Production	Cu M methane per year	Maintenance Cost/yr	Gross Income/yr	Net Income/yr	Capital Improvements	Annual Income	Sum of Capital and annual income
Year								-$2,500,000		-$2,500,000
2005	$2,500,000	248	248	2063856	$352,366	$679,562	$327,197	-$365,854	$327,197	-$38,657
2006	$365,854		248	2063856	$352,366	$679,562	$327,197	$0	$327,197	$327,197
2007	$0		248	2063856	$352,366	$679,562	$327,197	$0	$327,197	$327,197
2008	$0		248	2063856	$352,366	$679,562	$327,197	$0	$327,197	$327,197
2009	$0		248	2063856	$352,366	$679,562	$327,197	$0	$327,197	$327,197
2010	$0		248	2063856	$352,366	$679,562	$327,197	$0	$327,197	$327,197
2011	$0		248	2063856	$352,366	$679,562	$327,197	$0	$327,197	$327,197
2012	$0		248	2063856	$352,366	$679,562	$327,197	$0	$327,197	$327,197
2013	$0		248	2063856	$352,366	$679,562	$327,197	$0	$327,197	$327,197
2014	$0		248	2063856	$352,366	$679,562	$327,197	$0	$327,197	$327,197
2015	$0		248	2063856	$352,366	$679,562	$327,197	$0	$327,197	$327,197
2016	$0		248	2063856	$352,366	$679,562	$327,197	$0	$327,197	$327,197
2017	$0		248	2063856	$352,366	$679,562	$327,197	$0	$327,197	$327,197
2018	$0		248	2063856	$352,366	$679,562	$327,197	$0	$327,197	$327,197
2019	$0		248	2063856	$352,366	$679,562	$327,197	$0	$327,197	$327,197
2020	$0		248	2063856	$352,366	$679,562	$327,197	$0	$327,197	$327,197
2021	$0		248	2063856	$352,366	$679,562	$327,197	$0	$327,197	$327,197
2022	$0		248	2063856	$352,366	$679,562	$327,197	$0	$327,197	$327,197
2023	$0		248	2063856	$352,366	$679,562	$327,197	$0	$327,197	$327,197
2024	$0		248	2063856	$352,366	$679,562	$327,197	$0	$327,197	$327,197

Capital does not include initial LFG system installation
Assumes capital is spent 1 year before equipment operation
Gas Price of 2.7 RMB/Cu M from National Expert
O&M Costs from Project Designer and include labor, replacement, repair, chemicals, coal, etc.
Assumes no salvage value of equipment
No LFG Model was run for this project, actual gas generation rates are unknown
Design LFG flow rate 10,000 cu M / day at 62% methane
Methane Recovery Efficiency 0.96
IRR are before taxes
No inflation

PHOTOGRAPHS

NANJING LANDFILL

Photo 1 – Blower-Flare

Photo 2 – Control Room

Photo 3 – Electrical Transmission Tower

Photo 4 – Engine Expansion Area

NANJING LANDFILL

Photo 5 – First Engine

Photo 6 – First Engine

Photo 7 – Gas Pretreatment

Photo 8 – Landfill & Expansion Area

Photo 9 – Landfill Expansion Area

Photo 10 – Single Well

NANJING LANDFILL

Photo 11 – Three Engines

Photo 12 – Water Chiller

Photo 13 – Well Drilling

Photo 14 – Wellhead Cluster

NANJING LANDFILL

Photo 15 – Training Center Outside Look

Photo 16 – Training Center Gates

Photo 17 – Training Center

MAANSHAN LANDFILL

Photo 1 – Incinerator Loading

Photo 2 – Incinerator Loading

Photo 3 – Leachate Treatment

Photo 4 – Landfill Compactor

Photo 5 – Landfill Flare

Photo 6 – Landfill Wells

MAANSHAN LANDFILL

Photo 7 – LFG Blowers

Photo 8 – Medical Waste Incinerator

ANSHAN LANDFILL

Photo 1 - Absorber and Stripper

Photo 2 – Blowers

Photo 3 – Gas Processing

Photo 4 – Landfill

Photo 5 – Training Institute

Photo 6 – Large Class Room

ANSHAN LANDFILL

Photo 7 – Small Class Room

Photo 8 – Well Drilling

Photo 9 – Gas Dryer

Photo 10 – High Pressure Compressor 1

Photo 11 – High Pressure Compressor 2

Photo 12 - Reboiler

APPENDIX A
Renewable Energy Law

Authorized Release: The Renewable Energy Law

The People's Republic of China (Full Text)

Table of Contents

Appendix A – Renewable Energy Law

Chapter 1. General

Article 1—In order to promote the development and utilization of renewable energy, improve the energy structure, diversify energy supplies, safeguard energy security, protect the environment, and realize the sustainable development of the economy and society, this Law is hereby prepared.

Article 2—Renewable energy in this law refers to non-fossil energy of wind energy, solar energy, water energy, biomass energy, geothermal energy, and ocean energy, etc.

Application of this Law in hydropower shall be regulated by energy authorities of the State Council and approved by the State Council.

This Law does not apply to the direct burning of straw, firewood and dejecta, etc. on low-efficiency stove.

Article 3—This Law applies to territory and other sea area of the People's Republic of China.

Article 4—The Government lists the development of utilization of renewable energy as the preferential area for energy development and promotes the construction and development of the renewable energy market by establishing total volume for the development of renewable energy and taking corresponding measures.

The Government encourages economic entities of all ownerships to participate in the development and utilization of renewable energy and protects legal rights and interests of the developers and users of renewable energy on the basis of law.

Article 5—Energy authorities of the State Council implement management for the development and utilization of renewable energy at the national level. Relevant departments of the State Council are responsible for the management of relevant development and utilization of renewable energy within their authorities.

Energy authorities of local people's governments above the county level are responsible for the management of the development and utilization of renewable energy within their own jurisdiction. Relevant departments of local people's governments above the county level are responsible for the management of relevant development and utilization of renewable energy within their authorities.

Chapter 2 Resource Survey and Development Plan

Article 6—Energy authorities of the State Council are responsible for organizing and coordinating national surveys and management of renewable energy resources, and work with related departments to establish technical regulations for resource surveys.

Relevant departments of the State Council, within their respective authorities, are responsible for related renewable energy resource surveys. The survey results will be summarized by the energy authorities in the State Council.

The result of the survey of renewable energy shall be released to the public, with the exception of confidential contents as stipulated by the Government.

Article 7—Energy authorities of the State Council sets middle and long-term target of the total volume for the development and utilization of renewable energy at the national level, which shall be implemented and released to the pubic after being approved by the State Council.

Energy authorities of the State Council shall, on the basis of the target of total volume in the previous paragraph, as well as the economic development and actual situation of renewable energy resources of all provinces, autonomous regions and municipalities, cooperate with people's governments of provinces, autonomous regions and municipalities in establishing middle and long-term target and release it to the public.

Article 8—Energy authorities of the State Council shall, on the basis of the middle and long-term total volume target of renewable energy throughout the country, prepare national renewable energy development and utilization plan, which is to be implemented after being approved by the State Council.

Energy authorities of the people's governments at the level of province, autonomous region and municipality shall, on the basis of the middle and long-term target for the development and utilization of renewable energy, cooperate with relevant authorities of the people's governments at their own level in preparing national renewable energy development and utilization plan for their own administrative regions, which shall be implemented after being approved by people's governments at their own level.

The approved plan shall be released to the public, with the exception of confidential content as stipulated by the government.

In case that the approved plan needs to be modified, approval of the original approving authorities shall be obtained.

Article 9—In preparing the plan for the development and utilization of renewable energy, opinions of relevant units, experts and the public shall be solicited and the scientific reasoning shall be done.

Chapter 3 Industry Guidance and Technology Support

Article 10—Energy authorities in the State Council shall, in accordance with the national renewable energy development plan, prepare and promulgate development guidance catalogs for renewable energy industries.

Article 11—Standardization authorities of the State Council shall set and publicize technical standard for renewable energy electric power and the technical standards for relevant renewable technology and products for which technical requirements need to be standardized at the national level.

For those technical requirements not dealt with in the national standard in the previous paragraph, relevant authorities of the State Council may establish relevant industrial standard, which shall be reported to the standardization authorities of the State Council for filing.

Article 12—The government lists scientific and technical research in the development and utilization of, and the industrialized development of, renewable energy, as the preferential area for hi-tech development and hi-tech industrial development in the national program, and allocates funding for the scientific and technical research, application demonstration and industrialized development of the development and utilization of renewable energy so as to promote technical advancement in the development and utilization of renewable energy, reduce the production cost of renewable energy products and improve the quality of products.

Education authorities of the State Council shall incorporate the knowledge and technology on renewable energy into general and occupational education curricula.

Chapter 4 Promotion and Application.

Article 13—The Government encourages and supports various types of grid-connected renewable power generation.

For the construction of renewable energy power generation projects, administrative permits shall be obtained or filing shall be made in accordance with the law and regulations of the State Council.

In the construction of renewable power generation projects, if there is more than one applicant for project license, the licensee shall be determined through a tender.

Article 14—Grid enterprises shall enter into grid connection agreement with renewable power generation enterprises that have legally obtained administrative license or for which filing has been made, and buy the grid-connected power produced with renewable energy within the coverage of their power grid, and provide grid-connection service for the generation of power with renewable energy.

Article 15—The Government supports the construction of independent renewable power systems in areas not covered by the power grid to provide power service for local production and living.

Article 16—The Government encourages clean and efficient development and utilization of biological fuel and encourages the development of energy crops.

If the gas and heat produced with biological resources conform to urban fuel gas pipeline networks and heat pipeline networks, enterprises operating gas pipeline networks and heat pipeline networks shall accept them into the networks.

The Government encourages the production and utilization of biological liquid fuel. Gas-selling enterprises shall, on the basis of the regulations of energy authorities of the State Council or people's government at the provincial level, include biological liquid fuel conforming to the national standard into its fuel-selling system.

Article 17—The Government encourages workplaces and individuals in the installation and use of solar energy utilization systems of solar energy water-heating system, solar energy heating and cooling system and solar photovoltaic system, etc.

Construction authorities of the State Council shall cooperate with relevant authorities of the State Council in establishing technical economic policies and technical standards with regard to the combination of solar energy utilization system and construction.

Real estate development enterprises shall, on the basis of the technical standards in the previous paragraph, provide necessary conditions for the utilization of solar energy in the design and construction of buildings.

For buildings already built, residents may, on the condition that its quality and safety is not affected, install solar energy utilization system that conform to technical standards and product standards, unless agreement has been otherwise reached between relevant parties.

Article 18—The Government encourages and supports the development and utilization of renewable energy in rural areas.

Energy authorities of local people's governments above the county level shall, on the basis of local economic and social development, ecological protection and health need, etc., prepare renewable energy development plan for the rural area and promote biomass energy like the marsh gas, etc. conversion, household solar energy, small-scale wind energy and small-scale hydraulic energy, etc.

People's government above the county level shall provide financial support for the renewable energy utilization projects in the rural areas.

Chapter 5 Price Management and Fee Sharing

Article 19—Grid power price of renewable energy power generation projects shall be determined by the price authorities of the State Council in the principle of being beneficial to the development and utilization of renewable energy and being economic and reasonable, where timely adjustment shall be made on the basis of the development of technology for the development and utilization of renewable energy. The price for grid-connected power shall be publicized.

For the price of grid-connected power of renewable power generation projects determined through tender as stipulated in the 3rd paragraph of Article 13 hereof, the bid-winning price shall be implemented; however, such a price shall not exceed the level of grid-connected power of similar renewable power generation projects.

Article 20—The excess between the expenses that power grid enterprises purchase renewable power on the basis of the price determined in Article 19 hereof and the expenses incurred in the purchase of average power price generated with conventional energy shall be shared in the selling price. Price authorities of the State Council shall prepare specific methods.

Article 21—Grid connection expenses paid by grid enterprises for the purchase of renewable power and other reasonable expenses may be included into the grid enterprise power transmission cost and retrieved from the selling price.

Article 22—For the selling price of power generated from independent renewable energy power system invested or subsidized by the Government, classified selling price of the same area shall be adopted, and the excess between its reasonable operation, management expenses and the selling price shall be shared on the basis of the method as specified in Article 20 hereof.

Article 23—The price of renewable heat and natural gas that enters the urban pipeline shall be determined on the basis of price management authorities in the principle of being beneficial to the development and utilization of renewable energy and being economic and reasonable.

Chapter 6 Economic Incentives and supervisory measures

Article 24—The Government budget establishes renewable energy development fund to support the following:

1. Scientific and technological research, standard establishment and pilot project for the development and utilization of renewable energy;
2. Construction of renewable energy projects for domestic use in rural and pasturing areas;
3. Construction of independent renewable power systems in remote areas and islands;
4. Surveys, assessments of renewable energy resources, and the construction of relevant information systems;
5. Localized production of the equipment for the development and utilization of renewable energy.

Article 25—Financial institutions may offer preferential loan with financial interest subsidy to renewable energy development and utilization projects that are listed in the national renewable energy industrial development guidance catalogue and conform to the conditions for granting loans.

Article 26—The Government grants tax benefits to projects listed in the renewable energy industrial development guidance catalogue, and specific methods are to be prepared by the State Council.

Article 27—Power enterprises shall authentically and completely record and store relevant materials of renewable energy power generation, and shall accept the inspection and supervision of power supervisory institutions.

