Proposal for a National Action Plan for Recovery and Utilization of Landfill Gas In China

(Final draft)

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Colophon

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Executive Summary

China's current way of managing municipal solid waste pose a great danger to the future of China's environmental sustainability and consequently as a great nation. Environmental impacts caused by improper solid waste management can cause irreparable damage to the nation, especially for a densely populated country.

A sustainable growing economy requires sound waste management of municipal refuse. The treatment of waste in landfill sites has to be done in a sanitary way in order to protect the environment. The formation and emission of landfill gas, by anaerobic digestion can harm the global environment as a greenhouse gas, and the local environment due to smell and risk of explosion. However landfill gas can also be a renewable source of energy.
Nowadays the situation in China is such that there are vast opportunities to utilize landfill gas; challenging the country and therefore this action plan has been formulated to realize these opportunities.

The objective of this action plan is the promotion and widespread adoption of landfill gas recovery and utilization in China. Based on international best practices and a case study from an existing demonstration project in China, an analysis of barriers results in a strategy to remove the barriers and start up the implementation. All the actions needed to start up the wide implementation are presented in the action plan.
The goal is that both governmental bodies and parties in the market are actively involved in sanitary waste treatment, and that energy is produced from the landfill gas. The overall target should be that all waste is treated in a sanitary way in all the major Chinese cities by 2015.

Proposed actions could lead to:

- In 200 large cities in China, landfill gas will be utilized for energy in the year 2015.
- About 200 million ton of Municipal Solid Waste will then be treated in about 600 sanitary landfills
- The landfill gas collection will be about 11 billion m3 per year landfill gas (with about 60% methane), thus avoiding the emission of a major Green House Gas.
- The utilization of the gas for generation of electricity will yield about 20.000 GWh/year, at a capacity of about 2400 MWe.

The present situation is far away from this goal and an immense change in attitude, legislation, financial support, capacity building and market involvement is required to achieve this result. A concerted approach with all actors at central governmental level, local governmental level, entrepreneurs in the market and international support is needed.
International experiences reveal that it is possible to achieve these targets for China when it will organize the waste management in a market-oriented approach, but with strict governmental control. Economic drivers have to be introduced in a way that the polluters (citizens or industries) pay for the collection and treatment of waste. Financial incentives are initially needed for promotion of renewable energy from landfill gas.
The first start however should be a clear policy with a State directive outlining the legislation for waste treatment and landfill gas utilization. International support is required to realize a rapid capacity building and also financial support for demonstration.

SEPA is responsible for the introduction of this action plan and monitoring of the progress. The action plan should be executed together with the Ministry of Construction and the local

governments as well as with the entrepreneurs in the market. The Government should set the rules and formulate the conditions for the entrepreneurs in the market.

The following main actions are identified in order of priority, but all actions could start simultaneously:

0. Institutional and legislation development:
   - Formulation of a State directive on landfilling
   - Legislation development and enforcement of regulations
   - Planning at central level and regional level and formulation of regional action plans
   - Market enterprise involvement by restructuring waste management

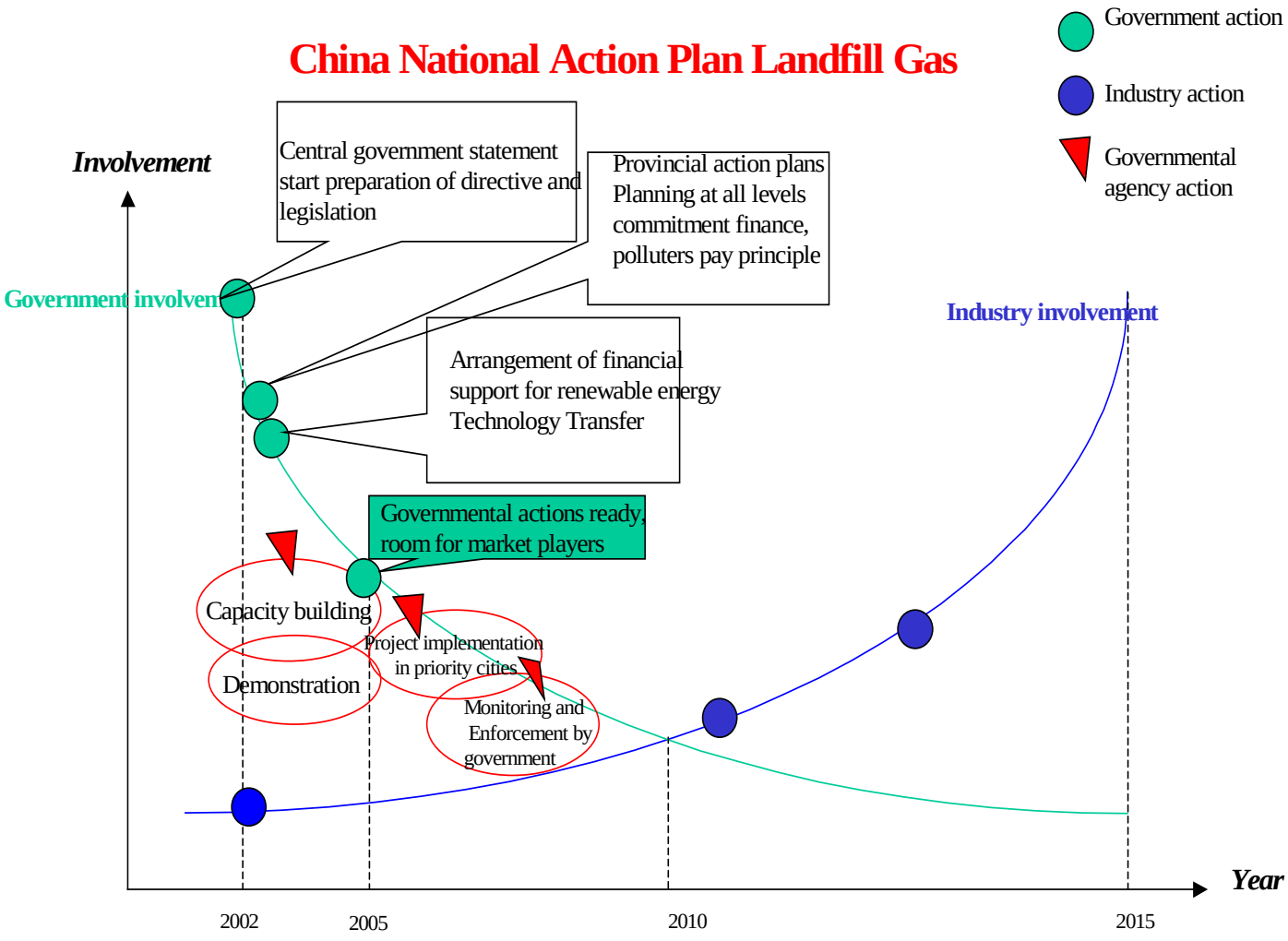
1. Financial support for Landfill Gas collection and utilization with a transition from governmental money to private money in the future
   - Financing of sanitary landfills by the 'Polluter Pays Principle' as part of the State directive and regional action plans.
   - Financial Support for utilization of landfill gas by a mandated share and tax incentives for renewable energy
   - Support for execution of the action plan and foreign aid for the start up.

