GLOBAL ENVIRONMENT FACILITY

MOHAMED T. EL-ASHRY
CHIEF EXECUTIVE OFFICER
AND CHAIRMAN

March 17, 1997

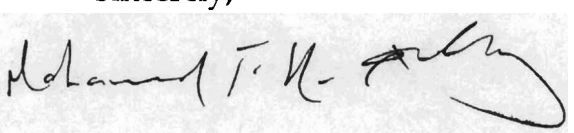
Dear Council Member:

UNDP, as the Implementing Agency for *China: Promoting Methane Recovery and Utilization for Mixed Municipal Waste,* has submitted the attached proposed project document for CEO endorsement prior to final approval of the project document in accordance with UNDP procedures.

Over the next four weeks, the Secretariat will be reviewing the project document to ascertain that it is consistent with the proposal included in the work program approved by the Council in April 1996, and with GEF policies and procedures. The Secretariat will also ascertain whether the proposed level of GEF financing is appropriate in light of the project's objectives.

If by April 14, 1997, I have not received requests from at least four Council Members to have the proposed project reviewed at a Council meeting because in the Member's view the project is not consistent with the Instrument or GEF policies and procedures, I will complete the Secretariat's assessment with a view to endorsing the proposed project document.

Sincerely,



cc: Alternates, Implementing Agencies, STAP

GEF SECRETARIAT, 1818 H STREET NW, WASHINGTON, DC 20433 USA
TELEPHONE (202) 473 3202 FAX (202) 522 3240/3245

United Nations Development Programme
GLOBAL ENVIRONMENT FACILITY (GEF)

6 March, 1997

Dear Mr. El-Ashry,

Please find attached copy of the UNDP/GEF Project document entitled: ***China: Promoting Methane Recovery and Utilization for Mixed Municipal Waste,*** approved by the GEF Executive Council in April 1996.

As per paragraph 29 and 30 of the *GEF Project Cycle*, we are submitting this project to you for circulation to the members of the GEF Executive Council for their review and comments, and subsequently, for your final endorsement.

Thank you in advance for expediting the review and approval of this project.

Yours sincerely,

Rafael Asenjo
Executive Coordinator

Mr. Mohamed El-Ashry
Chief Executive Officer
Global Environment Facility
Room G6005
1776 G Street
Washington, D.C. 20433
RH/pm

Street Address: 304 East 45th Street, 10th Floor
Mail Address: 1 U.N. Plaza, Room FF 1094, New York, N.Y. 10017
Telephone: (212) 906-5044
Fax: (212) 906-6998

UNDP/GEF
CLEARANCES

PROJECT NUMBER:	CPR/96/G31/B/1G/01
PROJECT TITLE:	***China: Promoting Methane Recovery and Utilization for Mixed Municipal Waste***

FOR THE PURPOSE OF:

☑ Circulating draft Project Documents of the approved Work Programme project to the GEF Secretariat

☐ Delegating signing of Project Document to the Resident Representative (for PDF B, PDF C, Enabling Activities) and approved Work Programme project

☐ Signing of Preparatory Assistance Document

TECHNICAL CLEARANCE: _____ DATE: Today

FINANCIAL CLEARANCE: P. Chan DATE: 4/5/97

United Nations Development Programme

Interoffice Memorandum

To: Mr. Rafael Asenjo
Executive Coordinator
GEF/SEED/BPPS

Date: 21 February 1997

From: for Nandita Mongia Cathy Mgè
Deputy GEF Coordinator
RBAP

Extension: 5893

Subject: China: Promoting Methane Recovery and Utilization from Mixed Municipal Waste - ($5.285M) - Submission of project document for clearance and onward transmission to GEFCEO

File:

We are pleased to forward herewith a copy of the project document for the project entitled "China: Promoting Methane Recovery and Utilization from Mixed Municipal Waste". As you will recall, the project brief was was approved in February 1996 GEFOP and was accepted into the Workprogramme by the GEF Council in April 1996. In developing the full operational document, we have carefully taken note of the comments provided during the GEFOP and GEF Council and have reflected them in the present document.

We are, therefore, in accordance with the GEF Project Cycle requesting your clearance of the document and onward submission to GEF CEO.

Thank you in advance for expediting the review and approval of this project.

cc: Messrs. N. Htun/S. Hasegawa
Mr. Holcombe, UNDP Beijing
Mr. Karcher / Mr. Walker

TO: Pat Martung		
FROM: Cathy Maize		
DC1-23, tel. 906-5893		22 February 1997

RE: China 'Methane Recovery' - CPR/96/G31

Please find herewith a clean copy of the project document for the above-mentioned project. As discussed with Dick on Friday, a hard copy was sent to his house by Federal Express. After sending the FedEx, I faxed him copies of revised budget (which has been reformatted to 2 pages) and implementation schedule. Dick indicated he would call to let you / me know if any further changes are needed prior to clearance.

Thanks for letting me know if there is any feedback from Dick.

Mr. Asenjo - original document

TO: Pat Martung

FROM: Cathy Maize Cathy

DC1-23, tel. 906-5893		22 February 1997

RE: China 'Methane Recovery' - CPR/96/G31

Please find herewith a clean copy of the project document for the above-mentioned project. As discussed with Dick on Friday, a hard copy was sent to his house by Federal Express. After sending the FedEx, I faxed him copies of revised budget (which has been reformatted to 2 pages) and implementation schedule. Dick indicated he would call to let you / me know if any further changes are needed prior to clearance.

Thanks for letting me know if there is any feedback from Dick.

("original" clean copy Evelyn Popiel's in-tray)

UNITED NATIONS DEVELOPMENT PROGRAMME

Project of the Government of

The People's Republic of China

Number: CPR/96/G31/B/IG/01

Title: China: Promoting Methane Recovery and Utilization from Mixed Municipal Refuse.

Duration: 4 Years

ACC/UNDP Sector & Sub-sector: 2000 - Environment

UNDP and Cost Sharing Financing	
UNDP/GEF:	$5,285,000
Govt. Inputs:	$14,280,000
of which,	
Baseline financing:	$10,770,000
Co-financing:	$3,510,000

Govt. Implementing Agency: National Environmental Protection Agency (NEPA)

Executing Agency: United Nations Department for Development Support and Management Services (UNDDSMS)

Estimated Starting Date: March 1997

Brief Description: The main objective of the project is to reduce global climate change through the capture of methane, which is released from landfills in China. Through field demonstrations at three sites, the project will illustrate the feasibility of technologies to capture landfill gas, extract methane and use it directly as fuel and for electricity generation. The project will also set up institutional mechanisms for the sale of extracted methane to neighboring users and electricity to the grid. In so doing, the project will demonstrate ways to overcome barriers to the use of landfill gas technology and to the fully competitive sale of methane and electricity to the energy bureaus/companies. The demonstrations and training activities will strengthen the capacity of the implementing agency (NEPA) to disseminate the results and to undertake similar projects elsewhere in China.

On behalf of	Signature	Date	Name/Title
The Government:	_____	_____	_____
UNDP:	_____	_____	_____
UNDDSMS:	_____	_____	_____

UN official exchange rate at date of signature: US $1 = 8.28 RMB Yuan

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A. CONTEXT

A.1 Description of the Sub-sector

1. Human activities have been substantially increasing the atmospheric concentrations of greenhouse gases (GHGs). Carbon dioxide and methane are two of the most significant GHGs. The Intergovernmental Panel on Climate Change (IPCC) determined in its 1995 assessment that, in all likelihood, anthropogenic emissions of GHGs will contribute to an increase in atmospheric temperature between 1 and 3.5 degrees C. by 2100. Such a cumulative temperature increase has not been witnessed over the past 10,000 years. Reducing GHG emissions will help limit global climate change, and the associated temperature increase, and will alleviate its adverse effects on natural ecosystems and humankind.

2. Methane is an important GHG that is about 22 times more potent than carbon dioxide on a mass basis in causing global warming. Compared to carbon dioxide, methane is a short-lived gas; with an atmospheric residence time between eight and twelve years compared to more than 100 years for carbon dioxide. This means that the warming associated with methane emissions is realized in the first few decades after its emission while that from carbon dioxide is realized gradually over centuries.

3. Methane emissions arise from (1) anaerobic digestion in landfills, rice production, and cattle, (2) the release of trapped gas in coal mines, and (3) the production of oil and gas. The approaches to reduce emissions from rice production and cattle are not completely understood as yet. But there is considerable worldwide, yet no Chinese, experience with technologies for reducing emissions from landfills.

4. China's population has lived largely in rural areas in the past, where the widespread use of composting techniques in agriculture contributed to slow growth of the nation's organic refuse. Commensurate with China's industrialization, and accompanying urbanization, the country's urban waste production is now increasing rapidly. Urban population increased at an annual rate of 4.2% between 1980 and 1994 compared to an overall population growth rate of only 1.4% over the same period. Rising incomes have also led to higher personal consumption, which is changing the composition of the municipal waste. Previously 80% of urban solid waste was industrial in nature, mostly coal waste materials, and though the non-organic proportion of urban waste remains high, an increasing percentage is now composed of biodegradable material due to rising waste from households and restaurants and other commercial establishments.

5. The municipal solid waste (MSW) and night soil disposed from Chinese cities reached 120 million tons in 1993 or about 329 thousand tons per day. MSW, which accounted for 88 million tons, is increasing at an annual rate of 10%. China is able to treat only 23% of this amount due to limited capacity of its treatment plants. At a growth rate of 10% a year, MSW will reach 175 million tons by 2000 and 480 million tons by 2010. By 1988, 6.6 billion tons of untreated solid waste had accumulated, occupying 55,400 hectares of land.

6. China has little experience with comprehensive solid waste management, or sanitary landfill practices, which currently characterize less than 8.3% of all sites. Due to its large population, low availability of arable land and increasing urbanization, China recognizes that it cannot continue to pursue a land extensive, unmanaged approach to waste disposal. Fifteen years ago, the disposal practices of MSW began changing from dispersive fill and level-up of holes, pits, tunnels and ponds into centralized dumping or landfilling. Most large and mid-size cities in China have covered dumps, and at least 20 landfills have been constructed with some degree of environmental protection.

7. Most landfills in China still do not meet Chinese or international construction and environmental standards. Most of China's waste sites are open pits located on the urban fringes, in stream or river valleys or on 'marginal lands' such as wetlands where mixed municipal wastes are deposited. This uncontrolled dumping constitutes breeding grounds for mosquitoes, other disease spreading insects, and rats. Ground water and drinking water aquifers are severely polluted in these areas; odors and trace toxic gases affect the health of the surrounding population; and the land has been rendered useless for other purposes. The release of photo-reactive hydrocarbons from landfill gas emissions is known to cause photochemical smog. Methane leaks through soil have been known to have caused dozens of fatalities in China in recent years. A methane explosion in Hunan Province which threw up 15,000 cubic meters of MSW and destroyed a pumping station and two dams at a distance of 40 meters characterizes the type of dangers that result from poorly constructed and managed dumps.

8. The anaerobic digestion of the biodegradable material in the solid waste releases landfill gas, about half of which is methane. National authorities estimate methane emissions from municipal waste to be in excess of 1 million tons or 1.5 billion cubic meters per year; a figure which will increase as China's municipal waste, and its organic content, increases. In comparison with China's stagnant natural gas production in 1993 of 17 billion cubic meters, the landfill methane emissions amount to a not insignificant figure of 8.9%.

9. In 1993, China generated 836.4 billion kWh from an installed capacity of 182.9 million kW. About 76% of the capacity is coal-fired, whose share is not expected to change significantly in the future. Despite the rapid growth of capacity, 9.9% from 1992, authorities estimate that there is a 20% shortage of electricity supply, which is expected to continue in the foreseeable future. Electricity derived from landfill methane thus has the potential to fill this shortage, and/or displace the electricity generated from coal power plants. Either approach will reduce China's GHG emissions (see section B.5.1 for a quantification of GHG reductions in either case).

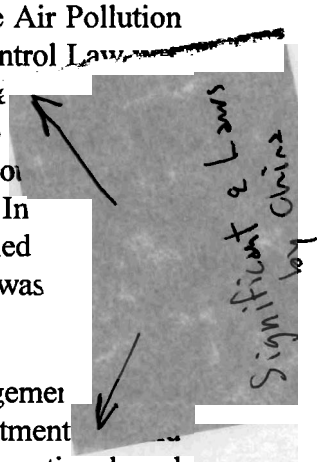
A.2 Host Country Strategy

10. Recognizing its own economic and environmental interest and its international obligation, China has attached increasing importance to environmental protection including the environmentally responsible management of solid wastes. Since the 1980s, a comprehensive regulatory structure that governs Chinese environmental protection has been formed. The Environmental Protection Law promulgated in 1989 establishes the basic principles for coordinated

development between economic growth, social progress and environmental protection, and defines the rights and duties of governments at all levels, all units and individuals with respect to environmental protection.

11. China actively participated in the 1992 UNCED Rio Summit and related activities and hosted the June 1991 Ministerial Conference of Developing Countries on Environment and Development. In the Beijing declaration that resulted from that conference as well as during UNCED, China pledged the commitment of global efforts towards sustainable development, provided that international community recognizes the specific rights, responsibilities and circumstances of developing countries. China was among the first ten countries to ratify the UN Framework Convention on Climate Change. As in the case of the Montreal Protocol, however, China's efforts are contingent on financial and technical assistance from GEF.

12. Significant environmental legislation passed in China includes the: Marine Environmental Protection Law (1983), the Water Pollution Prevention and Control Law (1984), the Air Pollution Prevention and Control Law (1987). The Solid Wastes Pollution Prevention and Control Law was adopted in October 1995. It sets the following basic principles for solid waste ma comprehensive management starting from generation, collection and transport to treatment; 2) maximization of recycling and utilization of solid wastes as a reso promotion of centralized treatment of solid wastes, particularly, hazardous wastes. In with this law, the National Environmental Protection Agency has worked out detailed and measures for submitting an application, registering and obtaining a license for was and its treatment.