Power supervisory institutions shall do the inspection in accordance with stipulated procedures, and shall keep commercial secret and other secret for inspected units.

Chapter 7 Legal Responsibilities

Article 28—If energy authorities of the State Council and the people's governments above the county level as well as other relevant authorities breach this Law and have one of the following, people's government of their own level or relevant authorities of the superior people's governments may order them to make correction, and impose administrative penalty for competent personnel that are liable and other personnel directly liable; in case that such breaches constitute crime, criminal liabilities shall be legally pursued.

1. Failure to make administrative licensing decision in accordance with law;
2. Failure to make an investigation when illegal activities are discovered;
3. Other acts of not legally performing supervision and management responsibilities.

Article 29—If the power grid enterprises breach Article 14 hereof and fail to purchase renewable power in full, which results in economic loss to the renewable power generation enterprises, such power grid enterprises shall be liable for compensation, and the national power supervisory institutions shall order them to make correction within a stipulated period of time; in case of refusal to make correction, a fine of less than the economic loss of the renewable power generation enterprises shall be imposed.

Article 30—In case that enterprises of natural gas pipeline network and heat pipeline network breach paragraph 2 of Article 16 hereof and do not permit the connection of natural gas and heat that conform to the grid connection technical standard into the network, which results in economic loss to the gas and heat production enterprises, relevant enterprises shall be liable for compensation, and energy authorities of the people's government at the provincial level shall order them to make correction within a stipulated period of time; in case of refusal to make correction, a fine of less than said economic loss shall be imposed against them.

Article 31—If gas-selling enterprises breach paragraph 3 of Article 16 hereof and fail to include biological liquid fuel that conforms to the national standard into its fuel-selling system, which results in economic loss to the biological liquid fuel production enterprises, relevant enterprises shall be liable for compensation, and energy authorities of the State Council or people's government at the provincial level shall order them to make correction within a stipulated period of time; in case of refusal to make correction, a fine of less than said economic loss shall be imposed against them.

Chapter 8 Miscellaneous

Article 32—Terms used herein shall have the following meanings:

1. Biomass energy: means energy converted from natural plants, rejecta as well as urban and rural organic waste.
2. Renewable energy independent power system: means independent renewable power system not connected to the power grid.
3. Energy crop: means herbage and wood plants specially planted and used as raw materials of energy.
4. Biological liquid fuels: means methanol, ethanol, bio-diesel and other liquid fuels derived from biomass resources.

Article 33—This Law shall become effective on Jan 1st, 2006.

A. Relevance to Government Priority and UNDP Mandate

Due to its large population, low availability of arable land and increasing urbanization, China's Central government realized that it cannot continue with its unmanaged approach to waste disposal. Furthermore, in recent years, recognizing its own economic and environmental interests and its international obligation, China, at the national level, has attached increasing importance to all aspects of environmental protection including the environmentally responsible management of solid wastes. However, the specific issue relating to the recovery and utilization of landfill gas has not been properly recognized as a priority environmental and energy issue.

FINDINGS:

- While the control and reduction of Greenhouse Gas and climate change are major concerns for the United Nations and a high priority for many developed countries, it was recognized that, at the time of project formulation (around mid 1990's), there was a lack of recognition for the importance of this type of projects for environmental protection as well as energy production in China. This lack of understanding was also much more evident at the local government level. The launch of this project had provided much needed impetus to China and in terms of establishing a core structure with technical and institutional capacity for the widespread adoption of LFG projects in China.
- The need to enhance the working relationship and cooperation among various ministries at the national level was clearly recognized at the stage of project formulation. The project design document specifically called for the formation of a project Steering Committee consisting of senior level officials from a number of relevant ministries. This Steering Committee was also to be supported with an Expert Advisory Group from these relevant ministries and agencies. The evaluators felt that this is an excellent provision of the Project Document in order to enhance institutional arrangements/capacities at those government departments and to further strengthen the working relationship between the State Environmental Protection Bureau and other relevant departments.

3.1 Definition of Problems, Objectives and Strategies

The Project Document presented a comprehensive description of problem statements, Development and Immediate Objectives, and a series of project strategies.

3.1.1 Definition of Problems

Along with its dramatic economic growth and rapid structural changes in its urban centres, China's large population in urban centres are generating an increasing amount of municipal solid waste. It is estimated that during the year of 2000, China generated an amount of 175 million tons of MSW, and this amount can reach 480 million tons by the year of 2010 at the current growth rate.

The implementation of this project provided the demonstration cities and a number of other agencies at the national level with the necessary experience, knowledge and technologies relating to the comprehensive solid waste management and operational practices for engineered sanitary landfill sites.

At the time of project formulation, it was recognized that:

1. China lacked the technology on landfill gas recovery and off-the-shelf equipment. The resulting high costs of imported technology and equipment prevented its widespread adoption across China.
2. There was a lack of skill personnel, such as managers, engineers, contractors and operators for the design, construction and operation of landfill gas recovery and utilization plants.
3. There was also a weak institutional structures to manage the landfill resource due to a lack of definition of institutional responsibility and resource ownership, Therefore, there was a lack of "energy service companies" (ESCO) to identify potential projects for harvesting this type of energy sources. In part, the lack of regulations or policy for determining the price that the energy bureau would be willing to pay for the methane gas or electricity prevented the formation of ESCO's.
4. With the rapid pace of economic development, China's local and municipal governments increasingly bear the economic and administrative responsibility to provide urban infrastructure and services such as transportation and communication. As a result, less attention has been given to channeling resources for "non-productive" local investments such as water and sewage treatment and waste disposal and management.
5. The government currently provides capital for the development of landfills. For independent companies to flourish in the operation of landfills for energy production, they will require access to either domestic or foreign capital markets, which are either weak or non-existent in most of China.
6. The electricity price offered by the local bureaus is inadequate to cover the cost of plants to recover landfill gas and generate electricity. The cost of the plants would have to be reduced by 43% or the electricity

price increased to 0.40 RMB Yuan per KWh in order for the revenue from electricity sales to offset the cost.

7. The Chinese government does not have an action plan to promote the use of methane recovery at landfills. Lack of an action plan has prevented the formulation of a national strategy that would address the above issues in an integrated manner.

FINDINGS:

- The above problem statements are very comprehensive with sufficient details.
- The evaluators believe that the problem statements also raised a number of key criteria by which the success of this project should and could be assessed, such as the need for establishing independent ESCO's and appropriate prices for power sale. Nanjing had successfully formed a joint venture arrangement with a foreign interest, which had directly resulted in the establishment of an independent ESCO in Nanjing. This local ESCO is currently actively seeking landfill gas and other related projects with other major population centres in China.
- This type of P3 (public-private partnership) projects will reduce the financial burden on municipal governments, establish independent ESCO's and expedite the widespread adoption of further landfill gas projects in China.
- The problem statements truly reflected the situations in China at the time of project formulation. The evaluators believe that the implementation of this project had developed several core groups of technically competent staff within government agencies and other relevant, but non-government institutions in the three demonstration cities. These technical staff gained a full spectrum of experience and skills and can help to facilitate the development of additional landfill gas recovery and utilization projects in China.
- The implementation of this project also involved local engineering and construction firms, thereby building up local technical skills and capabilities.
- Municipal government leadership and the subsequent priority assigned to this project are of critical importance to the success of this project. The municipal government leaderships and officials in the demonstration cities had demonstrated increased awareness about issues such as, global warming and climate changes. As a result, favourable policy and financial support are being given to the various stages of project implementation. For example, price paid for electricity generated by landfill gas project in Nanjing had been increased as a financial incentive as the project document originally anticipated. Various government departments had also demonstrated close coordination under the high level leadership of municipal

governments in Nanjing as well as Anshan in order to facilitate and expedite project implementation.

- There is a need to further strengthen the comprehensive regulatory framework for municipal solid waste disposal by clearly delineating regulatory and enforcement responsibilities among government departments. For example, environmental protection bureaus at national, provincial and municipal level are currently not directly accountable for environmental problems that may be caused by municipal landfill sites. The Construction Ministry and local construction bureaus and local City Appearance and Sanitation bureaus are “responsible for the siting, construction, operation and the overall management of municipal solid waste management as well as the managing potential environmental impacts of such facilities. This situation is likely to dampen the “vigilance” for instituting proper environmental controls and may even present a potential for “conflict of interest”.

3.1.2 Definition of Immediate Objectives

Prior to the definition of immediate objectives, the project design document presented end-of-project expectations, namely:

1. Demonstration plants to capture methane from landfills and use it to generate electricity and/or directly as fuel would have been established at the sites in Anshan, Maanshan and Nanjing. Plants would include landfill gas collection systems and equipment for energy production.
2. A facility would have been established to (1) educate, train, and assist landfill operators, energy service companies, municipalities and other businesses to build and operate landfill energy plants; (2) conduct research in order to develop more efficient methods for the above purposes; and (3) disseminate information on landfill gas recovery and the use of this technology.
3. Institutional arrangements would have been set up to operate landfill gas recovery technology, and to produce and sell gas and/or electricity at each site. In at least one location, independent companies will have been invited to build, own and operate the gas collection and energy generation system. As part of the pilot projects, new organizational structures will be tested, including ways to access non-government financing.
4. The project will have demonstrated approaches to obtain a price of electricity and/or to lower the cost of future plants so as to generate sufficient revenue from electricity sales to make landfill-gas-based electricity generation financially viable.
5. An action plan would have been prepared to promote widespread replication and adoption of landfill gas recovery technology in China. The action plan would address the issue of capital mobilization, the

formation of independent companies for the collection of landfill gas and production of energy, and their institutional relationships with government at all levels for expanded landfill gas recovery activity. On the basis of the experience with pilot plants, the action plan would illustrate ways to reduce the cost of landfill energy production, which may include the promotion of indigenous manufacturing capacity for landfill gas recovery. It would also identify geographic areas and specific landfills where the technical and institutional conditions would be appropriate to make energy recovery competitive.

Based on these overall project expectations, the project document presented three Development Objectives and three Immediate Objectives. These objectives are clearly linked to the formulation of the project strategies, which will be discussed in the next section.

The three Immediate Objectives are:

1. Definition of design criteria for the gas collection systems at the Anshan, Maanshan and Nanjing landfills through analysis of the municipal solid waste stream, assessment of the landfill gas that can be obtained from the waste stream and field trials.
2. Successful demonstration of landfill gas energy recovery technologies and institutional arrangements for the sale of energy through pilot projects in Anshan, Maanshan and Nanjing.
3. A mechanism for rapid dissemination of landfill gas energy recovery technology set up through preparation of an action plan and establishment of a technical reference centre,

The specific outputs and activities prescribed under each of these three Immediate Objectives provided further clarification regarding the project objectives. Specific parties who are responsibilities for each the activities were also identified in the project document.

FINDINGS:

- The evaluators fully agree with the Immediate Objectives and the associated outputs and activities. The achievement of these Immediate Objectives would certainly provided the necessary impetus for widespread adoption of similar LFG recovery and utilization projects. Overall, the demonstration project had completed the first two of the immediate objectives and is currently designing work plans for the third objective.
- Two of the three cities, Nanjing and Anshan, are well on their way to fully implement the project objectives. Demonstration plants will include the design and construction of landfill gas collection systems, gas

treatment and recovery systems and finally the energy recovery and production facilities.

- Anshan Landfill Technology Development and Training Centre had been established to deliver training programs to educate, train, and assist landfill operators, energy service companies, municipalities and other businesses to build and operate landfill energy plants. As stated before, the institutional capacities of the Anshan Centre can be further improved.
- The Nanjing and Anshan project components will fully demonstrate the establishment of institutional arrangements to operate landfill gas recovery technology, and to produce and sell electricity and gas respectively. In Nanjing, independent companies from a number of countries had been invited to build, own and operate the gas collection and energy generation system. As part of this GEF demonstration project, new organizational structures and independent ESCO had been established in Nanjing with non-government financing.

3.1.3 PROJECT STRATEGIES

The essence of the project design is well organized and presents a strategic approach to develop and effectively sustain China's technical and institutional capacity for LFG recovery and utilization.

FINDINGS:

- First, through the design, implementation of demonstration projects at three cities, the evaluators believe that the benefits, economic and technical viability of LFG recovery and utilization can be demonstrated in China. The three demonstration projects will serve as models for many other urban centres in a similar situation.
- Through the implementation process, China will be able to develop a core group of technical and management staff experienced in the complete spectrum of LFG recovery and utilization.
- The three cities were also strategically selected with respect to size, local geology, climate conditions, degree of urbanization and potentially different waste characterization. This was specifically planned at the outset, to derive maximum benefits from the demonstration projects as they will be serving as models for the rest of China,
- A basic structure of institutional capacity and arrangements to push further development in this area, including the development of independent "Energy Service Companies", domestic or international.
- The development of an action plan to analyze and make recommendations to SEPA, national policies in the areas of economic

and financial incentives, education and awareness promotion, taxation and institutional structures as well as standards and regulations for landfill gas control and recovery. This action plan will be able to serve as a foundation for further policy development on a national level. Through supportive policy mechanisms, the program will be able to develop institutional capacities and promote the widespread adoption of landfill gas recovery and utilization projects in China.

- A centre of excellence (Anshan Landfill Technology Development and Training Centre) will serve as a focal point for providing training, information depository and dissemination for widespread adoption of LFG projects in China. It is expected that this centre will continue to operate long after the GEF project has been completed.