2. Technology and transfer of knowledge for market introduction and project realization
   - Capacity building for landfilling and landfill gas utilization from central level to regional level with international support constituting of:
     - Awareness and education at all levels; municipalities, entrepreneurs and citizens
     - Improvement of sanitary landfill operation
     - Landfill gas collection and utilization
     - Project financing, organizational issues etc.
   - Demonstration projects
   - The establishment of advisory centers, with news letters, workshops etc.
   - Complex new relationship structures can be facilitated by guidance documents.

In order to implement the ambitious, but possible objective, the following stepwise approach is proposed:

Phase		Actions
1	2002 – 2005	formulation of directive and legislation, demonstration projects, capacity building, regional action plans, international support, entrepreneurial involvement from the market
2	2005 – 2010	Implementation in the major industrial/tourist cities, financial support by renewable energy support and Clean Development Mechanism
3	2010 – 2015	Implementation in the other cities financed by the market

This scenario shows that in order to achieve such a massive implementation the market has to be ready by the year 2005 and that only in the year 2015 a situation would be achieved where all the Municipal Solid Waste is either reused, incinerated, or sanitary landfilled. However the result will be that by then about 20.000 GWh electricity at a capacity of 2400 MWe can be generated from landfill gas. This shows that LFG collection and utilization are beneficial both from an environmental and financial viewpoint.


China National Action Plan Landfill Gas
Government action
Industry action
Governmental agency action
Involvement
Central government statement start preparation of directive and legislation
Provincial action plans Planning at all levels commitment finance, polluters pay principle
Government involvement
Industry involvement
Arrangement of financial support for renewable energy Technology Transfer
Governmental actions ready, room for market players
Capacity building
Project implementation in priority cities
Demonstration
Monitoring and Enforcement by government
Year
2002
2005
2010
2015

1. Introduction

Proper waste management is necessary to handle the growing municipal refuse amounts in China. Therefore it is important that, as part of an environmentally sound waste treatment, the emission related issues are taken care of. A major nuisance related to landfilling is the formation and emission of landfill gas, a product of organic wastes.
Since LFG is a combustible gas, it's use not only has direct advantages for the environment; after treatment it is also a relevant source of energy.

In 1996, municipal refuse disposal reached over 108 million tons. The amount is still increasing because of the growth of urban population and the residents' consumption level. In most cities in China, municipal solid waste disposals currently still are open dumping or simple landfilling (estimated at 80% or more). These occupy land resources, and also endanger the environment by leachate causing groundwater pollution and emission of landfill gas. The gas consists of methane, a major greenhouse gas, has a bad smell and creates risks of fire and explosions at the landfill site. The global warming potential of landfill gas is about 21 times of carbon dioxide. Due to its high methane concentration (typical 40 – 60 %), LFG is a valuable source of fuel. The beneficial use of LFG to energy has been proven in many developed countries.

Background of this study
The Government of China is aware of the problems associated with the current solid waste disposal practices and wants to formulate a strategy to improve the situation.
To boost the Government's effort and to reduce methane emission into the atmosphere, the United Nations are working with the State Environmental Protection Administration (SEPA) to implement a project funded by the Global Environment Facility (GEF) that will result in the widespread capture and use of landfill gas (LFG) in the country.
This project consists of the following components:

- demonstration projects of LFG recovery and utilization in Anshan, Maanshan and Nanjing
- The establishment of a national advisory center in Anshan: Landfill Technology and Development Centre
- A national action plan

The Energy Research Institute (ERI, SDPC) carried out and prepared a draft document, the "National Action Plan for Recovery and Utilisation of Landfill Gas"[1] in June 2000 under the consultation of UNDESA/SEPA. During the event of CERE 2000 (China International Environment, Renewable energy and Energy Efficiency Exhibition and Conference) in Beijing in November 2000, a side event of Sino-Dutch Workshop on Landfill Gas was held. It shows the appreciation of the European best practice in China. UNDESA/SEPA/ERI also expressed the wish of an expert review to the June 2000 version of the action plan to further improve its quality.

[1] It includes the main part of the action plan and four annexes.
- Institutional & Policy framework of municipal solid refuse management in China;
- China municipal solid resources assessment;
- Technology assessment for municipal solid refuse treatment, disposal and utilisation in China;
- Technology assessment for municipal landfill gas recovery and utilisation in China;

In the Netherlands, Novem, Royal Haskoning and Grontmij have been keen to take up this review with the following components:

- To review the major components of the Action Plan, including the assessment of the current status of municipal waste management, identification of various barriers and constraints of widespread adoption of LFG technologies in China;
- To present international best practices in LFG recovery and utilization, share successful experience and lessons learned in European countries;
- To outline priority areas and optimal process for implementing the Action Plan;
- To advise national experts on recommendations in comprehensive and supportive policy framework.