13. From 1990 to 1996, NEPA organized 36 studies on solid waste managemer covered industrial waste control technology, the integrated use and centralized treatment waste, etc. It is launching several demonstration projects with financing from national and provincial governments and international finance institutions.

14. The Ninth National Plan for Economic and Social Development (1996-2000) sets a goal to dispose 60% of municipal refuse in sanitary landfills by the year 2000. Accordingly, NEPA formulated the China Trans-Century Green Programme to mobilize domestic and international resources to achieve this goal. Of the five priority sectors for investment, solid waste management stands the third following water and atmospheric pollution control.. Within the Green Programme, 8.8 billion Chinese Yuan (US$ 1 billion) are targeted for solid waste management. This GEF funded project for landfill methane recovery and utilization will directly support the country's effort through the demonstration of new energy efficient technology and removal of institutional barriers to effective utilization of solid wastes.

A.3 Prior and Ongoing Assistance

15. The Global Environmental Facility (GEF) is financing two projects in the field of climate change and control of greenhouse gases with local environmental benefits in addition to their mandated global environmental objectives. These include: CPR/92/G31: Development of

Coalbed Methane Resources in China and CPR/91/G32: Issues of Greenhouse Gas Emissions Control.

CPR/92/G31 -. This GEF pilot phase project aims at reducing emissions of methane associated with coal mining production. Through advance recovery of methane before mining operation and its use as a new and clean energy resource, the project will also contribute to mining safety and alleviation of China's energy shortage. Under the project, a series of coalbed methane exploration and utilization technologies have been transferred and a policy and institutional climate supportive of the sustained development of coalbed methane industry has been created.

CPR/92/G32 - The objective of the project is to provide government authorities with policy advice concerning control of GHG emissions. It has established an inventory of GHG flows through studies of different industry sectors with a focus on energy production and consumption. The project result will be useful for the development of a national policy on energy efficiency and clean production processes.

A.4 Institutional Framework for Sector

16. The institutional framework pertaining to landfill methane recovery and utilization involves: 1) environmental protection authorities at national and local levels that provide policy, regulation and technical guidance for the building and management of landfill, and 2) city planning and construction departments who are responsible for urban waste collection and disposal and, in some cities, for the construction and operation of landfill. Public utility institutions such as town gas and electricity supply companies are also associated since they are potential users of landfill methane or electricity generated from the methane.

The State Environmental Protection Commission (SEPC)

SEPC is the apex of decision-making on environmental issues and includes the heads of all relevant ministries, agencies and provincial governments. SEPC provides national policy direction and ensures inter-agency coordination. It meets quarterly to review policy and strategy issues and approve important programmes. Solid waste management stands high on its agenda. The Commission depends to a large extent upon the National Environmental Protection Agency which functions as its secretariat.

The National Environmental Protection Agency (NEPA)

NEPA became an independent agency in 1988. It is responsible for all aspects of environmental policy, the formulation of national environmental regulations and issuance of national environmental quality standards. NEPA is entrusted by the cabinet (State Council) for the enforcement of regulations and standards and coordination of important environmental programmes and projects.

The Environmental Protection Bureaus (EPBs)

EPBs, as the NEPA's local branch, perform environmental quality monitoring and control work in each province and city. Regulatory actions concerning pollution control requirements for specific sources and locations are made by the local EPBs with approval by the local governments.

The Municipal Environment and Sanitation Departments (MESDs)

MESDs are city agencies responsible, among others, for collection, transport and disposal of urban waste. They manage waste collection stations and, in some cities, sanitary landfills. For this reason, MESDs are best placed to construct and operate landfills with methane recovery and utilization facilities.

Municipal Electricity Supply Departments (MESDs)

The responsibility of MESDs is to provide a city with reliable electricity. They report to the respective municipal government and electricity bureaus of the city. As the electric power industry makes its transition to a market economy, and independent developers enter the market, MESDs are expected to be in a position to negotiate the electricity price with independent power suppliers within a range set by the central government.

Municipal Town Gas Companies (MTGCs)

Residential and commercial use of town gas varies from one city to another and depends on the different levels of supply. In China's large cities (with population over 1 million), the majority of households have access to town gas, however, the supply is often insufficient. MTGCs are responsible for distribution of town gas and, at the same time, for the development of new sources of gas supply. Landfill gas may compete with town gas in certain markets.

17. In addition to the above institutions, over 300 research institutes at national and local levels are active in conducting studies and R & D activities to protect the natural resources and environment of the country.

SECTION B: PROJECT JUSTIFICATION

B.1. Problem To Be Addressed: The Present Situation

18. Methane recovery projects are being operated in many countries including the USA, Germany, the UK, Sweden, France, Denmark, Japan, Brazil and Chile, but there are none in China because of technical uncertainty, lack of skilled personnel and lack of evidence of economic viability in the current policy environment.

- China lacks the technology on landfill gas recovery and faces high costs of imported technology. The resulting high cost of landfill gas technology prevents its widespread adoption across China. Since this field of expertise is in its infancy, China does not have off-

the-shelf technology for drilling landfill gas wells, and specialized piping, compressors, blowers, and compactors which it can readily access and use for producing gas.

- In China, skilled personnel are not readily available for constructing and operating landfill gas plants. Construction contractors, operators who can manage the uneven gas flow, air ingress, leachate migration, etc., engineers who can design and managers who can oversee construction and operation have little or no experience with landfill gas piping and extraction technology.
- China also lacks the institutional structure to manage the landfill resource due to a lack of definition of institutional responsibility and resource ownership. It is not clear as to who will own the resource, and how the municipal, provincial and national governments should cooperate with private industry and households to harvest this resource. In the US, energy service companies (ESCOs) have taken the initiative to (1) identify prospective projects and reach agreements with landfill owners, (2) harvest landfill gas, (3) generate energy and (4) sell it to the utility company. Such independent companies, except joint-venture power developers, do not exist in China for any energy activity. In part, the lack of regulations or policy for determining the price that the energy bureaus would be willing to pay for the methane gas or electricity prevents the formation of ESCOs.
- .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 developing urban infrastructure and communication, less attention has been given to channeling resources for "non-productive" local investments such as water and sewage treatment and waste disposal and management.
- Capital for the development of landfills is currently provided by the government. 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 weak or non-existent in most of China.
- The electricity price offered by the local bureaus is currently inadequate to cover the cost of plants to recover landfill gas and generate electricity. As stated in the project brief, the cost of the plants would have to be reduced by 43% or the electricity price increased to 0.40 RMB Yuan/kWh in order for the revenue from electricity sales to offset the cost.
- 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 strategy which would address the above issues in an integrated manner.

B.2. Expected End-of-Project Situation

19. It is expected that at the end of the project:

- 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 will include pipes for gas collection, and the equipment for energy production.

- 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.

- 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.

- 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.

- An action plan would have been prepared to promote wide-spread 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 governments 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.

B.3. Target Beneficiaries

20. The direct beneficiaries of the project include the local environmental protection bureaus and the municipal governments in Anshan, Maanshan and Nanjing where the demonstration units will be set up. One of the three cities will also benefit from the building of institutional capability which will serve as a national center for methane recovery research and dissemination. At least one, and possibly all three, will also gain experience in establishing institutional arrangements for the operation of independent companies for the recovery of landfill gas and energy production. Small enterprises near the sites will benefit since the project will be creating jobs and wealth using raw materials that are currently wasted.

21. Citizens of each of the three cities will benefit since the environmental degradation associated with the operation of the landfills will be reduced. Landfill linings will prevent the percolation of contaminated water from the landfill into the groundwater. The technologies promoted by this project will effectively destroy significant amounts of photoreactive organic compounds that contribute to photochemical smog and traces of toxic and carcinogenic organic compounds that contribute to air pollution health risks.

22. Chinese environmental experts will also benefit from the project through extensive exposure to state-of-the-art landfill gas recovery and energy production technology and management. Under the project they will be able to interact with foreign experts to formulate the projects. The interactions and exchange between the Chinese environmental experts and their foreign counterparts will enhance understanding on both sides.

23. The indirect beneficiaries will be municipal governments in other regions, and the yet to be formed energy service companies, who will be able to incorporate the findings disseminated from this project into their own landfill gas recovery and use efforts.

24. The ultimate beneficiaries will be the citizens of the world who will benefit from the reduced GHG emissions and adverse impacts on natural ecosystems and humankind.

B.4. Project Strategy and Institutional Arrangements

B.4.1 Project Strategy

25. The project concept is to capture and burn landfill methane in order to either generate electricity, or to use the fuel directly, for industrial, commercial and domestic end-uses. The recovery of landfill gas and its productive use, however, is not common practice in China. There are both supply and demand side barriers which prevent the adoption of this technology. Supply-side barriers are largely technological dealing with the extraction, collection and use of the gas, whereas the demand-side ones are mostly institutional dealing with contractual arrangements for the use of the gas by direct users or for the purpose of electricity generation..

26. The project strategy is to overcome both the technological and institutional barriers by:

1. Conducting field trials at each of the three sites on 2 ha plots to assess the yield and composition of landfill gas (Figure 1), and using these data to calibrate a theoretical model of gas yield based on secondary data on waste composition at each site (Immediate Objective 1).

2. Establishing institutional arrangements for the sale of energy at each site and for construction and operation of the demonstration plant at each site. (Immediate Objective 2)

3. Building and operating a demonstration plant at each site using landfill gas from an 8 ha area (Figure 2) (Immediate Objective 2).

4. Disseminating information, maintaining a library and data bases, training all parties engaged in landfill gas technology, and conducting research on improving the technology and institutional arrangement through a center located at one of the sites (Immediate Objective 3).

5. 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).

27. The drafting of an action plan and its implementation to disseminate the results of the pilot plant operations are critical and important phases of the project. The action plan will 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, (4) supportive regulatory and institutional environment, and (5) sustainability of indigenous landfill methane technology including strengthening of national technical capacity. China has 50 cities with a population over 1 million each. A number of these have populations in excess of 10 million (Beijing, Shanghai, Tianjin). It would be reasonable to expect that the administrative and financial base of these cities of over one million could support the dissemination of the administrative approach and technology demonstrated through the GEF project over the next 10-20 year period. The trends of rural to urban migration, population growth and industrialization in China suggest that the number and size of urban centers will continue to grow rapidly in the future increasing further the subset of cities which could support the dissemination of methane recovery technology.

Descriptions of locations of field trials and pilot plants

28. The three trials, as well as the three permanent full-scale pilot plants, will be located at landfills in Anshan, Maanshan, and Nanjing. The main reasons for choosing these three cities as demonstration sites are as follows:

(a) The waste streams from each city are very different and represent different solid waste composition.

The organic content of the waste will vary from 60% in Anshan to 80% in Maanshan. The landfills will be located at a distance of 5 km from Maanshan and 15 km from Anshan. The methane percentage of landfill gas is expected to vary between 40 and 50% at each site. The three cities will generate refuse varying from 300 tonne per day (tpd) in Maanshan, to 800 tpd in Nanjing to 1200 tpd in Anshan. The waste composition of Nanjing city is more complex that the other two. Based on tests on older landfills in each city, the gas yield and methane fraction has been found to be consistent with international norms.

(b) The sites are different in terms of their age and level of technology/landfill practices.

Whereas the Anshan site is a new site where technology could be designed into the landfill process from the bottom up, Nanjing is an existing site where the challenges of technology introduction and changes in landfill site management will be explored during the implementation of the project. Maanshan is in an intermediate stage of its life cycle.

(c) The amount and method of leachate pollution control are very different in these cities.

(d) The geologic conditions of the three cities are very different. The geologic conditions at Nanjing, Anshan and Maanshan are clay, stony and waste mine quarries respectively. Anshan landfill does not require to be lined while Nanjing site is lined. The engineering designs are different at each site also.

(e) The sites are in parts of China that are not only geographically distinct but are from three very different types of cities that face different public policy and management challenges related to what stage of the transition to the market economy they find themselves in. Anshan in northeast China is characterized by heavy industry comprised of State owned enterprises running on the central plan model and which face an old style approach to municipal management based on allocative and administrative decision making. Nanjing on the other hand is a city more fully absorbed into the transition to the market economy where business and commerce run on market and price signals more so than on central planning. As such municipal planners and managers are more apt to experiment with new gas pricing and land management practices. Thus the institutional structures are different at each site, yet representative of other Chinese cities. This GEF project can demonstrate the benefits of landfill gas recovery in both the old and new contexts which are both present in China during the economic transition process.

(f) Each city has performed primary research on gas recovery systems, and have each identified different potential methods for utilizing the gas.

(g) Local governments have demonstrated greater interest in this topic.

29. These seven factors mean that different demonstration effects can be achieved at the three sites and technology could be compared for its effectiveness in different public policy and financing contexts.

30. A detailed profile of each of these three cities is provided in Annex 2.

B.4.2 Institutional Arrangements

31. It is important that the institutional arrangements for project implementation be well-defined and compatible with the project's overall objectives, since elements will be conducted at both city and national levels. Demonstration activities including recovery efficiency test, and design, construction and operation of the landfill will be carried out at each pilot city while the establishment of a research and dissemination center and formulation of a national action plan to promote landfill methane recovery and utilization will be managed by NEPA directly.