In summary, the evaluators find the project's immediate objectives and the strategies had an excellent linkage and were well defined and structured to achieve the expected project results.

3.2 Major Modifications to Original Project Design

There are two major modifications to the original project design:

1. One of the Project Strategy states that demonstration plants will be built and operated at each site using landfill gas from an area of 8 ha. However, soon after the field trials at all of the three sites and during the stage of conducting the feasibility studies, the NPMO and the PMO's of the pilot cities realized that there is a need to implement the demonstration project for the entire landfill site. The strategic reasons include:

    a. An 8 ha demonstration plant will not be able to fully assess the commercial viability of the landfill gas recovery and utilization project.
    b. A small demonstration project will be deemed to a "mere scientific research project" and is less likely to attract the attention of the city leaderships and receive necessary government policy and financial support.
    c. Only commercial scale projects will be able to attract the interests from national and international independent energy service companies and private investors.
    d. Small demonstration plants would also be difficult to serve as a model for effective dissemination of project experience and knowledge to the rest of China.

    As a result of these strategic discussions and assessments, the city project teams decided that project development and the feasibility studies would be conducted with a view to develop the entire landfill sites for landfill gas recovery and utilization. The evaluators fully endorse this positive decision.

As a direct result of this major change to the project design, planning and design considerations for project implementation had to change significantly, including not the least of all, the financial and investment needs for the demonstration projects. This modification represents a significant exceedance over the original project design. This modification must be recognized as a key success factor for this project. The development of the entire landfill site for LFG recovery and utilization proved to be a huge success in terms of demonstrating the economic viability of this GEF project as well as using this project as a model for future similar other project. It will have a real value when the results of this project are eventually disseminated to other cities in China.

2. The Project Document also states that an action plan will be developed. In reviewing Immediate Objectives, one can reach a conclusion that the action plan was intended to be a set of analyses and recommendations to SEPA, containing "national policy, standards and regulations for landfill gas control and recovery". With the assistance of its consultants, SEPA would also formulate " appropriate technical and financial incentives that will encourage municipalities to implement landfill methane collection and energy recovery facilities". However, it has become quite evident that such an action plan would contain issues that are well beyond the roles and responsibilities of SEPA. Many policy issues would have to be addressed by other related government departments at the national level. The need for multi-agency cooperation and coordination was fully anticipated at the stage of project design. The project document contains a provision for the establishment of a multi-agency Project Steering Committee, to be supported by a technical Expert Group.

   In November 2002, SEPA with the assistance from ERI organized and sponsored a multi-agency seminar to review the draft national action plan. The evaluators had the opportunity to participate at that event. A comprehensive range of environmental and energy policy issues were discussed. Positions and views from various agencies were exchanged and examined. The evaluator feel that this process was extremely effective and beneficial to the development of a comprehensive policy framework for the whole country, not to mention the positive potential of attracting appropriate agencies to take "ownership" of various policy initiatives and programs for their eventual implementation. Therefore, the evaluators recommend that SEPA organize further multi-agency seminars in its effort to develop a national policy framework.

APPENDIX B
National Action Plan for Recovery & Utilization of Landfill Gas

UNDP/GEF

Recovery and Utilization of Landfill Gas

National Action Plan
for

China: Promoting Methane Recovery and Utilization from Mixed Municipal Refuse Landfill Site

August 2005

Abbreviations

GHG	Greenhouse Gas
ADB	Asian Development Bank
CDB	China Development Bank
CDM	Clean Development Mechanism
CNG	Compressed Natural Gas
DOE	Department of Energy
ERI	Energy Research Institute
GCS	Green Certification System
GEF	Global Environment Facility
MMS	Mandatory Market Share
MOC	Ministry of Construction
MOST	Ministry of Science and Technology
NDRC	National Development and Reform Commission
NEPA	National Environmental Protection Administration
O&M	Operation and Management
ODA	Overseas Development Agency
PPA	Power Purchase Agreement
RPS	Renewable Portfolio Standard
SDPC	State Development and Planning Commission
SEPA	State Environmental Protection Administration
SETC	State Economic and Trade Commission
SSTC	State Science and Technology Commission
STA	State Tax Administration
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Program
VAT	Value-Added Tax
WB	World Bank

Appendix B – National Action Plan

Content

Preface

Municipal refuse has become one of the public nuisances in the world. With rapid economic development and continuously improved urbanization levels and consumption standards, the amount of municipal refuse is increasing day by day. The disposal of municipal refuse has become an important factor influencing environmental protection, city construction, residents' life and sustainable development. A large amount of residential refuse is dumped open or simply disposed, which has greatly damaged the environment: to cover large amount of land resources, to pollute soil, to pollute water resource, to pollute air and atmosphere, to spread diseases and influence environmental sanitation and residents' health.

The development of urbanization in China has accelerated with the sustainable increasing of national economy, and the problem of environmental pollution and ecological deterioration brought by urbanization has become one of important issues Chinese government concerns. With the great increasing of urban population and the enlarging of city scale, refuse management is a problem, which must be solved by the local governments in most cities. In order to control urban refuse well and effectively, many countries have spent large amount of human resource and finance, taken various technological measures and policy measures, so as to reduce its damage to environment and human's health. Moreover, municipal refuse has completely utilized as resources and energy, made the harmful to the beneficial, so as to benefit human beings.

At present, there are three main technology measures on municipal refuse disposal taken by countries in the world, namely sanitary landfill technology, incineration technology and comprehensive utilization (i.e. the production of organic compost and building materials, heating supply, and power generation, etc.). In developed countries, it has been several decades for the development and improvement of the technologies of disposing municipal refuse and utilizing the refuse as resource, thus the relatively mature industry with benign cycle mechanism has formed. Since the components of municipal refuse are complex, and there are such factors as economic development levels, energy composition, geographical environment, natural conditions and traditional customs which influence municipal refuse disposal, the disposal of municipal refuse abroad is generally different with different national conditions, and sometimes different regions in the same country utilize different disposal methods, hence it is hard to form a uniform disposal mode, but the final objectives are common, namely to realize the refuse harmlessness, reduction and resourciation.

Refuse disposal is one of the most common ways currently used to manage the refuse. By the end of 2000, there were bear 1000 landfills in the large and middle sized cities in China, in which about 90% were dumps. But the traditional refuse disposal will bring underground water resource pollution and air and atmosphere pollution besides other conventional pollution. At the same time, a great amount of landfill gas which mainly consists of methane will be produced which is an important Greenhouse Gas (GHG), and the potential green house effect of the equivalent amount of methane is 21 times of that of carbon dioxide. In the world, 818 million tons of methane is produced in the landfill sites every year, of which US has the largest proportion of 26 percent and China has the second largest proportion of 11percent. However, methane is clean energy. Practices on landfill gas

utilization in over 20 countries show that energy of the equivalent amount of 2 million tons original coals are recycled from landfill gas every year.

China is one of large emitters of GHG and a country with insufficient energy and resources. In recent years, green house effect results in exceptional global climate change. Natural disasters caused by this make China become one of the victims of green house effect. GHG reduction is more and more important for China's development. Efficiency of resources consumption must be improved for sustainable development of China.

Therefore, to consider the recovery and utilization of the landfill gas when establishing the sanitary refuse disposal system will be helpful to the safety of landfill site, GHG mitigation, saving energy and resources, and improving the environment quality.

In 1995, Chinese government and United Nations Development Program (UNDP) applied for a technical assistance project of "China: Promoting Methane Recovery and Utilization from Mixed Municipal Refuse Landfill Site" (hereinafter referred as Project) from Global Environment Facility (GEF), with the objectives of implementing pilot projects of landfill gas utilization in three cities including Nanjing, Anshan and Maanshan, analyzing the basic framework of municipal refuse management and the developing trendy of refuse resourciation technologies, developing the national action plan for landfill gas recovery and utilization, conducting the capacity building of landfill gas recovery and utilization, and achieving the global environmental objective of GHGs mitigation through the implementation of methane recovery and utilization projects. State Environmental Protection Administration (SEPA) is the national implemented agency for this project, and United Nations Department of Economic and Social Affairs (UNDESA) is the international implemented agency.

Energy is the basic power of social and economic development. Exploitation and utilization of renewable energy has become important options on energy development in 21st century of most developed countries and some developing countries. The new energy and renewable energy development target set out in the Tenth Five-Year Plan is: improving the efficiency, reducing production cost, enhancing the proportion in energy structure, and the real consumption should reach 390 million tce (including consumption of conventional use of biomass energy). After the implementation of Clean Development Mechanism (CDM) and Renewable Energy Law of P.R.China passed on February 28, 2005, landfill gas recovery and utilization will have more broaden market.

SEPA supported by UNDP and GEF, cooperating with UNDESA, has organized the national and international experts to draft the China National Action Plan for Methane Recovery and Utilization (hereinafter referred as Action Plan), which provides the reference for related government departments to conduct refuse management reform, formulate policy framework and promote CDM projects, on the basis of resource analysis for municipal refuse and assessment on refuse disposing technologies and landfill gas utilization technologies, and analysis on refuse management institution and policy framework in China, absorbing international experiences on landfill gas utilization management and the domestic experience of demonstration landfill sites. During drafting the Action Plan, SEPA got strong support from former State Development and Planning Commission (SDPC), former State Economic and Trade Commission (SETC), Ministry of

Construction (MOC), and Ministry of Science and Technology of P.R.China (MOST).

1. General introduction

1.1 Issue raised and statement for this document

The strategy of sustainable development of economy, society, environment and resource has been paid more and more attention by Chinese government since 1990s. The signing of Rio Environment Development Manifesto, formulation of China 21 Century Agenda and thenceforth a series of policies in environment and energy fields show the decision of Chinese government implementing sustainable development strategy. The recovery and utilization of methane from municipal refuse landfill sites, with the multi-benefits of saving resource, environmental protection and replacing energy, is in accordance with the requirement of Chinese sustainable development strategy. In the national Tenth Five-Year Plan in implementation and Eleventh Five-Year Plan in formulation, the recovery and utilization of landfill gas was listed in the fields to support for development by related governmental departments.

In 1995, Chinese government and UNDP applied for a technical assistance project of “China: Promoting Methane Recovery and Utilization from Mixed Municipal Refuse Landfill Site” from GEF, with the objectives of implementing pilot projects of landfill gas utilization in three cities, analyzing the basic framework of municipal refuse management and the developing trendy of refuse resourciation technologies, developing the national action plan for methane recovery and utilization, conducting the capacity building of methane recovery and utilization, and achieving the global environmental objective of GHGs mitigation, environmental protection, replacing conventional energy and promoting economic development through the implementation of methane recovery and utilization projects. SEPA is the national implemented agency for this project.

Being the subcontractor of the Project, Energy Research Institute of State Development and Planning Commission (ERI) was in charge of the study and draft work for the Action Plan. According to the requirement of the subcontract between UNDESA and ERI, only the issue of landfill gas recovery and utilization should be considered in the Action Plan. However, actually, the recovery and utilization of methane is only one part of municipal refuse management. First, without effective management system for municipal landfill sites, it is impossible to set up effective action plan for methane recovery and utilization. Secondly, even if a set of municipal landfill sites with effective management system are set up, nobody will engage in methane recovery and utilization business unless there is feasible energy policy. During the procedure of study of background and barrier analysis for Action Plan, both governmental officials and experts thought that to improve the level of management of municipal refuse is the basis of setting up effective system for methane recovery and utilization. Therefore, ERI group also draft the Guideline of Implementation of Municipal Refuse Comprehensive Management and Landfill Gas Recovery and Utilization (hereinafter referred as the Guideline), apart from the Action Plan.

Several international and local technical, policy and financial consultants and experts have provided support during the draft of Action Plan, especially experts from Dutch Novem have given many modifications for the English version of the Action Plan. There are lots of useful suggestions from Mr. Hardy Wong, Senior Technical Adviser for the whole project, UNDP officials, UNDESA officials etc. The Action Plan is important result of project

implemented agency cooperation with national and international expert in the field of landfill gas recovery and utilization, and was reviewed and discussed among former SDPC, former SETC, MOC, MOST and other ministries and agencies related to the subject. The Action Plan will provide the reference for related government departments to conduct refuse management reform, formulate policy framework and guidance for municipal government to formulate environmental protection plan.

1.2 Procedure of draft

ERI of SDPC signed the sub-contract of drafting national action plan with UNDESA in April of 1998. The main contents and framework of Action Plan were proposed in March of 1999 by ERI, and were publicized on the "UN-China: Mayors Seminar on Municipal Solid Waste Management and Landfill Gas Utilization" which was held in Nanjing in the same year. In October of 1999, the first draft of Action Plan was submitted by ERI group, and ERI also held a meeting with the participants of governmental officials to get opinions on November 10, 1999. After that, ERI submitted the Action Plan to local experts and governmental officials for more suggestions of modification again, and then prepared and submitted the Action Plan and its four annexes to UNDESA formally in June of 2000. The four annexes are, (i) China municipal refuse resources assessment; (ii) technology assessment for municipal refuse treatment, disposal and utilization in China; (iii) institutional & policy framework of municipal refuse management in China; (iv) technical economic assessment for municipal landfill gas recovery and utilization in China.