The result of this review is the National action plan, where the Dutch Expert Team has been the lead author for the main document and ERI the main author for the revised annexes.

This review is sponsored on a 50/50 basis by the Ministry of Economic Affairs of The Netherlands under the EXBIC contract and UNDESA contract no. ICA 930.

Goal of the National Action plan

The National Action Plan, as one of the outputs of the UNDP/GEF project is aiming for promotion and widespread adoption of landfill gas recovery and utilization.
It will 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.
It provides an up-to-date assessment about the situation of LFG recovery and utilization, a systematic and in-depth analysis about technical and institutional barriers to the widespread adoption of landfill gas recovery and utilization in China, and a set of policy recommendations to remove the barriers.

Reader

The **audience** of this action plan should be Chinese authorities, at a central governmental level; SEPA, Ministry of construction, SEPC, Ministry on health, who have to realize the actions on a political level that have to be carried out as part of this action plan.
At local governmental level; like municipalities this action plan gives actions on how to establish at a local level the sanitary landfills with landfill gas extraction.
The audience are also the Chinese Entrepreneurs: the project developers, the suppliers, power companies who will have a great market when this action plan comes into execution. And finally also international bodies & entrepreneurs who are interested in the Chinese Market will find a guidance on what will happen in the area of waste management and landfill gas utilization in China.

The Action Plan describes in chapter 2 the status of municipal waste in China and the expectations for the next 20 years.
The international best practice of waste treatment and landfills and landfill gas utilization is described in chapter 3. Here most aspects like technology, legislation, economic incentives, organization and information exchange is covered.
In chapter 4 the barriers to implementation sanitary landfills and landfill gas utilization are presented, based on the actual experience in China with the existing demonstration projects.

Based on the barriers, building upon the existing situation and the international best practice in chapter 5 a strategy is proposed to improve the situation and the actions are specified. These actions make clear for governmental bodies the policies and legislation to adjust. For entrepreneurs a market is evolving and it will be of interest for them to participate in this market.

2. Waste management situation and predictions China

2.1 Waste quantity

China has produced 108 Million tons of Municipal Solid Waste in 1996. The economic and population growth in China has an impact on the increase of waste amounts. Based on the economic population growth, the expected figures (see Annex 'China Municipal Solid Refuse Resources Assessment') are:

Table 1: Prediction of municipal solid waste in China

Year	Quantity of MSW per year (million tons)	Annual increasing rate of MSW over 5 years(%)	MSW per capita (ton/year)
1996	108		0.522
2000	162	10.74(1996-2000)	0.581
2005	223	6.58 (2001-2005)	0.615
2010	289	5.28 (2006-2010)	0.643
2020	408	3.51 (2011-2020)	0.708

These figures show that the MSW quantity will increase at a relatively high rate in the next 20 years. It can be expected that an improved waste management system, including prevention and recycling will have a positive influence on these figures. It is expected that 70% of the waste will be landfilled in sanitary landfills in 2010 (see annex 'Technology Assessment for Municipal Solid waste treatment, disposal and Utilisation in China') which results in an amount of 203 Million ton to be landfilled in 2010. Because prevention, reuse and incineration will improve further after 2010, it is expected that about 200 Mton per year will be landfilled in sanitary landfills after 2010.

2.2 Waste treatment in China

The main solution of waste treatment in China nowadays is disposal. In rural areas, waste is dumped uncontrolled nearby the residential areas, using wasteland or wetland. In larger cities, waste is dumped in an uncontrolled way, or brought to a controlled dumpsite. The level of environmental protection of controlled dumpsites is improving at sites nearby large cities.

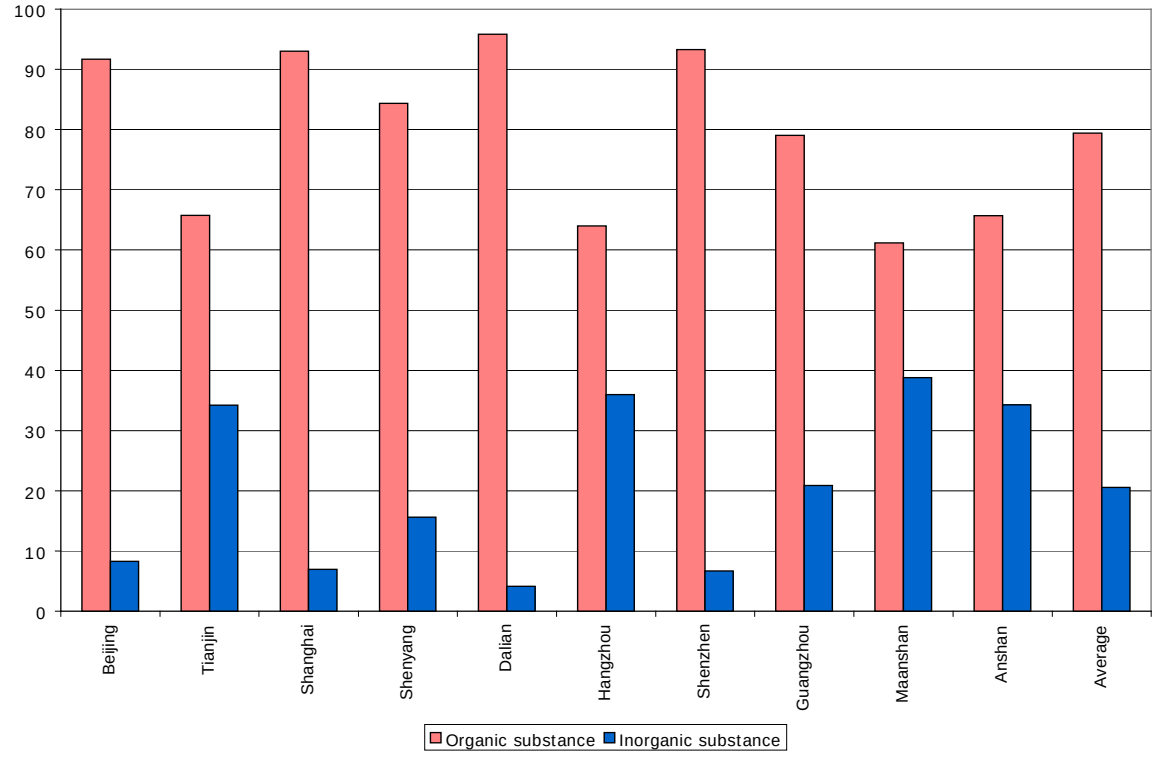
Other waste management practices as incineration and large scale composting are limited in China. Various small waste incinerators have been built in different parts in China, and large waste incineration facilities are planned to be built in big cities such as Beijing, Shanghai and Guangzhou. By the end of 1995, about 0.9% of the total MSW in China was treated by incineration (see Annex).