32. In order to implement the project in an effective and coordinated way, NEPA will set up a Project Steering Committee consisting of senior officials from the concerned ministries/agencies and the directors of the sub-projects. Also NEPA will establish a Project Management Office to handle day-to-day implementation of the project, and an Expert Group to advise the committee on technical issues. A National Project Director (NPD) will be appointed as the secretary of the Steering Committee and, concurrently, the head of the Project Management Office (PMO). Through the PMO, he/she will be responsible for the mobilization of domestic resources required for the project, organization of Steering Committee meetings, and management of project implementation. NPD will work to coordinate three pilot cities and government agencies to

ensure that project activities are carried out in a cost-effective manner and results of the projects are disseminated promptly to other cities.

33. The Expert Group will consist of senior specialists in landfill construction/ operation, power generation from landfill methane and municipal waste management, and also respected experts in environment-protection policy, project finance, and integrated management of urban development. The Expert Group will advise the Steering Committee on technical and policy issues, in particular, on the promotion of an institutional and financing environment favorable for the expansion of landfill methane utilization in the country. The Office and the Expert Group will report every six months to the Committee and accomplish any assignment identified by the Committee.

34. The Project Steering Committee, chaired by Deputy Administrator of NEPA, will be responsible for:

A) review of policy issues related to landfill methane development including the transfer from abroad, and dissemination throughout the country, of appropriate landfill construction and operation technology, the adoption of supportive economic measures, and the reform of institutional and pricing system. In light of the national policy, and the project document, it will decide, or recommend to the central government, on the strategy and actions for landfill methane recovery and utilization;

B) coordination among the pilot cities and various institutions involved in the project as to necessary policy decisions and direction of the project;

C) review and approval of the national action plan for landfill methane development and organization of dissemination activities,

D) review and approval of annual implementation plan submitted by the Executing Agency,

E) overall supervision of project implementation and availability of domestic inputs as specified under Section E-1, and

F) working with UNDP/DDSMS resolve major problems encountered as and when referred to by the sub-Project teams.

35. For each pilot city, day-to-day implementation will be managed by a Sub-project Office headed by Vice Mayor of the city. The Sub-project Office will report to the respective municipal government and to the Steering Committee on any important progress, problems encountered and appropriate actions. It is anticipated that the city personnel will play a major role in constructing and operating the methane plants, although independent landfill and energy companies might emerge to participate in the process.

36. Both NEPA and United Nations Department of Development Support and Management Services (UNDDSMS), the project executing agency, will rely on a variety of domestic and foreign

NGOs including institutes, universities, independent consultants and equipment manufacturers to perform much of the study, evaluation, design and engineering work and dissemination activities in every phase of the project. The work will be contracted out on a competitive basis according to UNDP rules and procedures.

37. In order to ensure the effective coordination of different project activities and foreign consultants, the Executing Agency will hire a Senior Technical Advisor (STA) prior to beginning the implementation of the project. The STA will undertake a mission at least once a year, or more often if needed, to work with the project authorities to identify specific technical needs of each sub-project including advisory services, equipment and training and recommend to UNDDSMS the terms of reference for services and training, and specifications of equipment as needed. He/she will assist the Executing Agency in managing the sub-contractor, coordinating the consultant missions, and facilitating purchase and delivery of equipment to meet project schedule. Detailed terms of reference will be developed by the Executing Agency in consultation with NEPA.

38. It is anticipated that individual subcontracts shall be awarded to implement the objectives and outputs related to the demonstration activities at the pilot cities. This is consistent with industry practice and will greatly simplify the completion of these objectives. It was determined that the activities for each pilot city should be subcontracted separately in order to demonstrate a possible broad range of technology and management for landfill methane recovery and utilization. Drafts of the terms of reference for the individual consultants and the subcontracts are included in Annex 3, and the final terms of reference shall be developed by the Executing Agency in consultation with the project authorities.

B.5. Reasons for Assistance from GEF/UNDP

B.5.1 Reasons for GEF Assistance

39. Municipal refuse undergoing anaerobic decomposition in landfills continuously emits greenhouse gasses, methane and carbon dioxide, for decades. Methane will soon rival carbon dioxide as the most important greenhouse gas. The methane produced from three landfills with annual MSW input totaling almost one million tons will be captured and used. As most fuel uses in China will replace coal, global warming will be mitigated in two other ways: decreased emissions of carbon dioxide, and decreased escape of methane from coal mining operations. The net effect will be reduced methane from landfills and coal mines, reduced carbon dioxide from power plant coal combustion, offset to a smaller extent by increased carbon dioxide emissions from methane combustion at landfills (see Table 1 below). If the methane-generated electricity is used to overcome the country's electricity shortage, then the resulting GHG benefit will be only the eight-fold decrease in radiative forcing from landfill methane (Rows 4 - 5 in Table 1).

40. When the three landfills are full, the quantity of waste in place will total about 16.8 million tonnes. The amount of landfill gas captured at those three sites would be approximately 518 million m^3 per year at a unit incremental cost of $4.52 per tonne of C equivalent (Table 1).

Table 1: GHG reduction			
	Item	Value	Explanation
1.	Landfill gas from the three sites (Mn. m^3)	270 + 66 + 182 = 518	Anshan + Maanshan + Nanjing
2.	Methane gas (Mn. m^3)	518 * .5 = 259	50% landfill gas is methane
3.	Methane gas (Th. Tonnes)	259 * .662 = 171.45	Density = 0.662 kg/m^3
4.	Methane gas avoided (Th. Tonnes C equiv.)	171.45 * 6 = 1028	Radiative forcing index = 22*12/44 = 6
5.	Methane combustion CO_2 release (Th. tonnes C)	171.45 * (44 / 16)*(12/44) =128	Mol. Wt. of CO_2 = 44 and CH_4 = 16, Atomic Wt. of C = 12
6.	CO_2 avoided from coal combustion (Th. tonnes C)	128 * 25.57 / 14.47 = 227	Carbon content (tC/GJ) of Coal = 25.57, Gas = 14.47 Assume same thermal efficiency of small gas and large coal power plants
7.	Avoided coal mining methane (Th. Tonnes C)	40	Assume 23.23 m^3 of methane /tonne of mined Chinese coal
8.	Net avoided emissions (Th. tonnes C)	1028 - 128 +227 + 40 = 1167	Rows(4 - 5 + 6 + 7)
9.	GEF funding (Mn. US $)	5.285	
10	Cost-effectiveness ($/tonne C)	4.52	Rows (9/8)

41. The proposed project has the potential to reduce substantial quantities of an important greenhouse gas, and it satisfies all GEF's generic criteria for selection. The potential for nationwide methane recovery will be many times that amount when plants are replicated throughout China. Given the lack of sanitary landfills in China, it is appropriate for GEF to assist the Chinese Government to establish demonstration projects for the purpose of utilizing methane.

B.5.2 Reasons for UNDP Assistance

42. Environmental protection is an overriding priority of UNDP among poverty alleviation, job creation and women's participation. The project will address environmental issues at both global and national levels. The organic breakdown of mixed municipal refuse in sanitary landfills and open disposal sites produces methane, and the capture and utilization of this energy resource will not only mitigate negative environmental impacts; but will also serve to provide valuable energy

services. This project is to develop a methane recovery and utilization programme appropriate for China, establish a regulatory and institutional structure for its implementation, and then to take measures to encourage its application within the country. In addition, the project will lead to the concurrent development of environmentally sensitive solid waste management practices, capture of other landfill gas pollutant emissions (e.g., volatile organic compounds) leading to ozone formation, protection of groundwater from leachate contamination, emissions offsets from energy services, etc.

43. UNDP has extensive experience in providing technical assistance in China's environmental protection and energy development. It is well placed to work with and advise the Government on policy, strategy and best approaches to meet serious environmental challenges. Through its executing agency, UNDP will introduce appropriate technical and managerial experience developed in other countries to reinforce China's own effort for environmentally responsible development. A large group of national experts and engineers will be trained in the next four years to make sure that the process started with the project in landfill methane recovery and utilization be sustained and disseminated in the country.

44. Further, the project will promote the creation of small enterprises at the local level that will be responsible for maintaining the operation of the landfill gas energy recovery facilities. These enterprises will create jobs and wealth using raw materials that are currently wasted. The project will by this means play a role in increasing employment and reducing poverty, both of which are UNDP priorities.

B.6. Special Considerations

45. The project is primarily aimed at reducing environmental degradation, but it will also assist other developing countries by making available a ready access to the library, database and research center that will be established by the project. The project therefore inherently lends itself to providing technical cooperation among developing countries (TCDC), another UNDP priority area.

B.7. Coordination Arrangements

46. In China, there are several hundred landfills at present, and about a dozen are under construction with support from the government. The activities of this project will be coordinated with the preparatory activities that are ongoing at the three project sites. There are no other landfill methane gas recovery projects ongoing in China. This project's activities, however, will be coordinated with those of any other project that may arise during the duration of this project.

B.8. Counterpart Support Capacity

47. NEPA has the personnel and support facilities necessary to carry out the project. NEPA will establish a Steering Committee of senior officials from the concerned ministries. Their participation will be important to overcoming institutional barriers that cut across ministries. The

genuine interest of NEPA staff, including the expertise in landfill gas technology of the current Director of the Foreign Economic Cooperation Office, will ensure prompt attention at the highest level for the effective management and operation of the project. NEPA has good access, and leverage, to engage national experts from well-regarded academic institutions, who will be part of an Expert Group to provide the NPD and the Project Management Office with technical back-stopping as needed.

48. NEPA has close relationships with the respective municipal governments and, in particular, environmental authorities of each of the three cities and with the research institutes that will provide technical back-up to the city offices. A Vice-mayor in each city will be the primary person responsible for the smooth conduct of the project. The offices described below for each city will work under his/her leadership in implementing this project. The municipal administrations in each city are strongly committed to the project and have been eagerly awaiting the approval of the project document. The implementing offices in each city have made the necessary technical preparations for project implementation, and discussed, and/or negotiated a price for the landfill gas and/or electricity that will be sold to the energy bureaus. The EPBs in each city do basic environmental monitoring of the landfill site for soil, air and water quality.

- **Anshan:** The Environmental Protection Bureau in Anshan has set up a Special Project Office that oversees the management and operation of its landfills and directly reports to the municipal government. It consists of 30 staff with about 24 engineers. This project will be housed in the Special Project Office. The Office has limited experience with landfill gas production, having drilled an experimental well, the gas from which is used for supply of heat to a greenhouse and as boiler fuel. In addition, the Office will draw on the expertise of the Anshan Environmental Research Institute (AERI) to analyze gas samples, soil and leachate quality, refuse anaerobic conditions etc. The Office will also rely for technical advice on the Anshan Coking Refractory Engineering Consultants, an engineering firm with 1500 staff, for design, construction and operation of the landfill gas technology.

- **Maanshan:** The Environmental Protection Bureau in Maanshan has set up a Sub-Project Office that oversees the management and operation of its landfills. The project management will be transferred to the Sanitation Division of the municipal government. This project will be housed in the Sub-Project Office. The Office has limited experience with landfill gas production, having drilled eleven experimental wells, the gas from which is used on-site for heating administrative buildings and a trial 5 kW power generation unit has been set up. In addition, the Office will draw on the expertise of the Maanshan Institute of Mining Research (MIMR) and for technical advice on the Maanshan Institute of Steel Design (MISD). The MIMR has basic chemistry laboratories for gas analysis. The MISD can provide engineering support for hydrology, ventilation, sewage treatment and other associated areas.

- **Nanjing:** The municipal government in Nanjing has set up a Nanjing Citylook Committee which looks after sanitation and planning functions. This Committee is responsible for the management of the two landfills in Nanjing. Nanjing is a large city and has access to many colleges and research institutions which can provide technical backstopping for this project.

In addition, its current landfills are managed with state-of-the-art environmental monitoring system and waste water treatment. The municipal government is already investigating the formation of an independent company to manage the landfill and/or the gas collection and power generation system.

49. The city of Anshan built a technical training center in 1993 for educating environmental engineers, operators, builders, planners, etc. from Liaoning province, and other parts of China, in pollution treatment technology, including the construction and operation of landfills. This center is financed by the Anshan EPB and is located about two km from the landfill. It has three classrooms, two meeting rooms, and 72 guest rooms. The center has eight professors, who are qualified to teach at the graduate level, and also has invited foreign faculty. The center could serve as the dissemination center envisaged by this project with some additional capacity in training, audio-visual equipment, library facilities, etc. The Anshan EPB and NEPA have both expressed interest in strengthening this center's capacity to disseminate information on landfill technology and related institutional issues.

C: DEVELOPMENT OBJECTIVE

50. The development objective of this project is to (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, and (3) promote the development of indigenous enterprises engaged in recovery, cleaning and use of landfill gas.

D. IMMEDIATE OBJECTIVES, OUTPUTS AND ACTIVITIES

51. There are three immediate objectives in this project. Each immediate objective has several outputs and activities that are described below. The activities for one output often run in parallel with those for other outputs. The sequence of activities for each output is explained in Annex 4, the Schedule.

1. Immediate Objective 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, field trials.

1.1 Output 1: Report characterizing the composition of the waste and disposal practices at the three demonstration landfills.

Success Criteria: Successful acquisition of secondary data for the characterization of the waste, and credible alternative projections of landfill gas generation for each of the demonstration project cities.

Activities for Output 1:

1.1.1 Obtain, verify and compile analyses and projections of the waste composition for each of the cities. [by City Team/Consultants]

1.1.2 For the three demonstration project landfills, identify the current and planned landfill design and operational practices that will affect gas recovery and utilization. [by Consultants/City Teams]

Include the following data: landfill configuration (area, depth, height), planned sequence of filling, types and quantities of soil used to cover wastes, design of lining and cover systems, configuration and operational parameters of any leachate collection system, configuration and operational parameters of any existing or planned landfill gas collection system.