During the "China International Energy Efficiency, Renewable Energy and Environment Exhibition and Conference" held in Beijing in November 2000, China and Dutch held the "Municipal Solid Waste Landfill Gas Utilization Seminar" jointly. At the seminar, Dutch experts introduced the advanced experiences in Europe, and Chinese sides reported the progress of the UNDP/GEF project "China: Promoting Methane Recovery and Utilization from Mixed Municipal Refuse Landfill Site" and drafting the Action Plan, expressed the wish that Dutch experts provide the assistance to modify the Action Plan (June 2000 version). In October 2001, Dutch experts submitted the English version of Action Plan. On the basis of absorbing the suggestions of Dutch experts and the experiences of three case studies of three demonstration cities, Nanjing, Anshan and Maanshan, ERI submitted the draft of final Action Plan, and held the review meeting in November 2001.

Before the project is finished, international and national implemented agencies organized experts revised the Action Plan and finished this final version with the support of GEF, on the basis of development of technologies and policies on landfill gas recovery and utilization in China.

1.3 Objective of action plan

The Action Plan analyzes various technical and structural barriers in China for the widespread adoption of landfill methane recovery and utilization projects to provide a series of suggestions to overcome these systemic barriers. The Action Plan provides a useful scientific reference for developing policies on marketalization of municipal refuse disposal and technical guidance for municipal administration designing and constructing landfill sites. The Action Plan is expected to provide a set of evaluation system for landfill gas recovery and utilization. It is also anticipated that the Action Plan will provide reference for international and national investors and developers identifying relevant joint venture projects.

1.4 Basic idea for action plan

Municipal refuse landfill methane recovery and utilization is a new content of the municipal refuse management in China. In quite a long time before, landfill methane emits naturally, no effective recovery and utilization system, mechanism and relating technical condition. Before implementation this project, there were few landfill sites with effective management system and hardly any examples in landfill methane recovery and utilization. This Action Plan is mostly worked out by taking the reference of international advanced experience of refuse management and the results in three demonstration cities.

Besides promoting the reconstruction of existing municipal refuse landfill sites with relatively effective management system, the more important for landfill gas recovery and utilization in China is to accelerate the construction of new modern landfill sites. The basic idea of the Action Plan of municipal refuse landfill methane recovery and utilization is; government is in charge of the plan, designing the pricing policy, and consigning related agencies developing proposals for engineering construction and operation. Enterprises conduct construction and operation after bidding. Basic equipments for landfill gas recovery and utilization will be provided after the rapid development of landfill sites. The free market competition mode is helpful to competent enterprises participating in the business of landfill gas recovery and utilization and attracting foreign investment and advanced technologies to enhance the whole level of the recovery and utilization.

1.5 Content of action plan

The main contents of the Action Plan are,

- status and prediction of resources of Chinese landfill methane
- international successful experiences and experiences from 3 demo cities
- current problems and barriers
- detailed action plan for landfill methane recovery and utilization
- implementation of action plan and related measures

2. Status analysis on landfill methane recovery and utilization

2.1 Assessment on municipal refuse resource

2.1.1 Status analysis on municipal refuse resource

The output of municipal refuse in China has being increased rapidly. As statistic data in 2003, the amount of refuse produced in 662 cities reached 164 million tons and increased at the annual average 8%. With the development of economy and improvement of living level, especially the improvement of residential fuel structure, the output and composition of municipal refuse have changed greatly. In order to make the municipal refuse resource in China clear, the questionnaire survey in 10 cities was conducted, with the following results: the output of municipal refuse in China is 0.66 to 2.62 kg per day per capita, and the average is 1.16 kg per day per capita; in some cities developed rapidly in south China, the output and composition of refuse are near those of refuse in industrial countries, for example, the refuse output in Shenzhen has exceeded that of Berkeley in California, US, reaching 2.62 kg per day per capita; the composition of refuse also changes greatly, and the organic substance has occupied 60-95% presently; the caloric value of municipal refuse varies in large range from 1850kJ/kg to 6413kJ/kg; the caloric value of refuse in 10 cities is relatively high, reaching 4000kJ/kg. The potential of municipal refuse resourciation in China is large.

2.1.2 Analysis on increasing trend of municipal refuse resource and landfill gas recovery and utilization

Major factors influencing the output of municipal refuse are as follows,

- Urban population: According to the result of survey in 10 cities, the output of refuse is over 1kg per day per capita. The city scales expand year after year and the non-agriculture population in the cities grows rapidly with the improvement of the urbanization and the increase of the city numbers in recent 20 years. There were 1.29988 billion people in China by the end of 2004. The number of cities increased from 193 in 1978 to 662 in 2003, urban population increased from 170 million to 520 million and urbanlization rate increased from 28% in 1993 to 40.5% in 2003. With the enlarging of city scale and acceleration of urbanization, the increasing rate of municipal refuse was about 8-10% from 1985 to 1995, and from 1996 to 2000, the increasing rate was reduced to 2-4%. After 2000, the increasing rate kept about 8%. With the population increasing, the output and accumulating amount of municipal refuse will increase year by year. It is anticipated that from 2000 to 2010, the increasing rate of municipal refuse will keep 8%; from 2010 to 2015, for the population is controlled effectively, environmental friendly production and consumption is widely popularized, the increasing rate of municipal refuse will decrease to 4%; from 2015 to 2020, the increasing rate will decrease to 3%.
- Resident's living and consumption level: The changes of the living and the consumption level not only influence the output of municipal refuse but also influence the composition of refuse. In recent 20 years, the residential living level increased year by year, from 1990 to 2003, the civil residents consumption increased at the annual average 6.6%. At the same time, the composition of refuse made corresponding changes, with the general trend of increase of organic substance ratio and combustible substance ratio. The result of survey shows that decomposable refuse and reusable refuse continuously increase, while the cinder content of refuse decreases. To compare with that in 1985, the

reusable refuse ratio increased by 3.8 times in 1996 and the decomposable refuse ratio increased by 52%, on the contrary, the inorganic contents such as cinder and soil decreased by 39%.

- Living fuel structure: Another important factor which influences municipal refuse composition is living fuel consumption structure. Coal is the major fuel in China, and 75% of the primary energy is coal. Coal is not only widely used in industry but also in family, and most of the families use coal as their main fuel for cooking and heating, therefore, there are a lot of coal cinder in municipal refuse, and this makes the relatively small organic substance content of refuse. Nevertheless, with the spreading of central heating and gasilization in the cities in recent years, the consumption structure of the residential fuel has had a great change; meanwhile it also causes the change of refuse composition. The inorganic substance in refuse from the area where coal is the main fuel is clearly higher than that from the areas where gas is the main fuel, on the contrary, the content of organic substance and reusable refuse from the central gas supplying areas is evidently higher than that from the coal used areas. On the other hand, residential living level in the coal-used areas is always lower than that in the gas-used areas. Kitchen refuse has become the main component because of the decrease of the cinder in the refuse, therefore, the water content of refuse increases accordingly.

  According to the historic data from 1995 to 2003 and the trend of refuse increasing in other countries, a model of forecast of municipal refuse increasing in China has been established. The calculating results are listed in following table.

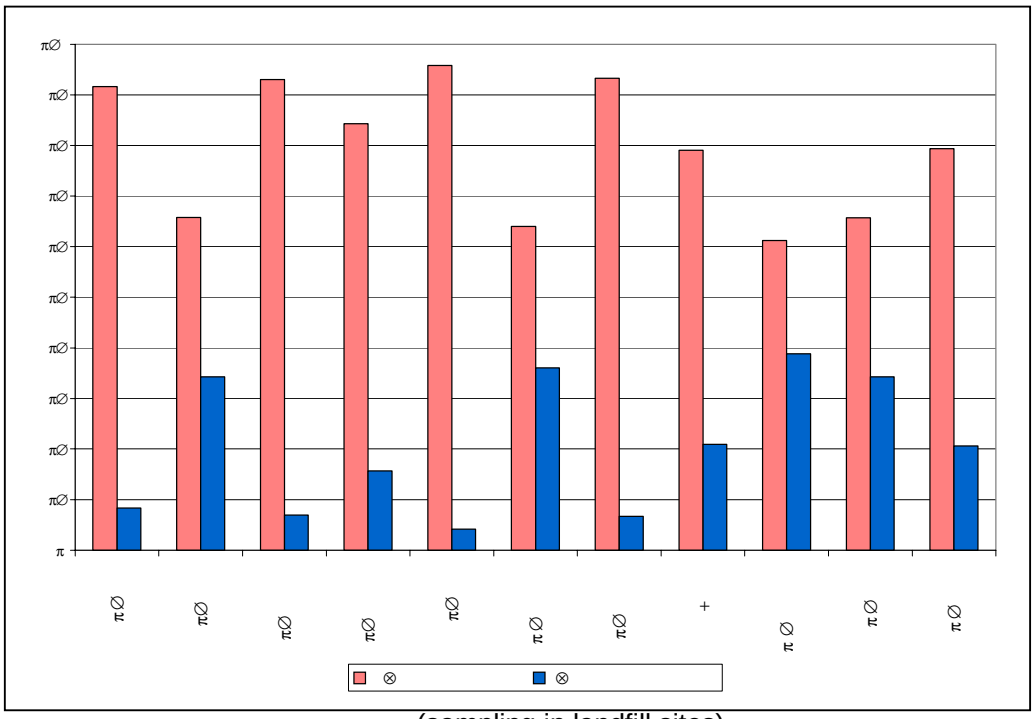
Table 1 Prediction of Chinese landfill gas resources

Year	Output of municipal refuse (million tons)
2000	118
2005	175
2006	189
2007	204
2008	220
2009	238
2010	257
2015	313
2020	363

2.2 Municipal refuse composition

The composition of solid refuse in China is similar as that in other developing countries, and it is quite different between solid refuse in the urban area and rural area. The disposal of municipal refuse is not managed well. Before municipal refuse enters the dumpsites, the refuse, which can be reused like metal, plastic and paper etc., is separated. In the municipal refuse in China, organic substance (kitchen refuse like vegetable and food) occupies large proportion, so the moisture content is high. Following figure is the compare of organic substance and inorganic substance of

municipal refuse in 10 Chinese cities. Averagely, the organic substance occupies 60-90%, while inorganic substance occupies 10-40%.



(sampling in landfill sites)

2.3 Generation of landfill gas

It is predicted and estimated by the experts that the output of municipal refuse will reach 175 million tons in 2005. The content of organic substance will occupy 79% and the content of inorganic substance will be 21%. The moisture rate of municipal refuse will be 57% and the density will be 340kg/ m^3. If 80% municipal refuse is disposed by sanitary landfill method (including simple landfill), and the landfill gas output of per kg refuse is 0.064 ~ 0.44m^3, totally 8.96 to 61.6 billion m^3 will be produced. The typical caloric value of landfill gas is 18,828-23,012kJ/Nm^3, while the low caloric value of natural gas is 37,300kJ/Nm^3. Calculated with the lowest caloric value of 18,828kJ/Nm^3, the landfill gas produced from landfill sites is equivalent to 1.2-8.3 billion Nm^3 of natural gas. The generation amount of municipal refuse in China will reach 313 million tons in 2015. Considered 60% of the refuse are disposed by landfill method, 188 million tons of refuse will be disposed annually. If all landfill gas is recovered, it is equivalent to 6.07-41.76 billion Nm^3 of natural gas, and it is huge energy resource.

2.4 Status of Chinese landfills and emission of landfill methane

At present, in China the municipal refuse is disposed using the technology of traditional landfill, without consideration of recovery and utilization of landfill methane. It is estimated that the annual quantity of municipal refuse filled is about 50 million tons. Almost all landfills have not equipped the system of landfill gas recovery, except several new built landfills, and the landfill methane is emitted to the atmosphere

openly. Lack of the on-site test information, it is difficult to estimated the total emission of landfill methane. In the study of UNDP/GEF project “China: Issues and Options in Greenhouse Gas Emissions Control” conducted by World Bank and former National Environmental Protection Administration (NEPA) jointly in 1995 and in the “Country Study for Greenhouse Gas Issues in China” conducted by former State Science and Technology Commission (SSTC) and sponsored by Department of Energy (DOE) of U.S., the emission of landfill methane in 1990 were estimated between 0.79 to2.5 Mt.

As the differences of component of municipal refuse and technology of landfill site management between China and developed countries, the emissions of landfill gas from landfills have great difference. Before 1980s, the component of inorganic substance in mixed municipal refuse in most cities in China was over 60%. Most refuse was disposed by open-dump and a few were disposed by simply landfill, hence the landfill methane could not be used as resource. After 1980s, with the enlarging of city scale, the improvement of people’s living level and the change of fuel structure, the inorganic substance in mixed refuse decreased, meanwhile, the state established the standards and criteria for refuse sanitary landfill by steps, therefore, the method of municipal refuse disposal started to change from open-dump to simply landfill. But landfill gas recovery and utilization is not considered in the sanitary landfill sites built earlier. In October of 1998, the first system of landfill methane recovery and utilization in China was built is Hangzhou, Zhejiang Province, and the landfill methane was used for power generation. In 2003, China had rapid progress in landfill gas recovery, disposal and utilization. Landfill gas burning torch system was set up in Beijing Bei Shenshu landfill site, A Suwei landfill site and Qingdao XiaoJianxi landfill site. Power plants in landfill sites in Xi’an, Wuhan, Beijing, Shenzhen and Fuzhou are being built or will be in use, such as Guangzhou Datianshan Methane Power Plant, Nanjing Shuige Landfill gas Power Plant and Wuhan Erfeishan landfill gas Power Plant are built in succession. However, the experiences for equipment construction and running management are scarce.

There were over 1,000 municipal refuse disposal sites in China in 2000, in which 70% were open dumps, so the dumps sites were about 700.