Composting technology treats a very small percentage of the MSW generated in urban areas in China. Many Chinese cities have set-up relatively low technology composting systems to process MSW. As a result of the fact that the value of compost is less than the cost of producing it, besides operating problems, the majority of composting facilities have been shut down [Henderson].

2.3 Waste composition

The waste composition in China is similar to other developing countries. The composition of waste in rural areas and urban areas show large differences. Waste treatment is mostly based on informal structures. Reusable materials (metals, plastic, paper) are being separated at source and by scavenging before the waste is being dumped. Organic waste (vegetable and food waste) is the largest component of the waste. Therefore the moisture content of the waste is relatively high. The Annex 'China Municipal Solid Refuse Resources Assessment' gives detailed information on the waste characterization. Figure 1 shows the differences in organic and inorganic substances of ten cities, including the average value of 80% organic material and 20% inorganic material. For further estimations the average values will be used, but it must be kept in mind that a wide range of these percentages exist.

Figure 1: the differences in organic and inorganic substances of ten cities in China



2.4 Waste management hierarchy

It is a good idea to describe the waste management hierarchy. However, there is still a lot of debate going on regarding whether Incineration with heat recovery is preferred over Final disposal in a landfill site with energy recovery. The life cycle analysis contains so many factors and they also relate to local conditions, etc. etc. So this fact should be highlighted when a hierarchy is presented, so as not to potentially mislead some "novel" reader and policy makers.

In order to achieve an integrated waste management situation in China, the so-called waste management hierarchy can be considered as an important tool. This hierarchy ranks waste management operations according to their environmental or energy benefits. The hierarchy is defined as follows, with the first entries having higher priority than those below:

- Prevention of waste
- Reuse of waste material
- Recycling (by material recovery or composting)

- Incineration with heat recovery
- Final disposal on a landfill site with energy recovery

The purpose of this waste management hierarchy is to make waste management practices sustainable. This hierarchy has been adopted in various forms by many countries all over the world. In China this hierarchy has already been implemented informally, in particular those related to reuse and recycling. The national solid waste law in China indicates the following hierarchy:
- Prevention
- Recovering and reuse of MSW
- Sanitary disposal

Sophisticated and expensive technologies, such as incineration, digestion and even completely isolated landfills are not yet feasible in many places, especially not in rural areas. As final disposal is still the most widely spread waste management practice in China, the landfilling method could be improved via a step-by-step approach: from open dumping to controlled dumping, to engineered landfill and finally to sanitary landfill.

2.5 Responsibilities

In China, the Ministry of Construction (MOC) mainly manages MSW, environment protection bureaus or city construction bureau's subordinate to local governments. These departments are responsible for the management of the cleaning, collection, storage, transportation and disposal of municipal solid waste, including financing of these activities. The State Environmental Protection Agency (SEPA) of People's Republic of China is responsible for unified supervision and management of the prevention and rehabilitation of nation-wide municipal waste environmental pollution. Industrial solid waste and hazardous waste are managed wholly by SEPA.

The construction department of the local government is responsible for the design and construction of landfills. The construction bureau and the environmental protection bureau have to cooperate closely in order to achieve the required level of environmental protection.

2.6 Regulations

It is stated in the National Solid Waste Law that the policy of solid waste management is to reduce the production of solid waste, fully recover and rationally utilize solid waste and conduct sanitary disposal. Governments of all levels have to add the solid waste management in the environmental protection program, and have to introduce economical and technological policies and measures to achieve the objectives.

The current policy system can be divided into three levels:
- regulations, laws and documents issued by the state;
- administrative regulations and documents issued at department level;
- laws and regulations issued by local government.

Environmental standards have been made to improve solid waste management, such as the Standard on Control of Landfill of MSW (GB16889-1997).

Technical Standard for Sanitary Landfilling of Domestic Waste(CJJ17-89) focuses more on construction, site identification and site management, etc. And the Third is: Technical Standard for Environmental Monitoring at Landfill Site for Domestic Waste.

2.7 Expectations

The expected waste quantity increases to about 289 Mton after the year 2010. The waste quality will change, but large differences between rural and urban areas will remain. The facility level of landfills will be raised, including the collection and Utilisation of LFG.

The amount of sanitary landfills will increase in the next decades.

> *In 1996 there were 874 waste treatment sites in China. From this 70% is dumping sites, so there are about 600 dumping sites.*
> *If we suggest that in 2015 there are about 200 cities in developed regions, and it is expected that an average of 3 sanitary landfill per city should be built by then, about 600 LFG collection and utilization units should be in operation. It is a great challenge to reach this amount of LFG units, and it shows the importance of the National Action Plan. The execution of the Plan has to be supported by every means in order to reach this objective.*

3. International Best Practice to improve landfilling and landfill gas utilization

Landfillling of waste and the utilization is widely spread practice around the world. The description of best practice in several countries will support the development of a strategy and the action plan for China.