1.1.3 Estimate the total quantities of annual waste that have been, and will be placed, in the landfills and the corresponding quantity of landfill gas production at each of the three demonstration sites. [by Consultants/City Team]

1.2 Output 2: Three reports, one for each city, on field trials of landfill gas collection technology in Anshan, Maanshan and Nanjing.

Success Criteria: Field trials demonstrate that landfill gas 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.

Activities for Output 2:

The same set of activities, which are listed below, should be carried out at each of the three sites. In either Anshan or Maanshan, horizontal gas collectors should be used as part of the gas collection system, since filling in the new landfill has not yet begin in these two cities. In Nanjing, vertical wells have already been drilled which should be used as part of the gas collection system.

1.2.1 Obtain the services of well drilling and piping and equipment installation contractors to install the landfill gas collection system for the field trials. Purchase well piping and other equipment for permanent installation. [by NEPA/UNDDSMS/City Team]

1.2.2 Develop and recommend modifications to the current and planned landfill design and operational practices (such as cover soil placement and final cover design) in order to facilitate successful gas collection field trials. [by Contractor/ National Consultants]

1.2.3 Design field trials of landfill gas collection technologies, taking into account the specific features of the site. [by Contractor/Consultants]

Horizontal gas collectors should be used as part of the gas collection system in either Anshan or Maanshan, since filling in the new landfill has not yet begun at these two sites.

The field trials should collect gas from at least two hectares of the landfill. Specify at least the following as part of the field trial design: 1) the spacing and layout of gas wells or horizontal collectors, 2) materials of construction including piping and well backfill materials, 3) exhauster and flare requirements including flow and vacuum capacity and ignition system to be used, 4) condensate drainage design and disposal requirements, 5) power requirements, 6) safety requirements, 7) the test program and database configuration, 8) test equipment specifications, 9) laboratory analysis requirements, 10) personnel requirements, and 10) schedule.

1.2.4 Conduct the field trials at the Anshan landfill. [by Contractor/City Team]

1.2.5 Compile and analyze the data. [by Contractor/City Team]

Achieve the following results in the data analysis: 1) estimate gas production on a per-ton basis at each site, 2) estimate typical region of influence that can be produced by gas collection wells or horizontal collectors in each site and corresponding well/collector spacing, 3) establish typical vacuum requirements at wellheads and optimum operational parameters, including blower settings, to achieve them, 4) establish typical range of gas composition (methane, CO2, O2, trace gases that could affect gas utilization equipment), 5) develop typical unit costs for extrapolation to full-scale systems, 6) estimate effects of different landfill cover designs and other landfill operational and design practices on gas yield, and 7) calibrate one or more commonly used models of gas generation in municipal solid waste landfills.

2. Immediate Objective 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.

2.1 Output 1: Develop institutional arrangements for the recovery of landfill gas and its use in Anshan, Maanshan, and Nanjing.

Success criteria: Development of institutional arrangements that can be agreed upon by all parties necessary to implement the demonstration projects. Successful sale of power from small landfill-gas-based generating plants into power grids and delineating ways to obtain financing for a landfill gas project.

Activities for Output 1:

2.1.1 Conduct a series of workshops to define the institutional arrangements for use and sale of energy products from landfill gas at the three pilot study landfill sites in Anshan, Maanshan and Nanjing. Four workshops will be held: an initial workshop in Beijing attended by all to establish basics applicable to all three projects, followed by a workshop in each city to establish the specific arrangements for the demonstration project in each city. [by Consultants/ NEPA/ City Team]

This activity will include a market study to identify potential end users of landfill gas near the landfill and local potentials for other gas utilization techniques.

At least one of the three projects will include direct transmission of gas via dedicated pipeline to an end user, and at least one project should include generation and sale of electric power.

The institutional arrangements must include at least the following: 1) mechanisms for financing construction and operation, 2) ownership of facilities, 3) agreements and pricing methods for purchase and sale of the energy products, 4) the roles and responsibilities of all legal entities who will take part in the institutional arrangements, and 5) delineation of management and regulatory responsibilities.

2.1.2 For one or more of the demonstration projects, develop institutional arrangements for an independently financed energy service company (ESCO). [by Consultants/City Team]

ESCO will initiate the project and reach agreements with the landfill owner for use of the gas and with the end user for sale of the energy products derived from the landfill gas.

2.1.3 Identify potential financing agencies and institutions. Involve them in establishing the institutional arrangements for the demonstration projects. [by Consultants/City Team]

2.1.4 After end-users of the energy products (either electric power or gas) have been identified, compute the avoided costs of incremental energy for that end-user as a basis for purchase and sale negotiations. [by Consultants]

2.1.5 Track the performance of the institutional arrangements set up for the three demonstration projects and report on progress, problems, and identify needed improvements. [by Consultants/City Team]

2.2 Output 2: Demonstration projects for landfill gas recovery and utilization in Anshan, Maanshan and Nanjing.

Success Criteria: 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.

Activities for Output 2:

2.2.1 **Obtain the services of** well drilling and piping and equipment installation contractors to install the landfill gas collection and recovery system for the demonstration project. [by UNDDSMS/NEPA/City Team]

2.2.2 Prepare contracts for and purchase gas cleanup, compression, and energy recovery and transmission equipment. [by UNDDSMS/NEPA/City Team]

2.2.3 Establish the basic design criteria for the demonstration project. [by Contractor/City Team]

The initial area of each demonstration site landfill from which gas is to be extracted for the pilot plant should be at least eight hectares. At one of the demonstration site landfills, leachate recirculation should be employed in the initial area of the landfill from which gas will be extracted for the demonstration project.

2.2.4 Estimate the curve of gas generation over the life of the project for the demonstration landfill. [by Contractor/City Team]

Use the curve to prepare a schedule for installation of incremental additions to the gas collection system and modular units to the energy recovery and delivery system. Prepare a table of estimated construction costs, energy or fuel sale revenues, and operation and maintenance costs corresponding to the schedule.

2.2.5 Prepare engineering designs of the landfill gas recovery projects. [by Contractor/City Team]

Designs should include drawings and specifications for the landfill gas collection system, the condensate collection and disposal system, the gas processing and cleanup system, the energy recovery system, and the energy (or fuel gas) delivery system for each site. Evaluate domestic and foreign technology capabilities and costs for major equipment.

The design must be modular and include drawings and specifications necessary for the first module. The design must also include site preparation sufficient for installation of subsequent modules that will be adequate to handle the maximum gas generation from the landfill at such time as that occurs. Facilities for visitor observation and instruments for collection of data relevant to the demonstration should be given high priority in the design.

2.2.6 Construct the landfill gas recovery demonstration projects. [by UNDDSMS/City Team/Contractor]

Construction will include site preparation, foundation construction, utility installation, building and enclosure construction as well as installation of landfill gas collection, cleanup, compression and energy recovery and delivery equipment. Assume that all permits will be applied for and obtained by local municipal authorities.

2.2.7 Conduct the startup and verify that all operating parameters are nominal. [by NEPA/UNDDSMS/Contractor/City Team]

Obtain the services of all equipment manufacturers' representatives to be present with troubleshooting equipment during the startup. Prepare a startup checklist for all parts of the system. Coordinate the startup among parties to the institutional arrangements for the demonstration project.

This activity will be more than a resolution of technical issues, since the project is serving as a demonstration project and both the gas recovery and utilization technologies will be undergoing initial applications in China. Since future projects will likely face similar issues during startup, it will be critical to carefully document all problems encountered and their means of resolution.

2.2.8 Plan the operation and maintenance of the facility until the end of the project duration. [by City Team/Contractor]

Estimate anticipated O&M personnel requirements and costs, including maintenance equipment, supplies, and spare parts. Conduct O&M for demonstration project period.

2.2.9 Design and conduct a testing program to provide data useful to designers of future full-scale gas recovery and utilization systems [by Contractor, Consultants/City Team]:

The program should conduct at least the following tests: 1) *Operational data including flow and vacuum in the main piping of the gas collection system and at each gas well or horizontal collector 2) Operational data for the condensate disposal and leachate recirculation systems, including volumes and dates pumped, 3) construction as-built records for the gas collection system as well as the gas processing and energy recovery and delivery systems, 4) performance analysis of the gas processing and cleanup equipment, 5) actual net efficiency of the energy recovery equipment, 6) continuous gas flow, quality, and energy or fuel output measurements in the energy recovery equipment, 7) performance analysis of the energy or fuel delivery system, 8) accounting of actual costs incurred and revenues collected, 9) a record of problem occurrences and unexpected shutdowns, and 10) recommendations for improvements in all of the above.*

3.0 Immediate Objective 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 center.

3.1 Output 1: An action plan for promotion and widespread adoption of landfill gas recovery and utilization.

Success Criteria: Verification by municipal landfill managers, energy service companies, and financing agencies, that the action plan will be useful in establishing landfill gas energy recovery projects elsewhere in China.

Activities for Output 3.1:

3.1.1 Identify and organize a group of experts representing national-level research institutes and experts on the various aspects of landfill gas collection and energy recovery who will serve as an advisory committee throughout and on all aspects of the project. Identify and compile national sources of existing information on waste characteristics that affect landfill gas production, and for waste streams that will be placed in municipal landfills. [by Consultants]

3.1.2 Conduct two study tours of successful landfill gas recovery facilities abroad and review the technical, economic and institutional arrangements at those facilities as well as problems encountered with each. [by Consultants/ NEPA]

3.1.3 Identify at least three alternative sets of institutional arrangements for implementing landfill gas recovery and utilization projects that can expected to be practical in China. [by NEPA/Consultants]

3.1.4 Identify potential uses for landfill gas, in addition to generation of electric power, that may prove to be common in different areas of China. [by NEPA/ Consultants]

Develop a list or table of potential uses for landfill gas and the corresponding conditions that would be likely to make each potential use feasible. Processing and use of the gas as vehicle fuel should be considered in this and the following activities.

3.1.5 Identify specific measures that can be taken in China to reduce the costs of producing energy products from landfill gas. [by Consultants/NEPA]

3.1.6 Conduct an economic analysis to show whether or not the use of landfill gas is competitive with fuels that are currently in use to produce the same results. [by Consultants]

The economic analysis should identify and focus on situations where use of landfill gas is likely to be competitive, including consideration of special situations such as proximity of landfills to end users, geographic considerations, types of fuel burners, etc.

3.1.7 Analyze and recommend to NEPA national policy, standards, and regulations for landfill gas control and recovery. [by Consultants]

3.1.8 Assist NEPA in formulating appropriate technical and financial incentives that will encourage municipalities to implement landfill methane collection and energy recovery facilities. [by Consultants/NEPA]

3.1.9 Plan an ongoing program of technical assistance, including economic analyses and advice on institutional arrangements, for municipalities embarking on and operating landfill gas collection and energy recovery facilities. [by NEPA/ Consultants]

3.2 Output 2: Establishment and continued functioning of a Research, Training, and Dissemination Center for landfill gas recovery and utilization technology.

Success Criteria: Development of four courses in fundamental aspects of landfill gas recovery. At least one hundred persons per year trained in fundamentals of landfill gas recovery. Maintenance of a technical library and database, with at least 200 library and database accesses by prospective project developers per year.

Activities for Output 3.2:

3.2.1 Evaluate the prospective institutional setting of a Research, Training and Dissemination Center, including expertise required, interaction with national and local agencies, international contacts, and personnel needs. [by NEPA/ Center/ UNDDSMS]

3.2.2 Develop a business plan for the Center, including goals, target dates, and budgets for sustaining the Center's activities after the project is over. [by NEPA/ Center/ UNDDSMS]

3.2.3 Evaluate physical requirements including physical space needs, training support requirements, accessibility, and proximity to pilot projects, specify equipment/facility needed and proceed with procurement. [NEPA/ UNDDSMS/ Consultants]

3.2.4 Establish a charter for landfill gas recovery-related activities of the center. Establish goals of research and dissemination programs, budgeting plans, and program and staff evaluation procedures. [NEPA/ Consultants/ Center]

3.2.5 Establish and maintain a library of information on landfill gas recovery from worldwide sources, and publish lists of information available in the library. [Center/NEPA/UNDDSMS]

3.2.6 Disseminate data summaries and reports on ongoing projects to municipal authorities responsible for landfill management across the nation. [NEPA]

3.2.7 Develop a database structure for information on the performance of landfill gas collection and energy recovery facilities in China. [Consultants/ NEPA/ Center]

3.2.8 Construct and maintain the database and develop and implement a program to obtain the data from new and ongoing projects. [Consultants/ NEPA/ Center]

3.2.9 Identify criteria for whom to train among interested municipal governments, landfill operations personnel, technicians, scientists and engineers. [Consultants/NEPA/Center]

3.2.10 Develop training courses. Conduct the training. [Consultants/ NEPA/ Center]

The following training courses will be developed, at a minimum: 1) basic landfill gas collection system principles and operation practices, 2) landfill gas safety, 3) economics of landfill gas recovery including obtaining financing for landfill gas recovery projects, and 4) fundamental landfill gas collection and energy recovery system design for engineers.

E. INPUTS

E.1 Government Inputs

52. Since this is a GEF funded project, government inputs for this project constitute baseline support which form a significant portion of the overall costs of the project. The government will provide project personnel, equipment and bear the costs of the operation of the landfill. In addition, the government will provide matching funds for the collection of gas and production and supply of energy.

Project Personnel

53. The direct input of the government will be the personnel associated with the construction and operation of the landfill. These will operators of the trucks, compacting equipment, and the

treatment plant and the associated supervisory staff of the landfills. These will be supported by office, technical and center staff.

Equipment and Supplies

54. The government inputs will include the acquisition of land, the setting up of transfer stations, provision of refuse collection vehicles, construction of the access and on-site roads, leachate treatment plant, landfill closing and soil and vegetation cover. The government will also provide a share of the gas collection and energy production equipment commensurate with its cost share, which is noted in the section below on Financial Cost-sharing. In addition the government will construct the buildings and associated equipment for a research and training center for the purpose of disseminating lessons learned from the project.