If 80% of municipal refuse is disposed by landfills in 2005 and 3% of landfills equips facilities of landfill methane recovery and utilization, the annual amount of recovery of landfill gas will be 420 million m^3, calculating 1kg municipal refuse generating 0.07m^3 landfill gas. If these landfill gas can be used, about 0.18 million tons of methane will be mitigated annually, equivalent to 3.78 million tons of CO_2. The benefit for environment is quite large. If the landfill methane is used for power generation, the power generation facility of 40MW capacity can be installed and annual power generation amount will be 390GWh. By 2015, if sanitary landfill technology and landfill gas recovery technology are adopted in 100 cities in the developed regions of China, and each city builds three landfills averagely, the ratio of landfill gas recovery after sanitary landfill to the whole municipal refuse generation will be 50%. Annual amount of landfill gas recovered will be 11.9 billion m^3, and mitigate methane 5.05 million tons. About 300 power generation facilities with each capacity of 2MW can be installed, and the annual power generation is 11.0 TWH and nearly 10,000 employment positions will be provided, with great social benefit.

3. International experiences of municipal refuse management and landfill methane recovery and utilization

It is in the primary stage of the construction of landfill sites that the landfill methane' recovery and utilization is considered in industrial countries. The corresponding pipes are installed in the process of refuse disposal to recover the landfill methane. After the first landfill gas recovery system in the world was built in Palos Verds in the south of California, US, now over 270 landfill sites in over 20 countries landfill gas recovery and utilization systems. Since the energy supply in industrial countries is sufficient, landfill methane is generally used for power generation instead of being used as living fuel or car fuel. Therefore the incentive policy will be made focusing on power generation.

In the implementing of British Nun-fossil Fuel Trade, landfill methane recovery and utilization is supported as renewable energy. Beneficial policy for renewable energy power generation is also applied to landfill methane power generation, which makes landfill methane power generation an important part of renewable energy power generation with its production cost being one of the lowest.

In some cities in Canada and the United States, municipal government invests on standard landfill sites and landfill gas recovery equipment and sell the right of using the landfill gas by auction to the public and therefore to make the developer to develop and utilize the landfill gas. Generally, the payoff period of the investment on landfill sites and equipment of landfill gas recovery and utilization are 10 years. By this way, the construction of landfill sites can be standardized and also the risk of the developing the recovery and utilization of the landfill gas is reduced. Thus the developer will be more active to be involved in this field. Making the landfill gas's recovery and utilization a marketing behaviour will reduce the cost.

In a word, the international experiences are summarized as following points.

3.1 Set up standard and regulation

In developed countries, sanitary landfills have to comply with strict requirements, such as waste acceptance procedures, bottom lining, top cover, leachate collection and treatment and LFG extraction and utilization. Furthermore monitoring activities and after care measures are required. These regulations and standards promote the recovery and utilization of landfill gas. European countries have to fulfill the requirements according to the European Council Directive 1999/31/EC on the landfill of waste. The Directive on landfill of waste sets out general requirements for all classes of landfill of waste. Its contents are,

- Detail standard for the new built landfill
- Rebuilt and management of old landfill
- Closing of landfill
- Standard for the O&M of landfill

All these regulations require that landfill gas be forbidden to be emitted to atmosphere directly, and must be recovered or disposed by burning.

3.2 Set up flexible organization and management system

There are three types of the organization and management systems for the landfill gas recovery and utilization project.

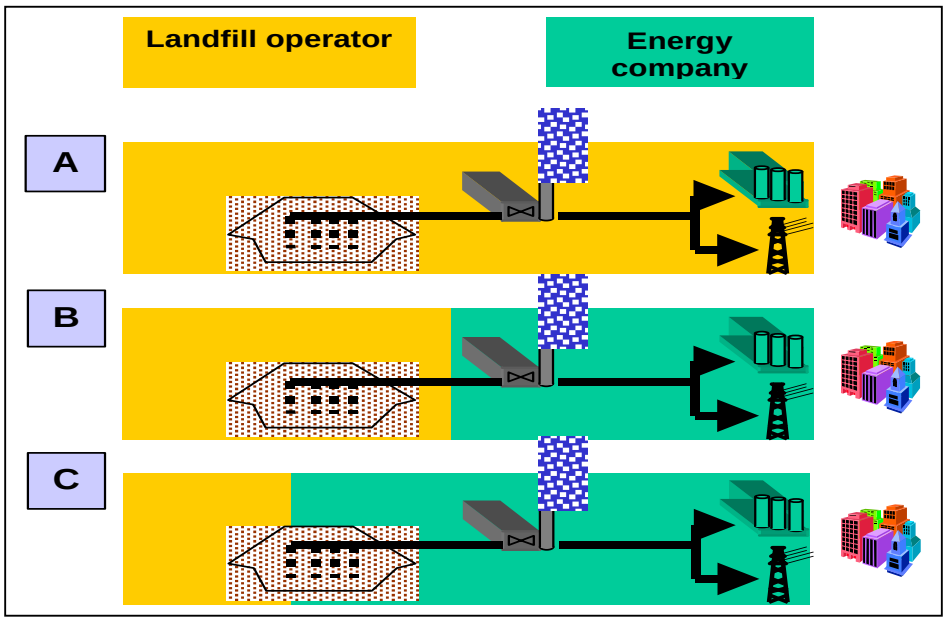


Figure 2 Types of the organization and management systems for the landfill gas recovery and utilization project

- Municipal utility is the owner of landfill site and facilities of landfill gas recovery and utilization, and it sells landfill gas to energy company. Energy company sets the landfill gas utilization and power generation facilities.
- Project developers sign the contract to be in charge of the O&M of the landfill, and they have the right of using the landfill gas or selling the landfill gas. They sell landfill gas to the energy company, and energy company sets the landfill gas utilization and power generation facilities.
- Individual developers build the landfills, and also equip the landfill gas recovery facility. They sell landfill gas to the energy company, and energy company build the landfill gas utilization and power generation facilities.
- Independent project developers sign the contract to be in charge of the O&M of landfill site and landfill gas utilization project. One independent developer may sign many contracts, to reduce the operating cost through enlarging the business scale. Furthermore, the cost of negotiation with power company is deducted.

In fact, there are cases of energy company in charge of the O&M of the landfill. For all types, government or users will pay the cost of landfill site, which makes the landfill gas recovery and utilization profitable.

3.3 Definite the economic incentive policies

3.3.1 Landfill and landfill gas collection

Generally, the investment and operating cost of landfill sites are paid by the government or the users. The government pays the cost from the tax or authorizing the landfill owners to collect the refuse charge. In most UN countries the households typically produce 1 ton of solid waste per year and pay between 80 -100$ for waste collection. Before 1990s, the general situation is that government paid such cost from the tax, but now, most cost are collected from the residents and the refuse producers. The owner of landfill site can get the preferential loan from the bank, and pay back the loan by collecting the refuse charge. The subsidy policy, which was implemented from 1970s, has promoted the building of landfill gas recovery and utilization equipment and the rebuilding of old landfills. Presently, it is clear that the landfill gas recovery and utilization project can get the profit. At present, in developed countries, the owners of landfill sites are also in charge of the building of landfill gas recovery and utilization facilities.

In summary, the economic incentive policies in developed countries are focused in following points,

- Refuse charge
- Preferential loan
- Subsidy to the landfill gas recovery and utilization demo projects to promote its commercialization

3.3.2 Energy utilization of landfill gas

In most developed countries, landfill gas utilization is supported by the government. Most utilizing methods are for power generation. Therefore, the economic incentive policies for landfill gas utilization are included in the framework of renewable energy policies. Major policies are,

- Grid connection policy: power company must buy the electricity produced by landfill gas enterprise;
- Power price policy: adopt Green Power Price or subsided price, generally the power price from landfill gas utilizing facilities is 3-5 cents/kWh
- Mandatory Share: it is being implemented in some countries. The green energy certificate market can also be used to meet an obligation to produce a specific amount of renewable electricity in a market.

3.3.3 Information centre and consulting service

The landfill gas recovery and utilization projects are all in small scale. In order to decrease the cost of project developing, the governments support to set up the technology, information centers and provide the consulting services. For example, the US Environmental Protection Agency specially set up the consulting center for landfill gas projects. In Netherlands, there are also such centers. These information centers provide following services mainly,

- Develop the national action plan
- Implement the demonstration projects
- Prepare and print the technical manual for the landfill construction and landfill gas utilization

- Publicize the information in this field
- Organize the training and seminars for the developers, engineers and governmental officials

International successful cases

In 1980s, US established the strict standard for the sanitary landfill, including the issue of landfill gas disposal. In many states of US, it is regulated that landfill gas must be recovered, and resource utilized or fire directly, meeting the related requirements of environmental protection. By the end of 1999, there were 259 equipment of landfill methane for power generation being operated, with the total capacity of over 750MW.

Considering the danger of landfill gas emitting directly, Netherlands began to implement the national plan of landfill methane recovery and utilization from the late of 1980s. Then Netherlands formulated the regulation of sanitary landfill, requiring that all landfill sites must recover the landfill gas and consider its utilization issue. During over ten years after this regulation was formulated, almost all new built landfills and old landfills equipped with the landfill gas utilization facilities. Netherlands is a country with small territory, and the population is only 15 million. However, over 40 landfill methane recovery and utilization facilities have been installed so far, with the total capacity of over 80MW.

It is estimated that by 2020, the urban population in China will be 700 million, and the landfills will be over 1600. If 360 landfills use the landfill methane recovery and utilization facilities, the total power generation capacity will be 720MW.

3.4 Experiences and lessons of three demo cities

Three demonstration projects of landfill gas recovery and utilization began to be implemented in three cities (Anshan, Maanshan and Nanjing) in China, which were financed and supported by UNDP/GEF project of “China: Promoting Methane Recovery and Utilization from Mixed Municipal Refuse Landfill Site”. In Maanshan, the landfill gas is used to burn medical wastes; the engineering construction was finished in May 2004 and in operation in June of the same year. In Anshan, the landfill gas is used as clean alternative fuel for cars. In Nanjing, the landfill gas is used for power generation and grid connection; the demo project was set up in May 2002 and in commercial operation. As the three demonstration projects get the international supports of technology and fund, their experiences are not only with international characteristics but also with Chinese features. Presently, the major problems of demonstration projects are,

- Power purchase agreement of landfill gas for power generation and the power price
- The determination of power capacity and the arrangement of time of facilities installed
- Purification of landfill gas for residential fuel and vehicle fuel

Furthermore, there are also some problems for the three demonstration projects in the aspects of institutional building, especially for the project operation mechanism and financing aspects. General speaking, local environmental and sanitary bureaus are in charge of the clean and disposal of municipal refuse, and the capital is from local finance. However, for the landfill gas recovery and utilization, it is necessary for local government to set up the special fund to ensure the capital for investment and O&M cost of landfill gas recovery and utilization projects. Regarding the three demonstration project, it is easy to be implemented because they are financed by the international cooperative projects. But generally, it is difficult for central government and/or local government to arrange special fund for landfill gas recovery and utilization.

In the aspect of institutional building, the landfill gas recovery and utilization are related with many governmental departments, such as environmental protection department, municipal planning department, labor and safety department, electric power department, transportation department and municipal appearance department etc. The work of municipal environmental and sanitary department is related with these departments. Therefore, it is necessary to set up a special office leaded by leader of local government in charge of the coordination of implementation of landfill gas recovery and utilization.

Case of Nanjing

A modern landfill site is built in Nanjing, with the lifetime of 20 years and the disposal capacity of 1200 tons per day. The annual amount of methane recovery will be 6.3 million m^3, and the capacity of power generation facility is 2.5MW at present and will reach 5.2 MW ultimately.

The Nanjing case has solved several problems and barriers of landfill methane recovery and utilization of modern landfill successfully, and its experiences are,

- Develop the model of calculating the landfill gas production, and calculate the landfill gas generation amount and its trend, which convince the developers
- Set up commercial operation mechanism separating the functions of government and enterprise
- Sign the Power Purchase Agreement and determine the power price which can be accepted by the developer and the government
- Set up BOT mechanism in the field of landfill gas recovery and utilization, and train the technical and business personnel

4. Problems and barriers of landfill gas recovery and utilization in China

Landfill gas has increased notably with the increase of refuse and its organic composition in China in the recent years, however, the technology levels for most of the landfill sites are relatively poor, and most of the methane is emitted from the landfill sites without control, which has caused serious environment pollution. The explosion accidents caused by landfill gas had been happened in the cities such as Shanghai, Beijing, Chongqing and Yueyang. Therefore, it is necessary to recover and use landfill gas from both the refuse dump sites and the new sanitary landfill sites.

According to the international experiences and the experiences and lessons from three demonstration projects, the problems and barriers of landfill gas recovery and utilization in China are in following aspects.

- Management mechanism barriers. Government and enterprises are not separated and the basis of industrialization has not formed.
- Economic policy barriers. The cost of refuse disposal is supported entirely by local finance.
- Technical barriers. There are not enough experiences in making, installing and operating methane recovery and utilization facilities.