3.1 Landfill gas

Landfilling of organic wastes, such as Municipal Solid Waste (MSW), results in anaerobic degradation processes in a landfill. Landfill gas is the major product from these processes. In undiluted form landfill gas will consist of approximately 60% methane (CH_4) and 40% carbon dioxide (CO_2) and trace amount of other components. When extracted, landfill gas is diluted with nitrogen and oxygen from the air, as a result of air ingress into the landfill and the extraction system.
Without any measures the landfill gas will emit freely into the air, directly from the surface of the landfill site, or by migration through the surrounding strata of the site. This may cause several effects, such as:

- odour emissions;
- explosion hazards;
- risk of asphyxiation;
- emission of greenhouse gases.

Due to sulfur components in the gas (hydrogen sulfide, mercaptanes, etc.) landfill gas is a malodorous gas. Especially in concentrated form the emission of gas may lead to odour nuisance.
The high concentration of methane in landfill gas makes it a flammable gas. Accumulation of landfill gas in confined spaces may cause high explosion risks.
The hazard of asphyxiation is related to the fact that landfill gas is a potential asphyxiant and toxin to humans and animals primarily due to the lack of oxygen in the composition of the gas. Due to oxygen depletion in the root zones of the subsoil, vegetation die-off may occur.
The last effect, the emission of greenhouse gases is mainly caused by the effect of methane. Because of the high concentrations of methane in LFG and the fact that methane has a Global Warming Potential that is more than 20 times higher than the effect of Carbondioxide, LFG is considered as an important greenhouse gas.

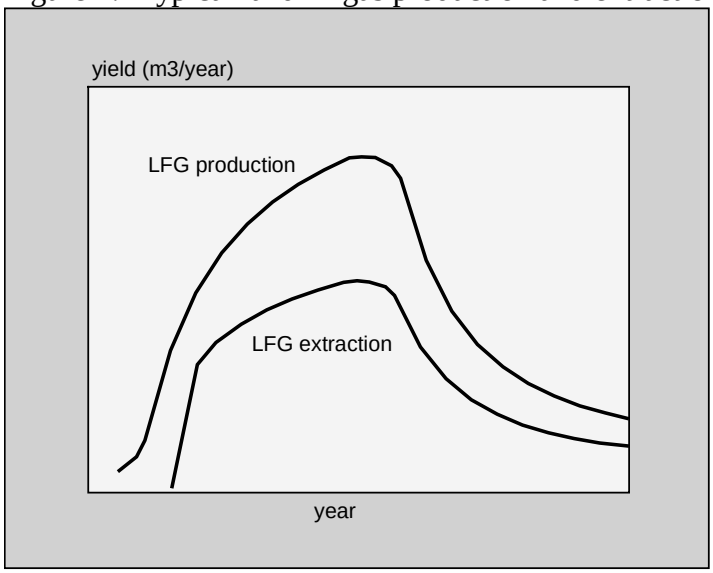
Landfill gas yield
The landfill gas yield that can be collected from a landfill site and utilized is dependent on several factors:

1. in practice the LFG production is lower than in theory, based on the organic content of the waste;
2. the efficiency of landfill gas extraction is not 100%. Since landfill gas production starts very early after waste tipping, it is practically impossible to recover all produced gas. Even after construction of a gas extraction system, not all gas can be recovered as a consequence of limitations of the gas extraction system.
3. For utilization reasons the quality of the extracted gas is important, setting limits to the gas collection. To achieve a high enough gas quality, the gas yield must be limited, which limits the effectiveness of extraction .

4. If the utilization capacity does not completely match with the extraction capacity, there could be situations in which more gas is extracted than can be utilized. This sets limits to the utilization efficiency.

Based on tipping data (waste composition, waste quantities, year of tipping, site geometry, local climatic conditions) the landfill gas production prognosis can be set up. From information of the tipping sequence and possibilities to install an extraction system, the recoverable gas yield can be calculated. The gas production will take several decades. A typical production and extraction curve is shown below.

Figure 2: Typical landfill gas production and extraction curve



To estimate the total potential energy yield of landfill sites in China, the energy production per ton of waste, based on an average composition is calculated:

Table 2: Energy production per ton of waste

Degradable organic composition of landfilled waste:	210 (kg/ton MSW)
Gas production potential(theory)	160 Nm^3/ton MSW
Gas production potential (practice)	110 Nm^3/ton MSW (gas with 60% CH4)
Gas recovery potential (practice)	50% in 20 years
LHV of the gas:	21,5 MJ/m^3
Energy production LFG:	1200 MJ/ton MSW

3.2. Landfill gas extraction

The most negative effects of gas emissions can be managed by collecting landfill gas in a controlled way. Active extraction of LFG concentrates the gas stream so that effective treatment is possible. Gas can be extracted from a landfill by means of a collection and transport system. This system will consist of the following components, mentioned in the order of the gas flow:

- gas wells in the waste body;
- regulating equipment to adjust the extraction rate of each individual gas well;
- connecting piping to collect the extracted gas from a well and to transport the gas to the processing location, including facilities for condensate removal;
- gas pumping unit (gas station) with compressor or ventilator to maintain a subpressure in the extraction system;
- flare equipment to combust the extracted gas;
- Utilization unit for energy recovery.

Different techniques are available for construction of gas wells, both horizontal and vertical systems. In any case the main construction of a gas well is a perforated PE-pipe, surrounded by gravel or other course material.
Construction during the operation of a site can give the opportunity to extract gas at an early stage of the operational period of the landfill site, while construction after finalizing the dumping activities will offer more reliability of the extraction system.