Transportation

55. The Project Authorities will provide the use of vehicles for the project and any on-site transportation that the UNDP consultants might require. When international and national experts and officials are visiting the project, the project authorities will be responsible for ensuring that their transportation requirements are met.

Financial Cost-Sharing

56. Total government inputs amount to $14.28 million. Of this, the $10.77 million budgeted for baseline activities will be spent on the construction of sanitary landfills at the three sites and a methane research and dissemination center (see the Project Brief for details). The remaining amount, $3.51 million, will be co-financed by the government as funds to match those provided by GEF/UNDP for the construction and operation of pilot plants at the three sites (see the Project Brief for details regarding the estimation of this figure).

E.2 UNDP Inputs

57. The country office of UNDP in Beijing, close to the project site, will play an important role in project management and implementation.

A) Being accountable to the funding agency, GEF, it will work with the Project Steering Committee to organize an annual review, a mid-term review and a final evaluation to ensure that the project is being conducted in accordance with the policies of GEF, NEPA and UNDP, and within the scope of the terms established in the project document;

B) In consultation with NEPA and UNDDSMS, it will review and approve annual implementation work plan and corresponding budget revision;

C) It will periodically visit each of the project pilot sites to monitor the progress in light of the work plan, identify problems, if any, and report to NEPA and the Executing Agency for actions to improve the project performance;

D) As the field representative of the Executing Agency, UNDP/Beijing will facilitate the timely delivery of project inputs including assistance in custom clearance for imported equipment, making logistic arrangements for visiting consultants and UNDDSMS programme staff, remitting payments as authorized by UNDDSMS to national consultants, fellowship holders and local suppliers of equipment, if any;

58. The above work is detailed and time-consuming, but very important for smooth implementation of the project. The project will compensate the incurred costs of the country office amounting to two percent (2%) of the total GEF/UNDP budget.

59. The project will be executed by the United Nations Department of Development Support and Management Services (UNDDSMS). UNDDSMS is designated by UNDP, in consultation with the Government (the Ministry of Finance and NEPA) because of its broad expertise and experience in implementing environmentally responsive energy systems.

60. The executing function of UNDDSMS is twofold: A) it will hold technical accountability to UNDP and GEF by ensuring all the project activities be implemented according to the GEF/UNDP's policy, programmes and procedures; and B) it will organize specific implementation work in a cost-effective manner, including the selection and fielding of national and international consultants, awarding of domestic and international contractors, purchase and delivery of equipment, and conduct of overseas training programme to meet the project requirements. UNDDSMS will perform the responsibility under the guidance of the United Nations rules governing a technical cooperation project. The project will compensate UNDDSMS support costs amounting to six percent (6%) of the total budget.

61. It is anticipated that advisory services required for the Anshan and Maanshan sub projects will be provided in the form of sub-contract between the United Nations and reputable consulting firms (see the E.2.2 below) The project personnel inputs will meet the following needs: A) the pilot methane landfill plant to be built in Nanjing, and B) activities for the overall project including the establishment and functioning of the national dissemination center and formulation of the national action plan. The draft terms of reference for consultant services are attached in Annex 3. (Also see Annex 7 for the detailed terms of reference for each consultant and the sub-conracts.) Detailed job descriptions will be prepared by the Executing Agency in consultation with NEPA.

E.2.1 Project Personnel

International Consultants		
Consultant expertise	Level of effort	Budget (US $)
Senior technical advisor	5 p/m	100,000
Landfill design advisor	3.5 p/m	75,000
Chemical engineer	1.5 p/m	27,000
Gas recovery advisor	2.5 p/m	50,000
Power generation advisor	3 p/m	60,000
Landfill operation advisor	4 p/m	80,000
Solid waste management	2 p/m	40,000
Environment economist	3.5 p/m	77,000
Landfill O&M trainer	5.5 p/m	110,000
Project evaluator	4 p/m	80,000
Subtotal	*34.5 p/m*	*699,000*
National Consultants		
National Consultant	1 p/m	2,500
Chemical engineer	17 p/m	53,000
Landfill design engineers	14 p/m	42,500
Landfill engineering advisor	13 p/m	40,000
Landfill O&M advisor	13 p/m	40,000
Senior financing experts	10 p/m	30,000
Senior environment economist	6 p/m	18,000
Regulatory advisor	4 p/m	12,000
Subtotal	*78 p/m*	*238,000*
Duty travel		*23,500*
Mission cost		*54,000*

E.2.2 Subcontract

62. Reputable international consulting firms will be selected on a competitive basis to provide engineering services to the pilot landfill methane plants each at Anshan and Maanshan.

Engineering services for Anshan	159,000
Engineering services for Maanshan	159,000

Domestic training on landfill O&M	36,000
Subtotal	*403,000*

E.2.3 Overseas Training

Study tours to selected country(ies)	60,000
Landfill Design and Test	50,000
Landfill Operation/Maintenance	50,000
Subtotal	*160,000*

E.2.4 Equipment

63. According to the project brief approved by the GEF council, UNDP will procure equipment and materials which are essential to achieving the project objectives and are not available, or seldom used, in China. Their beneficial use is not understood or appreciated yet. A list of the required equipment is attached as Annex 5. Procurement of equipment will be accompanied with training on installation and maintenance of equipment and other services. Total UNDP/GEF input for this purpose is *US$ 3,253,000.*

E.2.5 Services of the UNDP country office and UNDDSMS

UNDP Support Cost	*105,700*
UNDDSMS Support Cost	*317,100*

E.2.6 Miscellaneous

Miscellaneous	*31,700*
Grand total	***5,285,000***

F. MONITORING AND EVALUATION

64. The project will be subject to tripartite review (TPR) by a representative of the Government, UNDP and the Executing Agency, UNDDSMS, at least once every 12 months from the start of full implementation. TPR, chaired by the Deputy Administrator of NEPA, or his representative, will review progress in light of the project document, identify problems, if any, and decide on the corrective actions and responsibility of each party. The National Project Director shall prepare and submit to each TPR meeting a Project Performance Evaluation Report (PPER). Additional PPERs and/or progress reports may be requested, if necessary, during the project.

65. The project shall be subject to a mid-term evaluation in its third year of implementation. The evaluation, organized by UNDDSMS and NEPA, will look into the direction and effectiveness

of implementation and recommend to the Steering Committee and UNDP/UNDDSMS on any actions, as necessary, to ensure that the objective of the project be successfully achieved. The terms of reference and timing of the review will be decided after consultation between the parties concerned. The review will take place after field trials and institutional arrangements for the demonstration projects have been identified, but before detailed engineering design of the demonstration projects is done. Having the mid-term review at this stage will allow any modifications to the project that arise from the mid-term review and evaluation to be incorporated into the design of the demonstration projects. An evaluation report will be prepared from this exercise.

66. The project shall be subject to a final evaluation by independent evaluators. An evaluation report, and a project terminal report, will be prepared and submitted to the final TPR review. These shall be prepared in draft form sufficiently far in advance so as to allow review and technical clearance by NEPA and UNDDSMS.

G. RISKS

67. Overall, the risk of project failure is very low. The technology for landfill gas collection and use is well proven in industrialized, and other, countries (see Annex 6). So it is unlikely that the same, or similar, technology would fail in China. Even if the technology were not to succeed at one of the sites, the modular nature of the project will limit the costs to those associated with that module and ensure that this would not have a cascading effect on the other sites. The institutional risk of whether there will be a market for the gas and electricity at remunerative prices is moderate today, but over the four year duration of this project, the severity of the risk may decrease as China continues its long march towards a market economy.

1. Landfill methane yield is less than anticipated.

Risk and Remedial Measures: The severity of this risk is low. The landfill gas yield may be less than anticipated but this could be offset by the higher organic content and disposal rate of future waste. The organic content of China's MSW has been increasing and this factor would increase the production of landfill gas and its methane fraction. If the methane yield is lower than anticipated, then the cost of the gas collection system per unit of gas production would be higher than estimated, but the cost of energy production and supply would be correspondingly lower. A lower methane fraction or yield would increase the overall unit cost of the project.

2. Poor construction and operation of landfill gas system results in lower flow.

Risk and remedial measures: The risk is relatively low. Poor construction and operation would allow for air ingress and sporadic production of landfill gas, which could affect the regularity of the supply of gas and/or electricity to users. Experience in other countries has shown that it is possible to redress the problems encountered during operation, however, careful supervision and management during construction will be essential to reduce the risk of leaks and/or improper plant operation.

3. Agreements to sell gas and/or electricity cannot be negotiated at the assumed price.

Risk and remedial measures: The risk is relatively low, since electricity supply is often inadequate and the electricity bureaus have already offered to purchase electricity close to the assumed price of 0.23 Yuan/kWh. Further, the amount of electricity generated by the landfills' gas is very small compared to the local electricity bureau's level of generation and distribution. Thus the purchase of baseload firm electricity supply should not pose a problem at the assumed rate of 0.23 Yuan/kWh.

4. Center is not able to sustain its role after the end of the project due to lack of skilled personnel and/or lack of infrastructure.

Risk and remedial measures: The risk is medium. The Center will be located in Anshan where the local municipal government is keenly interested in modernizing and strengthening an existing environmental training center This will ensure that it receives adequate support from the local government. NEPA will ensure that it is adequately staffed to provide the necessary support for disseminating the results of this project. NEPA will have to commit to supporting the center after the project is over and budget adequate resources or charge other municipalities for the use of the center's facilities.

5. Failure to interest an independent energy service company to build, own and operate an energy production plant.

Risk and remedial measures: The risk is small, since the project can proceed without an ESCO with municipal operation of the landfill energy generation. Currently, there are no ESCOs operating in China. A sister GEF project has included this as one of its goals. As the Ministry of Power evolves into a company, it is not inconceivable that independent power generation will be the accepted norm within the four-year time period of this project.

6. Failure to replicate the demonstration projects elsewhere in China.

Risk and remedial measures: The risk is moderate, since failure to reduce the cost and/or to obtain a high enough price for energy would make future landfill gas projects uneconomic. Concerted action will be needed to translate the lessons learned from the demonstration plants into ways to reduce the equipment, construction and operation costs. In addition, the electricity bureaus will have to be persuaded to offer competitive remuneration for landfill-gas-generated electricity. This may require action at the national policy level should the bureaus be reluctant to offer competitive terms for the purchase of electricity. One task of the project is to identify geographic locations and institutional situations that are likely to provide competitive terms.

H: PRIOR OBLIGATIONS AND PREREQUISITES

68.

- The Government will allocate funds in its national budgets as indicated in Section E, Government Inputs.
- The Government and its ministries, agencies and administrations will provide the equipment and personnel as indicated in Section E, Government Inputs.
- The Government shall establish a Project Steering Committee headed by a ministerial level director, and including three deputies. The Government will assure that the Project Steering Committee meets on a regular basis to ensure the smooth functioning of the project.
- The Government will coordinate the selection and designation of counterparts from the various ministries, institutes and local municipal governments as required by the description of the Counterpart Support Capacity in this document.
- The Government agrees to make available to the consultants or project staff the data that are required for implementation of the project. In addition, these data will be translated into English by Government supplied translators.
- The Government will supply translators that have the necessary technical background to translate for technical consultants and project team members during the course of their work in China.
- The Government will provide or arrange for in-country transportation of equipment, and intra-city transportation of project team members where practicable. Where public transportation must be taken by the consultants, and project staff members, the necessary arrangements will be made by the Government to ensure their timely arrival.
- The Government will provide facilities for conducting the workshops listed in the activities section of the project document. The government will be responsible for designation of Chinese attendees according to the requirements and guidelines for qualifying participants, as set forth by the organizers of the workshop. The Government will provide transportation, housing, and daily subsistence allowance for the Chinese attendees.

I: LEGAL CONTEXT

69. This project document shall be the legal instrument for the management of the all project activities and UNDP funding.

70. The following types of revisions may be made to this project document with the signature of the authorized UN official only, provided he/she is assured that the other signatories of the project document have no objections to the proposed changes:

(i) Revisions in, or additions of, any of the annexes of the project document with the exception of the Standard Legal Text for non-SBAA countries which may not be altered and the agreement to which is a precondition for UNDP assistance;

(ii) Revisions which do not involve significant changes in the immediate objectives, outputs or activities of the project, but are caused by the rearrangements of inputs already agreed to or by cost increases due to inflation; and

Mandatory annual revisions which re-phase the delivery of agreed programme inputs, or reflect increased expert or other costs due to inflation, or take into account agency expenditure flexibility.