4.1 Technical barriers

4.1.1 Calculation of landfill gas generation amount

The generation of landfill gas from landfill site is a very complex procedure, and the investor need the detail estimation of landfill gas contents, its long-term generation trend. However, the calculation is quite complex and difficult. Following figure 3 is the typical landfill gas generation procedure, but to get the detail curve need careful investigation and accurate calculation. The difficulties are,

- *Calculation of the landfill gas generation amount.* The generation amount of the released landfill gas can determine the important problems such as whether the utilizing system of landfill gas can be practicable or not, what kind of method can be used to control and reuse the released landfill gas effectively and how much scale is the landfill gas collection system. However, the factors influencing the landfill gas generation amount are very complex, how to calculate the landfill gas generation amount accurately has become the important respect to control, recover and utilize the landfill gas.
- *Determination of the gas generation life and gas generation rate.* To evaluate the feasibility to use the released landfill gas, the gas generation life and generation rate are both important factors besides the gas generation amount. Each ideal landfill with a landfill gas recovery system should keep long-term gas generation life and steady gas generation rate with a high gas generation amount.
- *Mode to control, recover and utilize the landfill gas:* The following questions are important subject to study the landfill gas such as how to design the landfill gas collection system to increase the collection efficiency and what kind of mode is used to collect and utilize the gas to improve the utilizing efficiency.

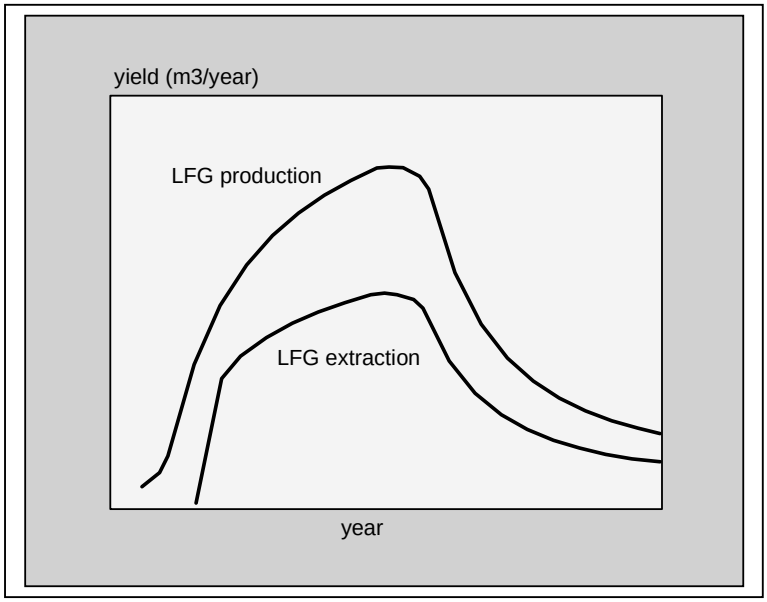


Figure 3: Typical landfill gas production and extraction curve

4.1.2 Landfill gas recovery and utilization technology

The options of landfill gas utilization mainly include power generation technology, residential fuel technology and vehicle fuel technology.

Power generation technology

Generating power from landfill gas is one of the most commonly applied technologies in the world. The advantages of this technology are,

- The technology is mature. The general generator with mature technology or special biogas generator can be used as the facility of landfill gas for power generation. Compared to other mode of landfill gas utilization, the cost is low;
- It is not limited by the local condition of the users and the power generated can be transmitted by grid;
- The fuel for power generation (landfill gas) can be stored for a short term, so the power generation from landfill gas power generation system can be as the peak-adjust power source. Compared to other renewable energy technologies, it is with good peak-adjust ability, so the power companies are willing to purchase the power generation from such facilities;
- The power capacity for one project is not quite large, so it is easy to be accepted by power grid, even if the grade of nearby power grid is not high;
- It has higher economic efficiency and is more commercially viable.

The main technical barriers lie in the distance between landfill sites and the power grid and the grid connection condition. Generally speaking, the barriers of power generation from landfill gas are mainly as following,

- *High cost of project preparation*: Generally, there is no power transmission system in landfill sites. Landfill gas power generation system need to be

approved by power companies and to get legal and formal grid connection agreement and reasonable grid connection price. Such procedure is very complex generally. The cost for preparation of conventional power generation project is about several million US$, which is about 1%-3% of the total investment. However, for the project of power generation from landfill gas, such cost of preparation is much higher.

- *Lack of practical financial incentive policies:* Although Chinese government has formulated a series of financial policies, such as the new passed *Renewable Energy Law,* to encourage the development of renewable energy, including power generation from landfill gas, the problem how to implement the policies in practice and problem of implementing procedure exist. The standard agreement for grid connection, Power Purchase Agreement (PPA), the method and criteria for calculation of power price are lack.
- *Lack of special methane power generation facilities:* The landfill gas power generation equipment used in Hangzhou Tianziling landfill site is made in the United States. At present, methane power generation equipment and manufacturing technology of China is lagged behind international levels.
- *Unstable production of landfill gas:* the production of landfill sites is unstable and it is difficult to estimate the suitable capacity of power, therefore, these make great difficulty for the preparation of feasibility study and making decisions.

Above barriers in the aspect of technology and policy limit the development of using landfill gas for power generation, especially the issue of grid-connection which is one major barrier of landfill gas power generation in the world.

Residential fuel technology

If there are small villages and residents near the landfill sites, the purified landfill gas can be used as resident's gas of good quality. The common coal gas equipment used in cities can be used for landfill gas. China is experienced in biogas utilization for living fuel. There is no technical obstacle in the landfill gas utilization for living fuel if there are users. The limitations for its utilization are,

- The purification of landfill gas and safety issue. The composition of landfill gas is complex and unstable, and landfill gas are with many kinds of noxious and hurtfully gas, so it require the high standard for the purification and its operation;
- The distance for gas transmission and the cost issue. Generally speaking, the factor to limit the development of this technology is the investment on landfill gas transmission pipe and pressure increasing system. Usually, there are not large residential areas near landfill sites, so the cost of the landfill gas transmission will be too high for the residents.

Vehicle fuel technology

Methane is the main content of the landfill gas purified, which can be used as the fuel of car like natural gas. The obstacle is the commercialization of the equipment for further development of the technology. The market as the fuel of car has not accepted the Compressed Natural Gas (CNG). Landfill gas can hardly reach commercialized operating scale since the limitation of its production. Moreover, the user scope is also limited. At present, the main user is the refuse transportation vehicle, which can reduce the cost of the gas as vehicle fuel significantly since it is not necessary to construct gas station beside the landfill sites.

4.2 Main domestic difficulties

4.2.1 Lack of facilities

Methane recovery and utilization is not included in the construction plan of old landfill sites and methane is produced and released free. This makes it difficult to develop methane recovery and utilization in existing landfill sites. If the reconstruction is done, a lot of inputs are needed.

4.2.2 Mechanism barriers

Landfill gas recovery and utilization along with refuse disposal is restricted by management and investment mechanism. Civil finance pays the municipal refuse disposal cost and agencies with governmental responsibilities conduct disposal. For lack of investment return policy and detailed marketalization measures, it is very difficult for enterprises to enter this field.

4.2.3 Law/regulation barriers

Statute for Civil Appearance and Environmental Sanitation Management and Law for Solid Waste Pollution Prevention and Control are two supreme regulations in municipal refuse management and don't prescribe other enterprises are entitled to engage in business in this field. This prescription is lagged behind the current trend, but not abolished.

4.2.4 Resource integrated utilization policy barriers

Although the government has formulated some policies in the fields of renewable energy and resources, such as the tax-free policy, such policies are not implemented quite well in demo cities. The main reasons are,

- The policies are difficult to implement;
- Most enterprise are not familiar with these policies;
- Some policies make the enterprises had to undertake the responsibilities of government.

Existing policies which can be used

The document issued by former SDPC and SETC: the industry of renewable energy and environmental protection is listed in the priority development and support industries.

Policies issued by Ministry of Finance (MOF) and State Tax Administration (STA): for the municipal refuse project for power generation, the Value-Added Tax (VAT) will be paid back.

Document issued by former SDPC and MOST: Power generation from renewable energy has priority to connect with power grid, and State Development Bank should provide the favorable loan and government provide subsidy for the interest of such loan. The power price should be the payback price.

Regulation issued by MOF: renewable energy project and environmental protection project should be included in the namelist of high priority fields of international cooperation.

4. 2.5 Lack of technology and management experiences

According to the experiences and lessons from demonstration cities, project organization and implementation are short of experiences in technology and management.

- The government is lack of the experience in marketalization for the municipal refuse disposal, as a result the matters related the project development are discussed for a long time but without any final decision;
- Enterprises are lack of the technical personnel of importing the facilities, thus they do not have the ability of finding the suitable cooperative partner in time;
- The project developers are not access to the consulting and information services, so they are not provided the fair and reliable business information;
- There is no systematic management mode during the approve of project;
- Standard approving project procedures have not been built;
- There is no continuity for the implementation and management of project;
- Lack of basic research on the component of the refuse and the landfill gas generation mechanism, lack of clear estimation and forecast of the generation of the landfill gas, lack of clear target of landfill gas recovery and utilization, as a result increasing the difficulty in recovery and utilization of the landfill gas;
- Lack of successful experience in landfill gas recovery and utilization, difficult to attract enterprises to join in the landfill gas recovery and utilization;
- The electrical utility system reform is just at the beginning stage, there is not a matured commercial market environment for Independent Power Producer (IPP) mechanism, the cost of developing landfill gas power generation project is too high, which limit the landfill gas recovery and utilization.

5. National action plan for landfill gas recovery and utilization

5.1 Technical objectives of action plan

Following table shows the predicted quantity of municipal refuse and corresponding landfill sites, calculated and estimated by the expert group. The objectives are to build 240 and 300 modern landfill sites with landfill gas recovery facilities by the year of 2010 and 2015 respectively, and to recover 2.5 billion m^3 landfill gas (equivalent to energy of 120PJ, and the emission reduction of 13 million tons of CO_2).

Table 2 Prediction of municipal refuse disposal and the recovery of landfill gas

Year	Refuse output (Mt/year)	Refuse disposed by landfills (Mt/year)	Amount of landfill sites	Quantity of landfills with landfill gas recovery facilities	Energy recovery (PJ/year)
2005	175	140	30	24	10
2010	257	180	240	216	100
2015	313	188	300	300	120
2020	363	218	360	360	120

5.2 Detail contents of action plan

In order to realize above objectives, the recommended Action Plan will focus on the following components, aiming at the problems and barriers of Chinese landfill gas recovery and utilization, and absorbing the international and local successful experiences:

- Legislation, regulation and standard development;
- Economic incentives;
- Education and awareness;
- Information dissemination and technical training;
- Institutional strengthen and barriers removal actions;
- Demonstration and promotion activities;
- Financial arrangement.

5.2.1 Legislation, regulation and standard development

Currently, most landfill sites are constructed in traditional way, which doesn't require landfill gas recovery and utilization and result in landfill gas release free, the environmental pollution and even accidents. Therefore the national action plan should pay attention on the following legislation and regulation development.

- To develop a national regulation, requiring the utility should purchase the electricity, gas, thermal or other energy products, which produced by the landfill system.
- To develop detailed rules for implementation of Renewable Energy Law;

- To set up legislation, which encourages private sector to construct, operate and manage the landfill site including landfill gas recovery and utilization;
- To develop standards on landfill gas recovery and utilization system design, construction and maintaining.

5.2.2 To accelerate the management institution reform and industrialization of refuse disposal

- Government authorities should formulate reform scheme for environmental and sanitary industry, improve the refuse charge policy and the implementation, and conduct refuse clear and disposal through enterprises and market;
- Operation of landfill sites should be supervised by environmental protection administration in order to ensure the landfill gas recovery system normal running.
- The recovered landfill gas should be used as power fuel, boiler fuel or other energy purpose and its directly emission is forbidden.

5.2.3 To develop economic incentives for promotion landfill recovery and utilization

Economic incentives are the major driving force for inducement of enterprises to adopt the landfill gas recovery and utilization. The major incentives should be included the followings:

- Prices incentives: fuel energy enterprises should buy the landfill gas, power generation, or other energy products with reasonable price, such as, the power purchase price should be not be less than the wind power price in the same region, the landfill gas sales price should be not be less than the natural gas price in the same region.
- Taxation incentives: the business for landfill gas recovery and utilization could get income tax reduction and exemption;
- Tariff incentives: The imported high-tech equipment for landfill gas recovery and utilization can get a duty free, which has applied for other high-tech equipment system;
- Equipment production incentives: Encourage enterprises to research and develop industries related to landfill gas recovery and utilization.

5.2.4 Education and awareness activities

The following activities for the education and awareness should be conducted:

- A senior level government staff international study tour for the landfill system construction and management should be organized, which consists of senior official of SEPA, National Development and Reform Commission (NDRC), MOC, and city mayors. The study tour is helpful for the senior government staff to better understand the importance of landfill gas recovery and utilization in terms of circular economy, environmental protection and human living quality improvement;

- To develop a training program for the personnel engaging in landfill gas recovery and utilization engineering design on the engineering design and installation of the landfill recovery and utilization equipments;
- To train the local environmental protection administration staff for their better understand of design, construction and management of landfill system equipped with methane recovery and utilization facilities and improvement of their capability of supervision;
- To develop education on Polluters Pays Principle as the basis of implementation of refuse charge system;
- To promote the public awareness on landfill gas recovery, waste recycling and building a resource efficient society by all kinds of media;
- The role of NGO in promoting public awareness activities should be played fully.