Under normal conditions an actual extraction efficiency of 50-70% can be achieved. This efficiency is dependent of the quality and quantity of the extraction system and operation. The quality of the extraction is limited by the subpressure in the extraction system and the permeability of the landfill cover. This causes dilution of landfill gas with air and thus decreasing calorific value. At specific minimum values the Utilization possibilities are restricted. To avoid problems the extraction quality has to be controlled regularly.

A gas station with pump maintains the sub pressure in the extraction system, while it boosts the gas to a delivery pressure so that it can be flared or utilized. Different utilization options are described in the following sections.

Combustion of gas in a flare
The minimal treatment of extracted gas is combustion in a flare installation. The methane is converted into CO_2 then and the odour components are destroyed. The combustion characteristics of flare equipment vary with the design of the installation. Best practice is the use of specially engineered closed flares which combust the gas in specific controlled conditions.

3.3. Landfill gas utilization

The concentration of methane in landfill gas (approx. 60%) makes it an interesting energy source. Although the calorific value (LHV) of approx. 21 MJ/m^3 is lower than that of natural gas, it still can be used in a profitable way. Table 1 presents the typical composition of landfill gas.

Table 3: Properties of landfill gas

Component	LFG*	
Methane	50-60	%
Carbon dioxide	35-40	%
Nitrogen	0-10	%
Oxygen	0-2	%
Calorific value (LHV)	18-21,5	MJ/m$^3_0$
Traces of pollutants		
Sulfur components	0-300	ppm
Chorine and fluorine	0-40	ppm

*= these ranges correspond with the majority of landfills

By utilizing landfill gas the available energy is used in a profitable way. LFG may be seen as a green energy source as it can be used as a substitution for fossil fuels.

The traces of pollutants may vary greatly in time and in place, since these levels are strongly dependent on the types of waste which have been landfilled. The application of landfill gas may be limited by process parameters. The sulfur and halogen concentrations are limiting in this respect. These components will form acidic products, sulfur dioxide (SO_2) and hydrogen chloride (HCl). If the flue gases are cooled to below the dewpoint of these products or the dewpoint of water, severe corrosion damage may occur. In this respect the sensitivity of stainless steel towards HCl is noteworthy. It should therefore be taken into account that the energy efficiency of an application of landfill gas is lower than that of natural gas for the same application.

Different utilization options are available to gain most advantage of the energy content of the gas in a specific situation. Utilization options for landfill gas are:

- direct use of the gas in a boiler or kiln (production of heat, steam or warm water);
- electricity production by a gas engine generator;
- upgrading the landfill gas into natural gas quality or vehicle fuel quality;
- supply of cleaned gas in town gas distribution grid.

Direct use of gas

As the landfill gas becomes available continuously in time, direct use of the crude landfill gas is most profitable if the gas can be used continuously, ideal for industrial processes The demand pattern of the consumer should show a continuous base load matching the gas production, since gas storage during nights or weekends is not a feasible option. In some cases the gas can be distributed to different consumers. The efficiency of the energy consumption can be in the range of 80 to 90%. This Utilization option is available with all landfill gas yields, although the economy of scale can set limits to low extraction rates.

Electricity production

At most locations the landfill gas is used to produce electricity. In these plants the energy content of the gas is used to drive an electrical generator with an engine or turbine. Depending on the electrical grid situation, the produced electricity can be delivered to the grid (24 hours per day). This is the major advantage of electricity generation from landfill gas, because the gas becomes available constantly in time.

In most cases engines are used instead of turbines, because of their higher efficiency (35 vs 25%). With various gas yield in time the use of engines is advantageous because the efficiencies only decrease marginally when running in part load. Turbine efficiencies will decrease substantially in that case. Electricity generation without further energy recovery has an energy efficiency of approximately 35%. By utilizing the heat of the exhaust gases and cooling water (Combined Heat and Power generation), the total efficiency can be increased to 85%. Electricity generation is technically possible in electrical power ranges of more than 50 kW_{el}.

Upgrading of landfill gas to natural gas quality or to vehicle fuel

The principle of upgrading landfill gas is to enhance the methane content by removing carbon dioxide in order to make it comparable to natural gas. Most important aspect is that the combustion characteristics correspond so that both gases are interchangeable. With this technique the main components methane and carbon dioxide are separated. Extensive control

and regulating is required to meet the special requirements for grid injection. Because separation of methane and nitrogen is hardly possible, ingress of air into the extraction system sets limits to the upgrading technique.

Landfill gas utilization in town gas supply
The use of landfill gas in town gas supply is rarely applied in the EU or North America, since direct supply is hardly possible because of differences in gas quality (gas supply is covered by high energetic natural gas). However, if the energy content of both gases show similarities, this utilization option shows good opportunities. The combustion properties should be comparable, so they can be interchanged. Special attention should be paid to the impurities of landfill gas, since these have corroding effects on pipelines and devices. Removal of sulfur and halogen compounds is obligatory.

Status and prospects
The status of LFG in the European Union is that sanitary landfilling is common practice. Part of the legislation of landfilling is the obligation of emission control. During the operational period of a landfill or shortly after, landfill gas extraction systems are being constructed. If economically feasible Utilization of landfill gas is developed. In most situations LFG is used directly for energy production or for the production of electricity, with or without heat recovery (CHP).

3.4. Legislation and standards for a Sanitary landfill

Dump sites and controlled landfills shall be improved to fulfil the latest requirements. Legislation can play an important role to achieve this.

> *For example in The Netherlands decades ago the initiation of landfill gas projects was more or less enforced by nuisance to the surroundings of landfills and from the point of safety. Once the legislation of landfill sites was introduced much more LFG projects were started. In the course of 20 years nearly all operational landfill sites as well as some older, abandoned landfill sites are provided with LFG systems.*

Modern landfill technology intends to:
- Protect soil, groundwater and surface water;
- Reduce air pollution and CO_2 emissions
- Reduce nuisance (smell, smoke, noise and vermin)
- Improve safety (for labour and neighbourhood).
- Ensure proper post-closure land use.