ANNEX 1 - PROJECT BUDGET/REVISION

CPR/96/G31/B/1G/01: Promoting Methane Recovery and Utilisation from Mixed Municipal Refuse

REMARKS: Expenditure in 1996 relates to project preparatory assistance

		Total Amt WM	1996 Amt WM	1997 Amt QM	1998 Amt WM	1999 Amt WM	2000 Amt WM
10.00	PROJECT PERSONNEL						
11.00	INTERNATIONAL EXPERTS						
11.01	Senior Technical Advisor	100,000		40,000	20,000	20,000	20,000
11.02	Landfill Design Advisor	75,000	15,000	40,000	20,000		
11.03	Env. Chem. Engineer	27,000		27,000			
11.04	Gas Recovery Advisor	50,000		20,000	30,000		
11.05	Electricity Generation Advisor	60,000			20,000	20,000	20,000
11.06	Landfill Oper. Advisor	80,000		20,000	40,000	20,000	
11.07	Solid Waste Management Advisor	40,000		20,000		20,000	
11.08	Environmental Economist	77,000	17,000	20,000	20,000		20,000
11.09	Landfill O+M Trainee	110,000		40,000	20,000	40,000	10,000
11.10	Evaluator	80,000				40,000	40,000
11.99	Subtotal	699,000	32,000	227,000	170,000	160,000	110,000
15.00	Official Travel						
15.01	Duty travel	23,500	3,500	5,000	5,000	5,000	5,000
15.99	Subtotal	23,500	3,500	5,000	5,000	5,000	5,000
16.00	Mission costs						
16.01	Mission Cost	54,000	6,000	12,000	12,000	12,000	12,000
16.99	Subtotal	54,000	6,000	12,000	12,000	12,000	12,000
17.00	National Professionals						
17.01	Nat'l Consultant	2,500	2,500				
17.02	Env. Chem Eng	53,000		15,000	15,000	15,000	8,000
17.03	Landfill Des. Adv	42,500		14,500	14,000	14,000	
17.04	Landf. Eng. Adv	40,000		10,000	20,000	10,000	
17.05	Landfill Oper. + Maintenance	40,000			20,000	20,000	
17.06	Senior Fin. Exp.	30,000		15,000	15,000		
17.07	Env. Economist	18,000		6,000	6,000	6,000	

		Total Amt WM	1996 Amt WM	1997 Amt WM	1998 Amt WM	1999 Amt WM	2000 Amt @M
17.08	Sr. Regul. Expt.	12,000		4,000	2,000	4,000	2,000
17.99	Subtotal	238,000	2,500	64,500	92,000	69,000	10,000
19.99	Component Total	1,014,500	44,000	308,500	279,000	246,000	137,000
20.00	Subcontracts						
21.01	Engineering svces for Ausd	159,000		100,000	59,000		
21.02	Engineering Svces for Maann	159,000		100,000	59,000		
21.03	Action Plan Formulation	49,000		49,000			
21.04	Landfill M+O	36,000			36,000		
29.00	Component Total	403,000	0	249,000	154,000	0	0
30.00	Training						
31.02	Landfill Design	50,000		50,000			
31.03	Landfill Oper. & Mgt	50,000			50,000		
32.00	Study Tour	60,000		60,000			
39,00	Component Total	160,000	0	110,000	50,000	0	0
40.00	Equipment						
41.01	Expendable for Anshan	135,000		55,000	30,000	25,000	25,000
41.02	Expendable for Mannshan	135,000		55,000	30,000	25,000	25,000
41.03	Expendable for Nanjing	135,000		55,000	30,000	25,000	25,000
41.04	Expendable for Center	28,000		10,000	8,000	5,000	5,000
42.01	Nonexp Eqp/Anshan	880,000		200,000	580,000	50,000	50,000
42.02	Nonexp Eqp/Maanshan	880,000		200,000	580,000	50,000	50,000
42.03	Nonexp Eqp/NJ	880,000		400,000	380,000	50,000	50,000
42.04	Nonexp Eqp/Center	180,000		60,000	60,000	40,000	20,000
49.00	Component total	3,253,000		1,035,000	1,698,000	270,000	250,000
50.00	Miscellaneous						
51.00	Communication	7,200		2,000	2,000	2,000	1,200
52.00	Reporting	16,030	630		5,200	5,000	5,200
53.00	Sundry	8,470	1,000	1,500	2,000	1,970	2,000
54.00	Project support (max. 2%)	105,700	0	41,425	44,875	11,650	7,408
59.00	Component total	137,400	1,630	44,925	54,075	20,620	15,808
90.00	Support Costs	0					
93.00	Agency Support Cost (max 6%)	317,100	1,028	124,275	134,625	34,950	22,222
99.00	Component total	317,100	1,028	124,275	134,625	34,950	22,222
999.0	UNDP Total	5,285,000	46,658	1,871,700	2,369,700	571,570	425,030

ANNEX 2 - DESCRIPTIONS OF LOCATIONS OF FIELD TRIALS AND DEMONSTRATION PLANTS

Anshan : Located in Liaoning Province, Anshan is a northeastern city at 41 degrees north latitude. It is the steel capital of China and has a population of about 1.35 million in its urban center. Anshan produces "town" gas from coal gasification. By 1990, its gas distribution network served 90% of the city, and district heating served 70%. Municipal refuse output averages 1,200 tons per day. Its organic content is very high, over 60 percent, because it contains little coal ash (typically a large waste component in northern Chinese cities) due to the availability of gas for cooking, and district heating.

Anshan has been using the Gangguanling Landfill for the past several years located about 10 Km outside the city. The facility has not been designed or operated as a sanitary landfill, e.g. there is no compaction, leachate collection, or application of daily cover. It must be closed as soon as the new landfill is open. More than one million tons (metric) have been deposited at this site at depths exceeding 12 meters in some places. One gas extraction well has been producing landfill gas on an experimental basis since 1990. The gas is used to complete combustion of medical wastes and to fire a hot water boiler used to heat a greenhouse constructed on site.

A new landfill site located about 15 km from the city has been selected, tested, and purchased. This facility will be designed as a sanitary landfill and will provide the gas for Anshan's methane recovery pilot plant. Land-filling is expected to begin at the end of 1997.

Maanshan: At 32 degrees north latitude, Maanshan is located in the east of Anhui Province, on the banks of the Yangtze River. Maanshan is also a steel city, ranking in the top ten in China. Its inner city population of about 400,000 is 80% served with a gas distribution network. The gas cooking and the very low heating requirements mean that very little coal ash goes into the municipal waste stream. Thus the over 300 daily tonnage of waste contains over 80% organic material. Waste tonnage is growing at about 10% per year.

In 1985 a landfill was built at Xiangshan, about 5 km north of the city. It was not originally designed as a sanitary landfill, but construction is underway to upgrade the new parts of the fill to national standards. A leachate treatment plant will soon be built to treat leachate from both the old and new sections of the facility. Eleven landfill gas extraction wells have been installed in the portion of the landfill that has been closed and capped. Gas from one of these wells is used on a daily basis to heat hot water for showers for sanitation workers and to fuel small stoves. Gas is also used to generate electricity from a 5 kW power plant.

Nanjing: Located 50 km north of Maanshan on the east bank of the Yangtze River, Nanjing is in the southwestern corner of Jiangsu Province and is its capital. It a fast growing commercial, manufacturing, and cultural city of about 3.6 million (urban only). Nanjing has developed into a busy international trading center, attracting foreign investments in its many ventures. It will soon be completing its international airport.

Nanjing's waste stream is currently more than 2000 tons per day and growing. The city is building three new sanitary landfills in three different directions from the center. Each will accept up to 800 tons per day at first. The Jiaozishen Landfill is complete and is being used. It has a fully operational leachate treatment plant. The Shuige Landfill, under construction until mid-1994, has also begun to accept wastes. Construction is just starting at the Tinajiawa Landfill. It is expected that either or both Jiaozishen and Shuige will be the site of the field trials, and only the larger one will be the site of the full-scale pilot plant.

ANNEX 3: TERMS OF REFERENCE FOR INTERNATIONAL AND NATIONAL CONSULTANTS, AND SUB-CONTRACTS

A. International Consultants

1. Tasks

1. *Waste Characteristics and Disposal Practices Study.* Travel to Beijing, Anshan, Maanshan and Nanjing to meet with NEPA, local solid waste management officials and national consultant. Review the existing data on waste characterization and disposal practices as they affect each of the landfill gas recovery demonstration landfills. Compile data on past waste disposal in the landfills and, to the extent practical based on data provided by local municipal officials, compile estimates of past waste disposal and projections of future waste disposal on an annual basis. Prepare a report on waste characteristics and disposal practices in the demonstration project cities. [Activities 1.1.1 - 1.1.3]

2. *Plan and Analyze Data from Field Trials.* Travel to China and tour the demonstration project landfill sites. Plan the field trials of landfill gas collection technologies for each of the demonstration project landfills. Include design of the collection system, an operational plan, schedule, and testing requirements. Make recommendations to the landfill operators for changes to landfill design and operational practices that will facilitate the field trials. Analyze the data from the field trials to determine design criteria for the demonstration projects. [Activities 1.2.2, 1.2.3, 1.2.5]

3. *Demonstration Project Planning and Design.* Travel to China to oversee a market study to determine potential end users of landfill gas energy products. Assist NEPA in organizing workshops to establish the institutional framework for the projects. Work with NEPA and the local solid waste management officials to establish the institutional framework for each project, based on experience with successful projects abroad as well as local requirements. Assist in establishing an energy service company (ESCO) for one of the projects. Establish the basic design criteria for each demonstration project. Estimate gas production from the landfill over time and prepare a schedule of estimated construction costs, energy or fuel sale revenues, and operation and maintenance costs corresponding to the incremental additions and removals of equipment over time. Prepare engineering drawings and specifications suitable for construction of the first module of energy recovery equipment at each site and site preparation for future modules. Include equipment specifications and vendor requirements for assistance during installation, startup and testing. [Activities 2.1.1, 2.1.2, 2.2.3 - 2.2.5]

4. *Demonstration Project Assistance During Startup and Operations.* Travel to China to observe construction of each of the projects and again to be present at the startup of each of the demonstration projects. Assist with startup and operations by preparing startup and operational checklists. Prepare a plan of anticipated O&M requirements and costs. Prepare a data collection and documentation plan. [Activities 2.2.7 - 2.2.9]

5. *Analysis of Demonstration Project Data.* Analyze the demonstration project data from all three sites, including performance analyses of the major equipment (including the gas collection system). Based on an economic evaluation of costs and revenues actually incurred and a performance analysis of the institutional arrangements prepared by a national consultant, prepare recommendations for development of future landfill gas recovery projects based on the data analysis. [Activity 2.2.9]

6. *Assist NEPA in Developing an Action Plan for Widespread Adoption of Landfill Gas Energy Recovery.* Organize and oversee two study tours abroad for Chinese solid waste management officials. Travel to China and work with NEPA and other appropriate agencies, developing up to three alternative models of institutional arrangements that are likely to be practical in China for landfill gas energy recovery projects. Identify and quantify the likely effects of measures to reduce the costs landfill gas energy recovery. Assist NEPA in formulating national policy, standards, and regulations for landfill gas control and recovery, financial aid policies, subsidies, or other incentive policies. Prepare a plan for providing ongoing technical assistance to developers of new landfill gas recovery projects. [Activities 3.1.1 - 3.1.9]

7. *Assistance in Establishing Landfill Methane Recovery Research, Information, and Training Center.* Provide technical assistance to NEPA in developing the charter, organization, and physical requirements for the center.

Travel to China and develop a database structure and data collection, maintenance and distribution program. Assist in planning and establishing a library of material on landfill gas energy recovery. Assist NEPA and a national consultant in developing and conducting the initial training courses. [Activities 3.2.3 - 3.2.5, 3.2.7, 3.2.8, and 3.2.10]

2. Personnel and Qualifications

The international consultant will be an international consulting firm that can provide personnel with the following qualifications:

Lead landfill gas engineer: Engineer with 10 years of experience in planning and designing landfill gas collection and recovery systems, excellent English writing skills. [All tasks]

Junior landfill gas engineers: Engineers with 5 years of experience in planning and designing landfill gas collection and recovery systems. [Tasks 1 through 5]

Economist: With master's degree and 5 years experience analyzing landfill-related projects. [Tasks 3, 5, and 6]

Civil engineers: With 5 years experience in design and operational planning for solid waste landfills. [Tasks 2 and 3]

Mechanical engineers: With 5 years experience in landfill gas recovery system design. [Tasks 2 and 3]

Electrical engineers: With 5 years experience in landfill gas recovery system design. [Tasks 2 and 3]

The international consulting firm will also be required to supply air pollution control engineers, engineers with experience in leachate treatment and recirculation, and instrumentation and control system design as they will apply to the project. Firms employing as permanent staff members persons with knowledge of Mandarin should be given priority.

B. National Consultants

1. Tasks

1. *Waste Characteristics and Disposal Practices Study.* Assist in formulating the approach to the study by collecting and compiling available data. Collect, compile, summarize and review the waste characterization and landfill design and operational information. [Activities 1.1.1, 1.1.2]

2. *Conduct Field Trials.* Plan the field trials. Assemble information on the landfill sites where the field trials are to be carried out and coordinating with the landfill operators. Make recommendations on changes in landfill design and operations to facilitate landfill gas energy recovery. Provide information on locally available materials, equipment, and laboratory services. Provide field data collection equipment. Carry out the field trials in accordance with the field trial plan and provide a data report. [Activities 1.2.2 - 1.2.5]

1. *Demonstration Project Planning and Design.* Assist NEPA in organizing workshops to establish the institutional framework for the projects. Work with NEPA and the local solid waste management officials to establish the institutional framework for each project, based on experience with successful projects abroad as well as local requirements. Specifically, identify and establish contacts with potential financing agencies. Collect data on and compute avoided costs for production of energy in the three demonstration project cities. Assist in establishing an energy service company (ESCO) for one of the projects. Prepare engineering drawings and specifications for the demonstration project gas collection and energy recovery systems. Assist with planning and designing demonstration projects. Provide information on locally available equipment and services, including costs, availability and delivery times. [Activities 2.1.1 - 2.1.5, 2.2.5]

4. *Demonstration Project Construction Observation, Startup, and Operations.* Provide technical and communications assistance during startup and operation of the demonstration projects. Observe construction and provide weekly reports to the landfill owner. Plan and carry out a data collection program during startup and operations, and compile the data into monthly reports. Provide the instruments to collect the data. [Activities 2.2.7 through 2.2.9]

5. ***Analysis of Demonstration Project Data.*** Prepare an economic evaluation of costs and revenues actually incurred in the demonstration projects. Plan and carry out a performance analysis of the institutional arrangements. [Activity 2.2.9]

6. *Assist NEPA in Developing an Action Plan for Widespread Adoption of Landfill Gas Energy Recovery.* Identify the technologies and end uses of gas that may be commonly practical in China. Conduct an economic analysis to determine the typical competitiveness of electric power generation and estimate subsidies that may be necessary. [Activities 3.1.4, 3.1.6]

7. ***Assistance in Establishing Landfill Methane Recovery Research, Information, and Training Center.*** Assist NEPA in designing a database for tracking data on landfill gas energy recovery projects throughout China. Construct and maintain the database throughout the project period. Develop four initial training courses and conduct them at the research and dissemination center. [Activities 3.2.7, 3.2.8, and 3.2.10]

2. Personnel and Qualifications

The national consultant will be an engineering consulting firm or firms that can provide personnel with the following qualifications:

Senior engineers: Civil, mechanical, or chemical engineers with graduate degrees and 10 years experience who can prepare and review design drawings for landfill gas demonstration projects and supervise the engineering inspections during the construction and startup. [Tasks 3 through 6]

Junior engineers: Civil, mechanical, or chemical engineers with bachelors degrees and 5 years experience who can assist in development of equipment specification and construction and installation design documents. [Tasks 2 through 5]

Research assistants: Persons with 2 years experience in researching information, familiar with engineering and technical terms and concepts. [Tasks 1, 2, 6 and 7]

Field technicians: Persons familiar with using standard instruments for measuring pressures, flow rates, and other engineering parameters associated with operating equipment. Two years experience. [Tasks 2 and 4]

Construction inspectors: Persons with five years experience in observing that civil works are in accordance with specifications and drawings. [Tasks 2 and 4]

C. Laboratory Testing Services

1. Tasks

1. Provide sample containers for gas and water samples at intervals throughout the field trials and demonstration projects, as determined during the plan preparation for these activities.