5.2.5 Information dissemination and technical training

Major information dissemination and technical training activities for the popularization of landfill gas recovery and utilization include following items:

- To conduct regional information dissemination workshop, seminars or trainings for the national and local government and enterprises;
- To organize technologies, equipment and system exhibition for national and international technical information exchange;
- To encourage the private and public participation for the landfill gas recovery and utilization, such as promoting residential to buy the landfill gas and its energy product like electricity, auto-fuel and thermal at green price;
- To set up information dissemination agency for landfill gas recovery and utilization.

5.2.6 Capacity building for action plan implementation

Capacity building is the basic foundation for all of the national action plan activities. Following capacity building activities should be conducted:

- To set up a national leadership or coordinating group, which consists of the senior government officials from SEPA, NDRC, MOF, MOST and MOC. Such group can supply guidance on policies and institutional coordination during the action plan implementation.
- To set up a program implementation office under the leadership group for the conduction the national action plan activities.
- To set up market operation agencies for the landfill gas recovery and utilization, such as energy service company for power, thermal or gas generation, distribution and marketing.

5.2.7 Enterprises' participation

Absorbing the international and Nanjing's successful experiences, it is suggested to encourage and support the project developers of commercial landfill gas recovery and utilization, and the main activities include,

- The national government encourages market operation and commercial development of refuse disposal;
- Publicize the information of project investment through seminars and provide the fair competition opportunity for the enterprises;
- Set up the large scale energy service company through market competition;
- The government formulates the standards and regulations to standardize the activities of enterprises.

5.2.8 Demonstration and promotion activities

In the inception period, the national action needs developing technical demonstration activities as following:

- Increasing the demonstration items in the three selected sites supported by GEF according to the national action plan;
- Selecting other 10 cities to conduct management system reform demonstration in refuse disposal industry.

  The demonstration items should include following:

  - Implementation of landfill system design, construction and maintenance and methane recovery and utilization equipments;
  - Management of commercial methane recovery and utilization project ;
  - Commercial mode for grid-connected price, power generation and sales.

5.2.9 Financing mechanism

The sufficient financial arrangement can ensure the successful of the national action plan. The financial flows can be from:

- Governmental financial budget, which has been put for the municipal refuse management;
- Bilateral assistance or Overseas Development Agency (ODA) financial support;
- GEF, WB and other international financial agencies;
- China Development Bank (CDB);
- Commercial banks; and
- Private investment.

More financing channels should be developed, including international assistance and domestic investment. The assistance from GEF, bilateral cooperation and ODA should be broadened, and make landfill gas recovery and utilization as the new item of the WB or Asian Development Bank (ADB) assistance. For domestic capital, private investment should be emphasized besides the governmental finance and capital from bank.

5.2.10 List landfill gas recovery and utilization in the national renewable energy program

The recovery and utilization of landfill gas should be listed in the national renewable energy development program, and be provided the same favorable policies of renewable energy projects.

5.2.11 International assistance plan

China is a developing country lack of resources with huge population pressure and serious contradiction between economic development and environmental protection. To solve the contradiction, strengthening the capacity building is an important way for China and foreign assistance is necessary.

Now, the recovery and utilization of landfill gas in China is in the starting stage, with relative weak management capacity, technical service capacity and public awareness, and all kinds of resource inputs are deficient. Therefore international assistance is necessary to strengthen the capacity building for landfill gas recovery and utilization. Major activities include,

· ***Formulate the technical standards for design and construction of modern landfill sites and landfill gas recovery and utilization projects.*** Taking the experiences of design and construction of landfills and landfill gas utilization in three pilot sites as reference, the technical standards for design and construction of landfill sites and landfill gas recovery and utilization will be formulated, combining the current technical standard of sanitary landfill in China. The related technical training will be also conducted.

· ***Establish training mechanism for landfill gas recovery and utilization.*** Support the training center built during the implementation of this project to strengthen staff building, compile the training materials, make out training program and hold technical training, and form the commercial training mechanism.

· ***Set up the propaganda and education program for landfill gas recovery and utilization.*** The technical information of landfill gas recovery and utilization will be disseminated and propagandized through various media.

· ***Enlarge the scope of technical demonstration for landfill gas recovery and utilization.*** Demonstration scope will be enlarged to 10-20 cities, which is the preparation for the formulation of related policies. It is suggested that these demonstration projects should be included in the bilateral and multilateral assistance projects.

5.3 Policies and measures for the implementation of action plan

In order to implement the action plan successfully, the government should adopt following methods.

5.3.1 Institutional reform

Implement institutional reform in municipal refuse clean, recovery and disposal

agencies supervised by municipal construction or supervision departments, and separate government and enterprises. Market-oriented competition mechanism should be introduced to refuse clear and disposal, landfill gas recovery and utilization industry. Engineering bidding mechanism should be implemented.

5.3.2 Economic incentive policy

It is suggested that power generation enterprises from refuse burning, landfill gas recovery and utilization enterprises share the economic incentive policies of renewable energy. The policies including:

- Grid connection policy: Power company must buy the electricity produced by refuse burning, landfill gas enterprise;
- Power price policy: the grid connection price is calculated based on payment for the principal and interest plus reasonable profit;
- Tariff policy: the key equipment used for landfill gas power generation shares the preferential import tariff and the import value added tax;
- Investment policy: CDB list the landfill gas power generation project in priority projects to support and offer interest subsidy like wind power project.

5.3.3 Industrialization policy

Enterprises are encouraged to develop industries related to landfill gas recovery and utilization. Private companies, foreign owned companies are encouraged to join in the development of landfill gas recovery and utilization industry. The landfill gas recovery and utilization should be listed in the inventory of industries given priority by country. Foreign investment should be absorbed in municipal refuse comprehensive utilization project including landfill gas recovery and utilization.

5.3.4 Financing mechanism

The government should encourage the development of finance sources. Apart from the governmental finance, private banks, enterprises and international agencies should be included. To encourage the private agencies to participate in the projects will decrease the budget of governmental finance greatly. Presently most municipal refuse management programs are financed by the international assistance funds. Few large modern refuse disposal equipments are supported by local finance.

6. Implementation of action plan

The Action Plan should be implemented through stages.

6.1 Initial stage of commercialization

First three pilot projects on landfill gas recovery and utilization in Anshan, Maanshan and Nanjing will be implemented, and demonstration of technologies will be done to obtain the experience data. After the institutional reform in three cities is implemented, the plan for large-scale technology dissemination will be formulated. US$6,000,000 support from international assistance will be needed in this stage, in which US$5,300,000 will be used for technology demonstration, and US$700,000 will be used for institutional reform. Main projects are as following:

- Build three municipal landfill sites meeting the international standard;
- Build facilities of landfill gas recovery and utilization for power generation, residential fuel and vehicle fuel;
- Establish energy service companies using landfill gas as energy product;
- Establish training centers for landfill gas recovery and utilization technology;
- Work out technical standards for plan, construction and operation of landfill sites;
- Implement management institution reform in three demo cities, and build new management institution following the international experience.

6.2 Medium stage of commercialization

10 to 20 cities will be selected for the demonstration of landfill gas recovery and utilization. This program need a total funding of US$60 million to support these selected cities to fundamentally reconstruct old landfill sites to modern ones with landfill gas recovery and utilization systems in five years. Meanwhile, related commercial development policies for the landfill gas recovery and utilization should be formulated. Main projects are as following:

- Reconstruct 20-30 existing landfill sites, and more landfill gas recovery and utilization facilities should be equipped;
- Conduct commercial operation for landfill gas utilization project;
- Promote the refuse management institution reform, summarize the experience of demonstration and pilot projects to make out institutional policy, economic incentive policy framework in government of central, local and municipal level.

6.3 Stage of commercialization

In this stage, the international assistance will be mainly in the field of capacity building of related governmental departments, through support on the technical training, policy study and information service. The management institution, technology level (including research, design, installation and operation), and management capacity (including project management, environmental supervision) will be improved in ten years. All types of enterprises have opportunities to participate in municipal refuse disposal (including landfill gas recovery and utilization) project to realize marketalization and industrialization of that.

7. Key points of action plan

Appendix B – National Action Plan

Issue	Major barriers	Actions overcoming the barriers	Related agencies for implementation of actions
Landfill gas recovery	Lack of mechanism of coordination and management	Set up coordination group	Related governmental sectors
	Lack of capital for building modern landfill sites	(i) increase government input (ii) user charge (iii) preferential loan from CDB (iv) bilateral and multilateral fund (v) commercial finance	(i) local government (ii) municipal residents and other customers (iii) NDRC and CDB (iv) MOF, MOC (v) WB, ADB, local commercial banks, private investment etc.
	Lack of successful experiences of landfill gas recovery and utilization projects	Develop demonstration projects on the basis of international experiences	Anshan, Maanshan, Nanjing and other ten cities
	Lack of O&M experiences for modern landfills	(i) implement the demonstration projects (ii) edit training materials (iii) build training centers (iv) conduct the related training	(i) GEF, local governments and enterprises (ii) International and national experts (iii) Municipal government in demonstration cities, etc. (iv) Staff of SEPA, MOC and related agencies
	Shortage of the awareness of harm of direct emission of landfill gas	(i) propaganda by various media (ii) study tours to other countries and other cities (iii) print brochures	(i) TV and newspaper (ii) SEPA, MOC (iii) Training center and other educational agencies
	Shortage of special facilities for the operation of landfill sites	R&D and import of special facilities	MOST, enterprises, research institutes, etc.
	Lack of the technology of calculation of landfill gas generation	Develop the software and models according to Chinese conditions on the base of international experiences	Research institutions, MOST, GEF

Appendix B – National Action Plan

Issue	Major barriers	Actions overcoming the barriers	Related agencies for implementation of actions
Landfill gas utilization for power generation	Lack of definite and attractive policy of power price	Determine the power price of landfill gas for power generation, taking the reference of the regulation of wind power price	NDRC, power company, and local price departments
	Without standard Power Purchase Agreement (PPA)	Make up standard PPA	GEF, demonstration cities, power company etc.
	Great difficulty in grid connection	(i) adopt the power grid-connected policy of renewable energy (ii) Mandatory Market Share (MMS) (iii) Green power price	(i) existing policies, implemented by the power companies (ii) World Bank projects in research or demonstration now (iii) NDRC, power company, and local price departments
	Difficulty in determination of power installation capacity for lack of the technology of calculation of landfill gas generation, as a result the great	develop suitable models of landfill gas generation and optimal power capacity	GEF, research institutes, MOST etc.
	Lack of project developer of small scale power generation	(i) encourage small scale power generation project developers (ii) encourage small scale power generation systems (iii) formulate the standard procedure of small scale power generation projects	(i) MOF, NDRC (ii) NDRC, power company (iii) GEF, enterprises, power company
Landfill gas utilization for alternative fuel (such as vehicle fuel, residential fuel etc.)	Lack of purification technology of landfill gas	Develop the purification technology	GEF, enterprises, MOST etc.
	Small scale, as a result without useful value	(i) enlarge the scale of landfills, and several cities build landfill site jointly (ii) look for small scale customers	(i) suitable for the cities in south of China, with relative large population density (ii) local environmental protection

Appendix B – National Action Plan

Issue	Major barriers	Actions overcoming the barriers	Related agencies for implementation of actions
		(iii) preferential price policy for landfill gas as fuel, no less than that of local gas with the same caloric value	bureaus, and small towns/villages (iii) local price departments

8. Policies development on landfill gas recovery and utilization

8.1 Clean Development Mechanism (CDM)

The Kyoto Protocol, an international and legally binding agreement to reduce GHG emissions world wide, entered into force on 16 February 2005. In Article 12 of Kyoto Protocol a Clean Development Mechanism (CDM) is defined, which is a cross-border reducing GHG emission mechanism, which is a flexible mechanisms of the Kyoto Protocol. CDM permits Parties included in Annex I to achieve compliance with their quantified emission limitation and reduction commitments by provide Parties not included in Annex I with investment and technology for GHG reduction projects. CDM is a double-win mechanism. For developed countries, it brings cost effective reduction schemes and more broad market of technology transferring. For developing countries, it brings more opportunities including: (1) alleviating the negative effect of climate change; (2) broadening financing channels and getting advanced technologies; (3) promoting capacity building; and (4) reducing regional pollutant, etc.

China carried out the UN Framework Convention on Climate Change effectively and ratified the Kyoto Protocol in August 2002. Chinese government promulgated the Temporary Management Measure for CDM projects in July 2004. This Measure defines the priority fields, approving qualifications, management and implementation agencies, procedures and other arrangements of CDM projects. In China, the major priority fields for CDM projects are increasing energy efficiency, developing new energy and renewable energy, and recovery and utilization of landfill gas and coal gas.

China is one of the developing countries with great GHG reduction potentials and has broad prospects for cooperation. WB study shows that China is the largest market for CDM projects provision and occupies nearly 60 percent of the CDM projects in the world.

At present, there are two major CDM projects in landfill gas recovery and utilization in China. One is Adding Landfill Gas Comprehensive Disposal Project. Facilities made in US are selected after bidding in this project. The advantages of the selected facilities are vaporizing landfill leachate by burning landfill gas recovered to realize methane reduction and control wastewater by using waste gas. This project, the first CDM project in China, is finished and put into use with good result. The other is Landfill Gas Recovery and Utilization in Handan Harmless Disposal Landfill Site Project. The intent cooperation agreement with an Italian corporation was signed in June 2005, which means this project was in the implementation stage. Handan Harmless Disposal Landfill Site has become the first one for implementation CDM project in landfill gas recovery for power generation.