In developed countries, sanitary landfills have to comply with strict requirements, such as waste acceptance procedures, bottom lining, top cover, leachate collection and treatment and LFG extraction and Utilization. Furthermore monitoring activities and after care measures are required.

European countries have to fulfil the requirements according to the European Council Directive 1999/31/EC on the landfill of waste. The Directive on landfill of waste sets out general requirements for all classes of landfill of waste, including inert, non-hazardous and hazardous wastes.

The EC has put forward technical standards for landfill sites with a view to guarantee the same degree of environmental protection throughout the EC.

Annex I and II of the Directive on landfill waste give details of these standard requirements in dealing with establishment and operation of a (new) landfill, the conditioning plan of an existing landfill and the closing of a landfill.
Annex III of the directive deals with procedures in the operation phase and aftercare phase.

The Directive on landfill of waste defines three landfill classes are defined:
- landfill for hazardous waste
- landfill for non-hazardous waste
- landfill for inert waste

All classes need a natural geological barrier (or equivalent artificial made geological barrier). An artificial lining and a leachate collection system are required for landfills for hazardous waste and non-hazardous waste. A top cover is required for both classes of landfills (see Table 4).

Tabel 4: European landfill classification and top cover requirements

Type of landfill	**Hazardous waste**	**Non-hazardous waste**
Gas drainage layer	Not Required	Required
Artificial liner	Required	Not required
Mineral liner	Required	Required
Drainage layer >0.5 m	Required	Required
Top layer > 1 m	Required	Required

According to the Directive on landfill of waste, appropriate measures shall be taken in order to control the accumulation of LFG. LFG has to be collected from all landfills receiving biodegradable waste and the LFG has to be treated and used. If the LFG collected cannot be used to produce energy, it must be flared.

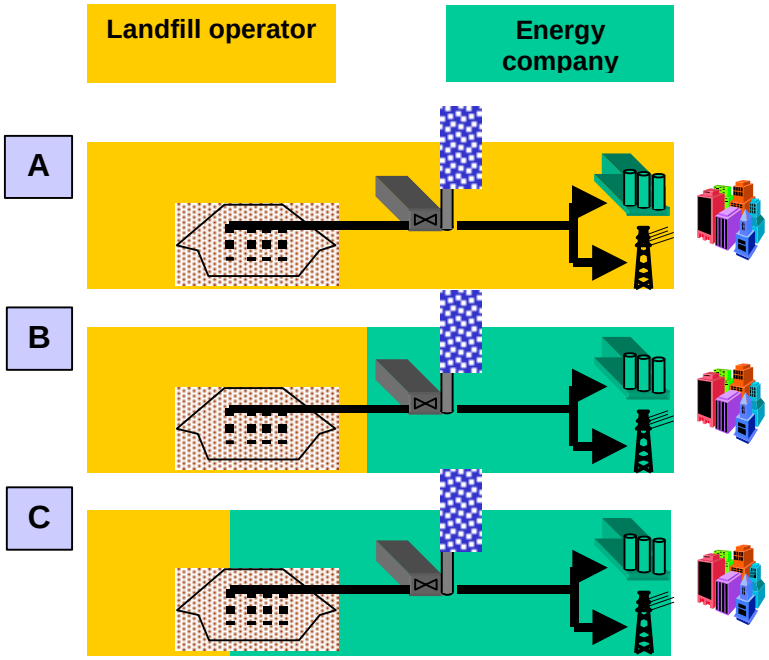
3.5 Organizational Structures

The organization of landfill and landfill gas utilization projects can be complicated by the number of parties involved in the realization of the project. In most countries, landfills remain the responsibility of local government or governmental bodies that own the land and have the responsibility for the waste. Traditionally landfills are owned by municipalities who have the responsibility to handle the waste. Because of the shift towards larger landfill sites and privatization private companies nowadays own sites as well. The company itself can have several shareholders and sometimes the municipalities remain a shareholder to keep the influence on the management. At present in most countries the majority of the ownership is in the public domain, except for the UK and the USA where companies own the active sites.

When the same body as the owner of the landfill site carries out the project development, there are usually few problems with LFG utilization. However, if a gas project is owned by an LFG developer, and the landfill is operated by a waste disposal company, who leases the site from a different landowner, and the energy recovery facility needs to be located elsewhere, on another party’s land, complications are likely to arise. Even in the case of ownership by

companies, the local government remains responsible for the environmental sound treatment of the waste and has to control the operations of the companies on a regular basis.

Figure 3: Organizational options



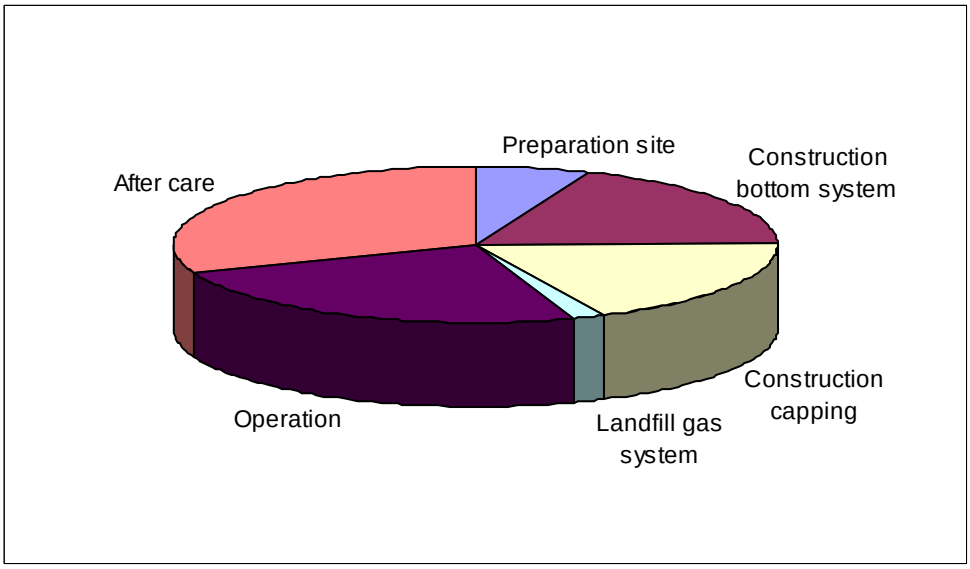
The landfill site owner can own the gas recovery facility and gas engine and sell the power to the grid (situation A). In the Netherlands, often the landfill site owner owns the gas extraction equipment and sells the gas to gas recovery facility. This gas recovery facility can be owned by the utility (situation B), or by a separate company that is owned by the utility and the landfill site owner together. This separate company then sells the electricity or gas to the grid. Depending on the local situation and the project several combinations can be seen. Also banks might become an owner when they lease the plant under an operational lease construction. All parties will look for a win-win situation.
Another option is that a separate company owns the total gas recovery and Utilization plant, which can be the energy company (C). This company is then responsible for the gas recovery from the landfill site and could earn its money from the maximization of the gas utilization. The landfill owner, in principal the gas producer may sell the gas to the recovery company. Special attention must be paid to put maximal effort in the gas recovery in order to meet with the obligations of emission reduction of the site.