2. Provide analyses of landfill gas, including the following parameters:

Methane

Carbon dioxide

- Nitrogen
- Oxygen
- Lower heating value (kcal per cubic meter)
- Trace organic compounds

  Total organic chlorides

  Total sulfur compounds

3. Provide analyses of landfill gas condensate, including the following parameters:

   Trace organic compounds
   - Total organic carbon

   Chemical oxygen demand
   - pH

   Total dissolved solids

C. Sub-contractors

1. Construction of Field Trial Gas Collection Systems:

Perform the following at each of the demonstration project sites:

Construct the gas collection system for field trials in accordance with the design prepared by the Consultants, including the following items:

1. Provide the use of a bucket auger drilling rig and drilling crew to install up to 6 landfill gas collection wells. (up to 80 m. deep) Provide safety equipment to protect the drilling crew and prevent the ignition of landfill gas. Prior to beginning drilling, submit a safety plan to the project director for review. Dispose of the drill cuttings as directed by the landfill owner. Construct the wells as designed. Provide and construct well head equipment as specified in the design. Equipment will be identical and interchangeable among the individual wells.

(Note: Delete item 1. if horizontal or vertical wells are installed by the landfill operator prior to construction of the field trial gas collection system)

2. Provide and construct, piping, valving, condensate drains, and temporary condensate tanks to carry the gas from the landfill to the temporary blower.

3. Install small diameter PVC pressure monitoring probes in the landfill to the depth required by the field trial design. Provide appurtenances to allow pressure measurement and gas sampling as required by the field trial design. The probes shall be constructed airtight and appurtenances installed to allow airtight connection of sampling and testing devices.

4. Provide skid mounted electric-powered centrifugal blower and power source. Blower flow rate range and vacuum capability shall be as required by the design. Approximate flow rate range prior to design is 2 to 16 m^3 /min. and vacuum requirement is -20 kPa. Provide a temporary flare to handle up to 16 m^3 /min and an ignitor and flare inlet flame arrestor. Provide appurtenances necessary to take gas samples and

measure gas flow rate as required by the design. Coordinate with the field trials operation subcontractor to ensure that all installation is compatible with field trial operation and monitoring equipment. One blower with power source and one temporary flare may be provided and used at each of the three sites if the field trial schedule allows and if the capacity requirements of the three field trial designs allow use of a single blower for all three.

5. Startup the system and demonstrate that no leaks exist in the piping and that all parts function as intended and as specified in the design.

6. Provide as-built drawings and well installation logs documenting construction of the system in accordance with the design.

Following completion of the field trials, transfer ownership of the skid mounted blower and power source and the temporary flare to the project for future use at other landfill sites. Provide one year manufacturer's warrantee on this equipment.

2. Operation of Field Trial Landfill Gas Collection System:

Perform the following at each of the demonstration project sites:

Operate the gas collection system for field trials in accordance with the field trial design for at least four weeks or longer if required by the design, including the following tasks:

1. Operate the system continuously, extracting gas from the test wells for at least four weeks. Maintain and repair the system as necessary to its continuous functioning as intended.

2. Provide the use of portable field equipment during the field trial to measure pressures, gas flow rates, and gas composition and to take gas samples for laboratory analysis, as required by the field trial design.

3. Measure gas flow rates and gas composition from each well and at the blower inlet on at least a daily basis.

4. Measure pressures at each wellhead, at the blower inlet and blower outlet, and at each pressure monitoring probe on at least a daily basis.

5. Vary the flow rates and measure effects in accordance with the field trial design.

6. Record all measurements in the format required by the field trial design and provide a data report and data summary at the end of the field trials.

3. Construction of the Demonstration Project Gas Collection Systems and Energy Recovery Plants

Perform the following at each of the demonstration project sites:

Construct the gas collection system for the demonstration projects in accordance with the design prepared by the Consultants, including the following items:

1. Provide the use of a bucket auger drilling rig and drilling crew to install up to 25 landfill gas collection wells (up to 80 m. deep). Provide safety equipment to protect the drilling crew and prevent the ignition of landfill gas. Prior to beginning drilling, submit a safety plan to the project director for review. Dispose of the drill cuttings as directed by the landfill owner. Construct the wells as designed. Provide and construct well head equipment as specified in the design. Equipment will be identical and interchangeable among the individual wells.

(Note: Delete item 1. if horizontal or vertical wells are installed by the landfill operator prior to construction of the demonstration project gas collection system)

2. Provide and construct, piping, valving, and condensate drains to carry the gas from the landfill to the temporary blower. Construct a permanent condensate drain piping system and pumps, sumps and discharge piping to carry the condensate to the leachate treatment system.

3. Install small diameter PVC pressure monitoring probes in the landfill to the depth required by the demonstration project design. Provide appurtenances to allow pressure measurement and gas sampling as required by the field trial design. The probes shall be constructed airtight and appurtenances installed to allow airtight connection of sampling and testing devices.

4. Ensure that all construction and environmental permits have been obtained.

5. Perform earthwork and site preparation work as required by the demonstration project design. Work includes clearing, grubbing, stripping, grading, temporary and permanent erosion control, and site drainage construction. Dispose of materials as directed by landfill owner.

6. Construct equipment foundations, enclosures, and buildings as required by the design. Provide utility connections and arrange for connections to utilities including electric power and water. Construct sanitary facilities and systems as required by the design.

7. Provide and construct a permanent centrifugal blower and permanent flare with automatic ignition system and flame arrestor as required by the design. Connect this equipment to the gas collection piping and to electric power supply. Make all arrangements for electric power service for the blower. Provide all required instrumentation and a control system for operation of the blower and flare in accordance with the demonstration project design.

8. Provide and construct gas cleanup and compression equipment as required by the design. Connect to gas piping and construct condensate drainage piping, traps, sumps, and pumps. Provide all instrumentation and control equipment required by the design for the gas cleanup equipment.

9. Provide and construct energy recovery equipment as required by the design.

For electric power production projects only, perform 8a through 8e:

9a. Connect to the gas piping, switchgear and electric power grid protection devices as required by the design.

9b. Provide and construct electric power switchgear and grid protection devices as required by the design.

9c. Provide and construct the power transmission cable and supporting structures from the demonstration project to the connection substation designated by the power utility.

9d. Provide and install electric power metering equipment as required by the design.

9e. Coordinate startup with the electric power utility

For projects that implement direct delivery of gas for use as fuel only, perform 9f. through 9k:

9f. Connect the compressor to the gas pipeline.

9g. Construct the gas transmission pipeline to the end user, including all necessary civil engineering work.

9h. Construct modifications to end users gas equipment as required by the design

9I. Provide gas metering equipment

9j. Construct condensate drainage piping, traps, sumps, pumps and piping to the leachate treatment system.

9k. Coordinate startup with the gas end user.

10. Provide and install all instrumentation and control equipment as required by the design, including permanent gas analyzers, pressure gauges and transducers, control wiring, relays, switches, programmable controllers and programming thereof, display equipment, and telemetry equipment.

11. Obtain services of manufacturers' representatives and perform startup of all equipment and demonstrate operation in accordance with design requirements.

12. Provide one year manufacturers' and installation warrantee on all equipment.

13. Provide spare parts as required by the design.

14. Provide complete operation and maintenance manuals for all equipment.

15. Provide as-built drawings for all construction and well installation logs documenting construction of the system in accordance with the design.

4. Operation of the Demonstration Project Gas Collection Systems and Energy Recovery Plants

Perform the following at each of the demonstration project sites:

Operate the gas collection system and energy recovery equipment in accordance with the project design for the entire duration of the project, including the following tasks:

1. Operate the system continuously, extracting gas from the test wells for the duration of the project. Maintain and repair the system as necessary to its continuous functioning as intended.

2. Provide the use of portable field equipment during the field trial to measure pressures, gas flow rates, and gas composition and to take gas samples for laboratory analysis, as required by the field trial design.

3. Measure gas flow rates and gas composition from each well and at the blower inlet on at least a daily basis.

4. Measure pressures at each wellhead, at the blower inlet and blower outlet, and at each pressure monitoring probe on at least a daily basis.

5. Maintain continuous recording of the gas flow rate and gas quality at the inlet to the energy recovery equipment.

6. Maintain continuous recording of the energy output of the plant. Compute the thermal efficiency of the plant by comparing gas flow and quality inputs vs. total energy output on a weekly basis.

7. Dispose of waste products as directed by the landfill owner.

8. Maintain optimum gas flow rates from each well in accordance with the field trial design. Measure gas flow and quality at each well on at least a monthly basis and adjust accordingly.

9. Record all measurements in the format required by the demonstration project design and provide a data report and data summary at the end of the field trials.

5. Study Tour

Perform the following tasks:

1. Assist NEPA in identifying locations to tour. Make contacts with responsible persons at those sites and confirm the features of the facilities that will be on the tour.

2. Arrange and provide transportation, meals, and lodging for the persons participating in the tours.

3. Prepare a detailed itinerary for the tour from departure to return to China. Include times of travel, location names, lists of accommodations, names of hosts and other responsible persons at the tour sites, and summaries of the features of each facility on the tour. Distribute the itinerary to each tour participant.

6. Landfill Gas Recovery and Utilization Training

Perform the following tasks:

1. Work with NEPA to develop the course content, scope, number and length of sessions, course schedule and list of training materials and activities for each course.

2. Develop a budget for the training program.

3. Develop and prepare the training course materials. Materials will include audio-visual aids, textbooks, and demonstration equipment. Provide all materials necessary for all training courses conducted during the project.

4. Retain the services of national and international experts in landfill gas recovery to review and assist with preparation of the training materials.

5. Provide and train instructors for the training courses.

6. Conduct the training courses at the landfill gas energy recovery research and dissemination center in Anshan. Present each training course at least one hundred persons.

7. Provide separate training courses covering the following topics:

- basic landfill gas collection system principles and operation practices,
- landfill gas safety,
- economics of landfill gas recovery,
- fundamental landfill gas collection and energy recovery system design for engineers.

ANNEX 4 - Implementation Schedule

		MONTH				
Task	0	6	12	18	24	30
1. Initial Demo. Project Study (Output 1.1)		xxxxx				
2. Institut. Arrangements workshops (Output 2.1)		xx				
3. Field Trials - Nanjing (Output 1.2)		xxxx	xxxx			
4. Design/ Construct. Plan - Nanjing (Output 2.2)			xxxx	xxxxxx	xxxxxx	xx
5. Operate Plant - Nanjing (Output 2.2)						xxxxxx
6. Field Trials - Anshan (Output 2.2)				xxxxxx	xx	
7. Design/ Construct. Plan - Anshan (Output 2.2)					xxxxxx	xxxxxx
8. Operate Plant - Anshan(Output 2.2)						
9. Field Trials - Maanshan (Output 2.2)					xxxxxx	xx
10. Design/ Construct. Plan - Maanshan (Output 2.2)						xxxxxx
11. Operate Plan - Maanshan (Output 3.1)		xxxx	xxxx	xxxx	xxxx	xxxx
12. Field Trials - Maanshan (Output 3.2)		xxxx	xxxx	xxxx	xxxx	xxxx

ANNEX 5 - EQUIPMENT REQUIREMENTS

Non-Expendable Equipment List for Field Trials

Gas Well Installation Equipment:
- Bucket auger drilling rig, capable of drilling 0.6 to 1.0 m. hole to a depth of 80 m.
- Fans and generator for surface emission control
- Personal methane and hydrogen sulfide monitors for drilling crew
- Well casing and backfill materials
- Wellhead equipment (valves, test ports, flow measurement devices)

Piping and control valves for connecting wells to blower
Temporary flare with flame arrestor and ignitor
Centrifugal blower (capacity estimated based on field trial plan) with portable power supply
Temporary condensate knockout pot
Temporary condensate drainage piping and tank
Portable gas analyzer with the following capabilities:
- Measures CH4, O2, CO2 in percent by volume, temperature in degrees C., pressure in kPa (to the nearest 0.1 kPa).