8.2 Renewable Energy Law

To promote renewable energy development, increase energy supply, improve the energy structure, guarantee energy safety, protect environment and realize the sustainable development, Renewable Energy Law in P.R. China was passed in February 2005. This law will take effect on January 1st, 2006.

Five important systems are defined in the Law to overcome regulation, policy and market barriers in renewable energy development and utilization, such as difficulty in

grid connection, and high charge in grid connection, and support the development of renewable energy technology, market and industry.

- Total volume of renewable energy system

Total volume of renewable energy system requires the related governmental departments set out total volume target of renewable energy to define the market scale of renewable energy development and utilization, the trend of investment and technology, on the base of resource conditions, economic capacity, and energy demand, etc. Other systems are defined, such as plan, mandatory grid system and differential price system, to guarantee the realization of total volume.

- Mandatory grid system

Power grid enterprises must purchase all the power generated by renewable energy. Besides, power grid enterprises should invest in and construct transmission connection components of grid-connected renewable power projects, which define the social responsibilities of power grid enterprises.

- Differential price system

The purposes of this system are simplifying the approval procedure, confirming the return from market, promoting involvement of investors and promoting involvement of investors. The principle of determining power price is: based on the difference among different renewable energy power generation and local conditions, the price should be determined according to the principle of promoting renewable energy development and economic feasibility, and adjusted on the development of renewable technology. The price should be publicized. The price determined by bidding should be carried out by the bidding price but no more than the price of grid connection of similar renewable energy power generation.

- Electricity price sharing system

This system, based on the combination of citizen's obligation and national responsibility, requires different areas share additional cost of developing renewable balanced relatively.

- Special capital system

Electricity price sharing system focuses on the additional cost of renewable energy power generation. Special capital system is the optimal choice for solving the financing confines of renewable energy development. It is used to offer renewable energy development projects, which electricity price sharing system don't cover, the subsidy, assistance and other financing support.

8.3 Renewable Portfolio Standard (RPS)

Renewable Portfolio Standard (RPS) is a policy to solve market mechanism and combine mandatory policies and incentive policies best among the incentive policies and mechanisms for renewable energy. It is the summary of activities and experiences of different countries developing renewable energy and used for reference for China.

The policy ensures that a minimum amount of renewable energy is included in the portfolio of electricity resources serving a region or country. The soul of RPS is that power generated by renewable energy equivalent to portfolio standard can be traded among different areas (grids) to solve the problem of unbalanced renewable energy. It is a mandatory regulation aimed balance renewable energy power generation in different areas and will promote the renewable energy market of China.

Main characters of RPS include:

- Setting the level of the standard, including the term, procedures and levels for different technologies;
- Applicability of the standard, like power generation plant, power grid and consumers;
- Type of renewable energy and power generation technology, position of the plant and production period;
- Renewable Energy Credits trading system;
- Statute for the standard implementation, including penalty level for each Credit that the generator fails to produce as required;
- Confine of production and trade cost of renewable energy power generation.

8.4 Mandatory Market Share (MMS)

The Primary issue of studying the market share policy is to establish a new incentive policy framework meeting needs of China with combination with actual conditions. By comparing and analyzing renewable energy policies in both home and abroad, relevant experts believe that the new incentive policy China needed should ensure the performance with the law, regard market competition as motive force, complement it with assistance of essential economic incentive policy, and realize the goal of stipulated proportion of renewable energy power generation in the total power supply. On the basis of the above mentioned elements, Mandatory Market Share (MMS) is put forward as a new concept.

In brief, MMS is a policy for the central government or provincial governments to stipulate the market share of renewable energy power generation by mandatory means, in other words, the renewable energy power generation must occupy stipulated proportion in the total power supply. The renewable power generation refers in particular to the power generation from wind, solar energy, biomass power (including refuse, rice husk, bagasse and methane), small hydropower, terrestrial heat and tide. MMS is operated with a market competitive mechanism named “Green Certification System (GCS)”. The main effect of GCS is to realize renewable energy market share with the lowest cost by means of market. In the case of the price of renewable energy power generation being higher than the routine price, MMS follows the Consumer bearing principle to solve the price difference.

The main objectives of MMS are as follows:

- Encourage the technical process of renewable energy, and promote the home-production and commercialization of renewable energy industries;
- Reduce and eliminate the rural non-electricity areas, and boost the economic development of western rural areas;
- Improve the energy structure, and strengthen safety of energy supply;
- Reduce air pollution, and protect environment.

9. Annex document

9.1 China municipal refuse resources assessment
9.2 Technology assessment for municipal refuse treatment, disposal and utilization in China
9.3 Institutional & policy framework of municipal refuse management in China
9.4 Technical economic assessment for municipal landfill gas recovery and utilization in China
9.5 Guideline for implementation of municipal comprehensive management and landfill gas recovery and utilization

APPENDIX C
Key Recommendations and Actions Taken

Appendix C – Key Recommendations of the Mid-Term Report

Key Recommendations Are:

- *In order to fully achieve one of prime objectives of this demonstration project, that is to promote the widespread adoption of LFG recovery and utilization projects in China, it is essential that the success (and failures as lessons learned) of this project be effectively disseminated throughout China through proper channels. It is, therefore, highly recommended that UNDESA, with the assistance from NPMO (and SEPA) and UNDP, develop a publicity program that can be launched prior to the completion of this project. Such a publicity program could include the production of project documents, videotapes, TV programs, special interviews, seminars, articles and presentations at national and international conferences and symposiums. The recipients of the publicity information must be carefully selected so as to ensure maximum benefits for these activities.*

This recommendation should be further supported by making special invitations to international LFG energy developers to offer proposals for projects in China.

- *In launching the project dissemination effort, information must include:*
    - *Environmental Benefits*
    - *Economic and Technical Viabilities*
    - *Innovation in Project Financing*
    - *Establishment of independent Energy Service Companies, and*
    - *Project Management and Institutional Capacity*

The status of this effort is unknown.

- *With the assistance from NPMO, UNDESA and UNDP, the local PMO's of Anshan, Maanshan and the Anshan Training Centre should provide the necessary co-financing for continued project implementation.*

This is actively being pursued.

- *NPMO should aggressively activate the operation of project Steering Committee and the workings of the Expert Group to provide a national focus for the finalization of the national action plan that will be consistent with China's overall strategy and direction for municipal solid waste management and the sustained development of LFG projects in China.*

This action plan is complete and designed to accomplish these tasks.

- *Anshan must immediately establish a project coordination and management function to provide tighter control over the remainder of project implementation and provide liaison with sub-contractors.*

This action is still needed to complete the project.

- *The Anshan Centre must now focus its effort on the development of its institutional capacity. The Centre should:*
    - *Establish a comprehensive reference depot for all technical information produced through various stages of project implementation.*
    - *Develop training program curriculum and course content for Landfill gas recovery and utilization as well as landfill design and operation.*
    - *Establish links with other national and international organizations and under the leadership of SEPA build up its reputation as the "one-window" contact and facilitator for other landfill gas project in China.*

It is unknown if a comprehensive reference Depot has been established. This could also be a function of SEPA to help organize.

Anshan has developed a training manual for enhanced LFG Recovery.

The outcome of the final recommendation is unknown.

APPENDIX D
Terms of Reference

APPENDIX D

Terms of Reference for the Final Evaluation

UNDP/GEF Project CPR/96/G31 – Promoting Methane Recovery and Utilization from Mixed Municipal Refuse in China

A. Introduction

The UNDP/GEF Project CPR/96/G31 - Promoting Methane Recovery and Utilization from Mixed Municipal Refuse in China was signed in May 1997. The project consists of five specific components: 1) Three demonstration landfill gas recovery and utilization projects in each of three cities, namely, Nanjing, Anshan and Maanshan; 2) Development of a National Action Plan to serve as a policy document for the government for promotion of the landfill gas recovery and utilization in China; and 3) Establishment of a training facility. The project is executed by UNDESA (formally UNDDSMS). The government implementing agency is State Environmental Protection Administration (SEPA, formally called NEPA). The project has a GEF input of US$5.285 million. The government inputs amount to US$14.28 million.

The main objective of the project is to reduce global climate change through the capture and use of methane released from landfills. Through the field demonstrations in the three cites, the project will illustrate the feasibility of technologies to capture, recover and utilize the methane, one of the main greenhouse gases, as an environmentally-friendly energy source. The project will also set up and improve institutional capacity for the necessary infrastructure and policy instrument to guide relevant agencies in landfill gas recovery and utilization. Both the demonstration and training activities will strengthen the capacity of the national and local agencies and increase the awareness for turning the waste into the energy, thereby disseminate the results and undertake similar projects elsewhere. The project has three immediate objectives to related outputs to cover the three components stated above.

The project has duration of 4 years, but the actual implementation process has been longer due to various reasons. Except the demonstration project of Anshan City, all the components of the project are basically completed. The project had undergone a mid-term evaluation in 2002 organized by UNDESA and SEPA. The evaluation reviewed whether the cities had taken the right approach and technical design for the LFG demonstration projects to ensure right direction and effectiveness of the project. The evaluation produced the mid-term evaluation report. The project had undergone a mid-term evaluation in early 2002. The

evaluation was concentrated on the technical design and feasibilities of the demonstration projects in the three cities.

B. Objectives of the Evaluation:

The objectives of the evaluation are to review the achievements of the project immediate objectives and outputs. However, the evaluation is of forward looking to focus on the institutional setting, economic feasibilities and financial mechanisms for extension. In this regard, the recommendations to be generated by the evaluation mission will not only for improvement for the current project and cities, but more importantly for assisting the Chinese Government for future promotion of landfill methane recovery and utilization in the country.

C. Specific Tasks for the Evaluation

The evaluation will cover three areas as specified below:

1) Review of the institutional framework and funding mechanisms for promotion of the LFG recovery and utilization in China as the results of the UNDP/GEF project and other similar projects managed by SEPA:

   - Policy and regulation setting at the national and local levels for promotion of the LFG recovery and utilization in China.

   - Institutional arrangement dimension in terms of lead agencies in planning, financing, development, technical expertise, training capacity, etc. in the area.

   - Existing funding mechanisms in China and elsewhere that have great potential for popularising landfill gas recovery and utilization.

   - Opening and involvement by the private sector in both investment and technology transfer.

2) Assessment of outcome of the technologies designed and applied in the three demonstration projects:

   - The operational managements in supporting the demonstration projects in the three cities.

   - Technical feasibility of the engineering designs and technology selections applied by each city in recovery and utilization of the methane.

   - Economic viability and return of the demonstration projects to find out if the price of the LFG (Nanjing and Anshan) and the fee collection

(Maanshan) can make the projects sustainable and support possible replication elsewhere.

3) Evaluation of the achievements and performance of the project:

- Relevance of the project to address to global concerns of the climate change issues and the relevant awareness of the landfill methane.
- Assessment of the contribution of the three demonstration projects in the three cities to the GHG reduction in comparison to the original design.
- Status of the achievements of the immediate objectives and outputs with the input from the government and GEF.
- Capacity building of the project staff in the three cities in design, building and managing the LFG demonstration projects and in provision of services to assist similar projects in other cities.
- Any major issues and barriers encountered during the project implementation and any useful lessons learned in achievements of the project results.

Findings of the review and recommendations by the evaluation mission will be summarized in the report and communicated to the government agencies, project authorities and cities, UNDESA, UNDP and GEF.

D. Products Expected from the Evaluation

The evaluation mission should complete and submit a Project Evaluation Report in conformity with the format set forth in the UNDP Guidelines for Evaluators. The mission shall de-brief at the end of the mission to present by the evaluation team for its main findings and recommendations to parties concerned. The finalized report in both electronic and hard copies should be completed and submitted within 14 days after departure of the mission member from Beijing.

E. Composition of the Evaluation Team

The mission will consist of two staff: one international expert to be recruited jointly by UNDP and UNDESA, who will act as the team leader; and one national expert to be recommended by SEPA. Both of the experts should have broad knowledge of greenhouse gas emission and climate change, and the team leader to be focused on the economic policy development and institutional set-up while the nation expert on technology design and application for projects of landfill methane recovery and utilization. The experts should hold degree of advance studies relevant to the subject and at least 7 years working experience in the subject or relevant areas.

F. Schedule and Duration of the Mission

The evaluation mission is scheduled in the second half of October 2005, lasting for two weeks, the first week for field visits to the three demonstration projects and the second week for meeting with agencies concerned and for paper review and report writing. An itinerary for the mission shall be proposed and arranged by SEPA in consultation with the cities, UNDESA and UNDP.

G. Roles and Support to the Evaluation Team:

The evaluation team will report to the UNDP country office regarding the mission tasks, arrangements and final report in accordance to the TOR. The team leader will be jointly recruited by UNDESA and UNDP. SEPA/the PMO, UNDESA and UNDP will provide necessary documents and reports to the evaluation team to understand issues and progress of the project. The PMO will draft the schedule of the field visits and meetings with parties concerned, including the government focal points of GEF and climate change, as well as the logistical support for the evaluation team. The UNDP-GEF Regional Coordinator for Climate Change for Asia and the Pacific will assist the UNDP CO in preparing for the final evaluation.

List of Documents and Reports for the Evaluation

1. Project document (UNDP)
2. Evaluation Guideline (UNDP)
3. Project Implementation Report/Terminal Report (the PMO)
4. Mid-term evaluation report (UNDP)
5. Financial Report (UNDESA)
6. Other supporting documents, technical reports, proceedings, etc (the PMO)

Revised on 16 September 2005