Portable gas flow measuring device (pitot tube, orifice plate, or hot-wire anemometer)
Notebook computer with spreadsheet software for field data reduction

Non-expendable Equipment List for Demonstration Projects

The following equipment is needed at each of the three sites:
Well installation equipment (same as for field trials)
Piping and control valves for connecting wells to blower
Permanent flare with diversion valves, flame arrestor, and ignitor
Centrifugal blower (capacity based on field trial plan) with portable power supply
Temporary condensate knockout pot
Temporary condensate drainage piping and tank
Portable gas analyzer with the following capabilities
- Measures CH4, O2, CO2,in percent by volume, temperature in degrees C, pressure in kPa (to the nearest 0.1 kPa)

Portable gas flow measuring device (pitot tube, orifice plate, hot-wire anemometer)
Notebook computer with spreadsheet software for field data reduction

The following equipment is needed for landfill gas-to-electric power projects:
Compressor (capacity and type based on requirements of engine/generator set)
Modular engine/generator set (output kW based on field trials)
Transformers, switchgear, and grid protection devices (as required by electricity bureau)
metering equipment (as required by electricity bureau)
Power transmission cable to power transmission substation

The following equipment is needed for direct-transmission-of-landfill gas projects:
Compressor (capacity and type based on end user volume requirements and distance from landfill)
Transmission pipe
Condensate drains, traps, pumps and discharge to sewer in transmission line
Gas flow and quality metering at end user site
Switchover valving and burner orifices at end user site

ANNEX 6 - LANDFILL GAS RECOVERY TECHNOLOGY

What is Landfill Gas?

Landfill gas is generated by bacteria that decompose organic matter after it is buried in a landfill. These bacteria thrive only in environments where all oxygen has been excluded. They produce a gas mixture that consists of approximately half methane and half carbon dioxide. Because of its methane content, landfill gas is flammable and must be prevented from migrating through subsurface conduits away from the landfill to basements and other locations where it may cause a hazard. In addition to being flammable, methane is explosive when mixed with air at concentrations between 5% and 15% by volume.

In addition to the methane and carbon dioxide, landfill gas typically contains trace organic compounds, some of which are toxic, many of which are malodorous, and some of which can be harmful to energy recovery equipment. For this reason, energy recovery projects almost always include equipment to remove these materials from the gas stream.

Because production of landfill gas is a biochemical reaction, its production can be modeled with equations that represent the metabolic processes of microorganisms. First order kinetic models have been found to closely approximate the change over time of landfill gas generation from a given mass of solid waste. However, estimates of landfill gas production based purely on theoretical inputs have generally overestimated gas production. For landfill gas recovery projects in Europe and North America, several international consultants and the U.S. Environmental Protection Agency have developed models of landfill gas generation based on empirical data from operating gas recovery projects. The better of these models allow calibration for site-specific conditions such as waste composition and moisture content in the landfill.

The fuel value of landfill gas is approximately half that of natural gas, which is primarily methane. Thus the fuel value of landfill gas is approximately 4,500 kcal per cubic meter.

How is Landfill Gas Collected?

A landfill gas collection system is constructed by installing gas wells in the landfill and connecting them via piping at the surface to the inlet side of a blower that applies a vacuum to the wells. The wells are typically drilled through nearly the full depth of the landfill, after the entire planned thickness of fill has been put in place in a given area in the landfill. (For this reason, planning a landfill gas recovery project requires close coordination with the fill sequence plan for the landfill.) Two wells per hectare of landfill surface area are typically installed.

Control valves and monitoring ports and devices are placed on every wellhead. This is required to adjust the gas flow at each well to what is sustainable for that well. The sustainable gas flow varies significantly from well to well because of differences in the landfill depth, other aspects of the landfill configuration, and the characteristics of the waste within the region of influence of the gas well. Furthermore, the sustainable gas flow changes over time within a given well. If too much gas is extracted from the landfill, air will be pulled in through the landfill cover. In addition to diluting the landfill methane, the introduction of air into the landfill can destroy the gas producing organisms, and in some cases has caused smoldering fires in landfills by promoting high-temperature aerobic reactions. For these reasons, a regular monitoring and well flow adjustment program, with at least monthly adjustments at each wellhead, is typically necessary.

An alternative type of well that has been used successfully in several landfill gas recovery projects is the horizontal trench collector. Rather than installing drilled wells after the fill has reached its final grade, trenches are cut into layers of refuse as they are placed during landfill operations. These trenches are backfilled with gravel and perforated plastic piping before being covered with additional layers of waste. The perforated piping at the ends of the trenches is outfitted as a vertical wellhead would be and connected to piping that carries the gas to a blower and on to the energy recovery equipment. Projects in the USA and Canada have shown that this method of collecting landfill gas can function effectively and has lower construction costs than vertical wells. It has the further advantage that the wells can be connected to the gas recovery piping and used to collect gas before the fill has

reached final grade. The chief drawback of this method is that it requires very close coordination with filling operations on an ongoing basis.

How is the Energy in Landfill Gas Converted to Electric Power?

Gas collected from the landfill must be processed to remove excess water vapor and the trace compounds that may be harmful to the energy recovery equipment. These compounds include organic halides and sulfur compounds. Fortunately, these compounds are often removed to acceptable levels through refrigerative removal of water vapor from the gas stream. In other cases, additional processing must be done to remove these compounds to lower levels. Processes to clean the gas include packed bed scrubers and activated carbon beds. The process required depends on the gas stream composition and the tolerances of the energy recovery equipment.

To produce electric power, the landfill gas is burned in either an engine or a gas turbine attached to a dynamo generator. These are typically installed in modular units that are some fraction of the planned overall generating capacity of the project. The reason for this is that the rate of gas generation at a given landfill starts out low and increases over the years as more waste is added to the landfill. Thus a typical landfill gas recovery project will start out with one or two initial modules of energy recovery equipment, and more will be added over time as the landfill becomes larger and gas flow increases. Using the same type and size of units allows spare parts to be used interchangeably and maintenance procedures to be similar for each unit.

The power from the generators used in landfill gas recovery projects must normally be transformed before it is introduced into the power distribution grid. Electric utilities also require automatic protection equipment that will disengage the unit from the grid if its alternating frequency or power exceeds a specified range. Metering and switchgear must also be installed. The power is normally introduced to the grid at an existing transmission substation in the vicinity of the landfill, and can be carried to the substation by either overhead or buried cables.

How is Landfill Gas Processed for Direct Transmission for Use as Fuel by End Users?

Landfill gas can often be used directly as fuel for boilers, in furnaces and kilns, and for space heating, if end users are present in the vicinity of the landfill. This option is usually considered if an end user for a sizable quantity of gas exists, or is planning to build a facility, within 10 km of the landfill.

To deliver the gas, a buried pipeline is constructed from the landfill to the user's location. The gas is processed at the landfill to remove any constituents that may be harmful to the user's equipment, then excess moisture is removed and it is compressed to meet the user's requirements, taking pressure drop through the transmission pipeline into account.

Often, existing burners must be modified to use landfill gas, which has a lower energy content than natural gas. Valves and meters are installed. The nature and sophistication of the metering and recording equipment are a function of the gas user's requirements. The advantage of this method of recovering energy from landfill gas is that the thermal efficiency of direct heating applications is much higher than conversion of the gas to electric power. The thermal efficiency of the energy transfer from the gas to a boiler typically exceeds 90%, whereas the thermal efficiency of electric power generation is typically less than 40%.

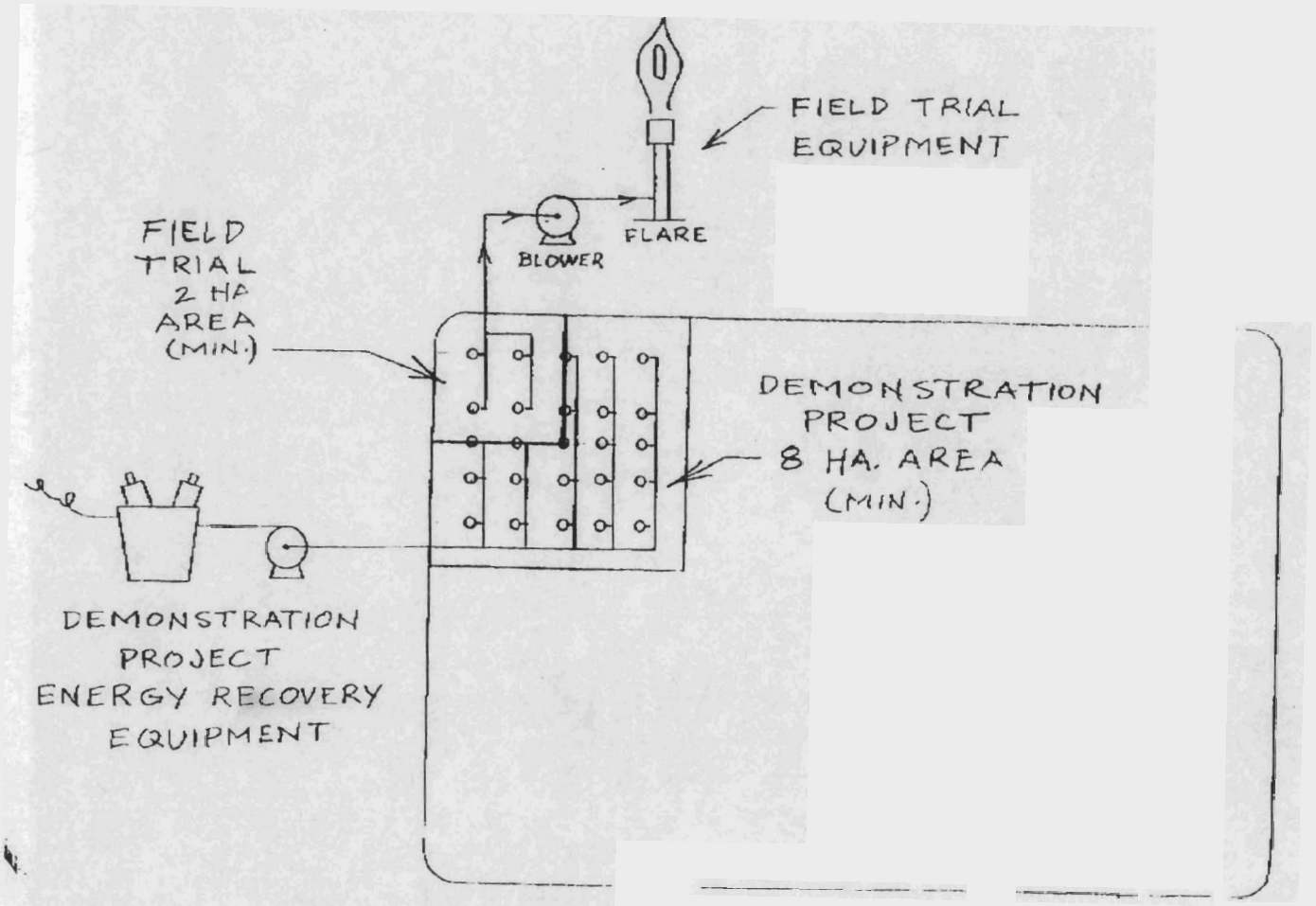


FIGURE 1. - FIELD TRIALS AND DEMONSTRATION PROJECT LAYOUT.

CFR/96/431 Methane Project.

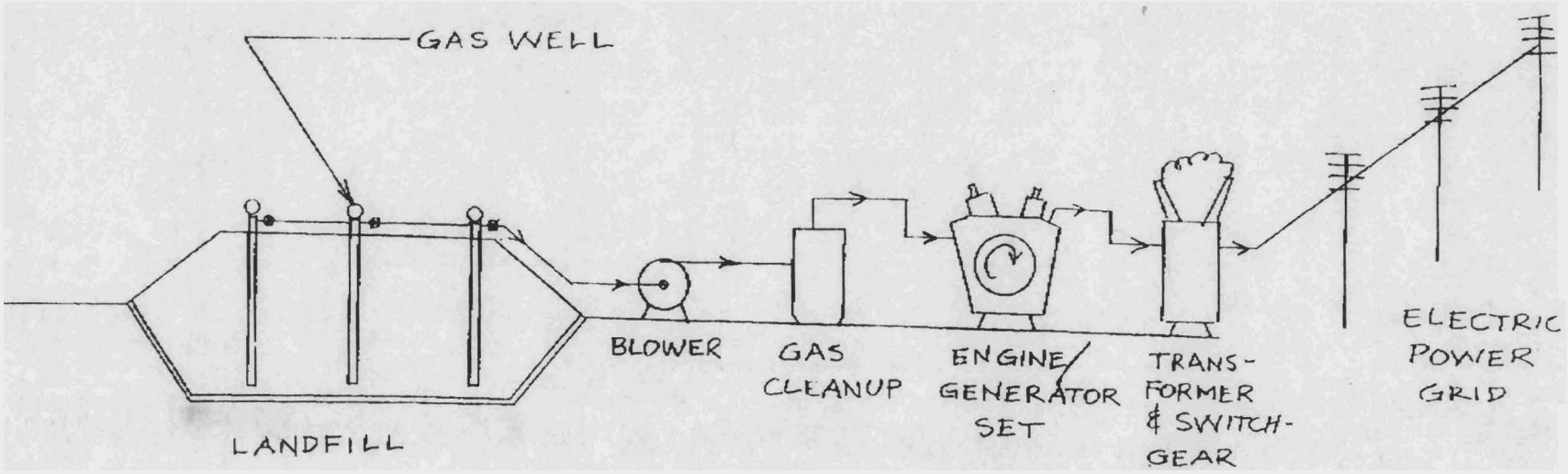


FIGURE 2. - GAS RECOVERY EQUIPMENT SCHEMATIC

CIR/96/631 Methane Project