3.6. Economic and Financial Incentives

Landfilling and landfill gas production
Landfilling, gas extraction and gas utilization should be distinguished as separate parts within waste management. The most expensive part is the landfill activity itself (bottom lining and top cover, leachate collection and treatment, operational costs etc.). The costs of gas extraction, as part of the emission reduction of landfills, are only 1–2 % of the total costs and typically comes to 0.5$ per ton of waste. All these costs have to be covered by the gate fee, which will vary between 25 and 50 $ per ton of waste in Western countries.

As sanitary landfilling is relatively expensive, governments or international agencies could accelerate the implementation by subsidies, ''cheap'' loans etc. The payback period depends on the (slowly) increasing gate fee.
In most OECD countries the households typically produce 1 ton of solid waste per year and pay between 50 -100 $ for waste collection and treatment and 50 $ for wastewater treatment. In the past they paid much less, or the money came from municipal funds. Payments started in most countries as a levy on the water or power bill.

Figure 4: Distribution of costs of landfilling (costs per ton of waste)



Landfill gas for Energy utilization
As the gate fee includes the gas extraction costs, the gas is in principle available for free. The additional costs are for Utilization (direct use, electricity production, gas distribution or vehicle fuel). Thus the pay-back period of the Utilization unit has to be calculated without the investment costs of the gas collection unit.

International or governmental support for Landfills
Between 1970 and 2000 many countries have used subsidies to implement new systems such as sanitary landfilling with gas extraction. Subsidies are meant to overcome the risks in the first projects and show the economic viability at a local scale. After several demonstrations the market will pick up the technology under favorable economic conditions. These favourable conditions are: right legislation and the polluter pays principle.

Support for Energy Sales:
The competitiveness of LFG Energy recovery will depend on the open market price of competing energy sources. The typical cost price of electricity from landfill gas is between 0.03 and 0.05 $/kWh(e), see the previous paragraphs about landfill technology, and it depends on the distance to the grid. The economics of LFG use are directly tied to the grid sales price, unless incentives are in place. Such incentives are available for the investment in the equipment and the sales of power to the grid or gas net. A typical selling price of power to the grid is between 0.03 and 0.05 $/kWh(e).
Financing:

Landfill projects and landfill gas projects can be financed by:
- internal finance from corporate or municipal funds or a corporate loan,
- externally financed by project financing or leasing.

Many loan institutions, as banks are willing to finance (part of) the project when the project is large enough. One of the risks financiers see, is the risk of gas shortfall. This requires an accurate prediction of the gas supply as explained in chapter 2. Governments can support investments by fiscal incentives.
Some countries have a tax scheme where a company investing in specific equipment, e.g. a gas engine at a landfill site, can receive a deduction of taxes or tax credits. In some countries the external loan for the project is available at a lower rate (1 %point) because it comes from a Green fund.
Support for a higher energy price: Many countries have introduced a scheme to support electricity from Renewable Energy financially. Either a fixed price (e.g. Spain, or Germany), a bidding process (e.g. NFFO in UK), or taxation of fossil fuels and a free green market with fiscal support (e.g. Netherlands). In Europe a green certificate system is introduced to facilitate trading of renewable electricity between the different countries. These systems are described in more detail in reference. [Deployment of Renewable Energy in a liberalized energy market by Fiscal Instruments in the Netherlands, Ir. Kees W. Kwant, Walter Ruijgrok, http://www.iea.org/impag/Deploy/INDEX.HTM].
The renewable energy (green) certificate market can also be used to meet an obligation to produce a specific amount of renewable electricity in a market. (Mandatory Share) This might be introduced in the Renewable Energy scale up program of the Worldbank for China.

3.7 Information Exchange and built up of know how

At one side there is often the need to encourage managers/decision makers and legislators to recognize the economic, energy source and global environmental benefits of energy recovery from LFG. At the other side, though collecting and using LFG is technically and commercially proven, there are many potential pitfalls to success. Owners of landfill gas collection and use schemes should provide contractors and staff with the necessary experience and skills to design, install, commission and operate schemes successfully. In all these aspects the information exchange plays an important role to build up the know-how by training and education and to create awareness.

Advisory Centers
Several countries have set up bodies to promote the use of landfill gas. The aim is to disseminate information, so raising awareness of energy recovery from LFG and informing potential operators of the risks and benefits of using LFG.
For example, in the **USA**, the US EPA Landfill Methane Outreach Program works with landfill owners and operators, states, utilities and other federal agencies to promote the use of landfill gas as an energy source. The aim is to overcome barriers that prevent otherwise economic LFG projects from progressing.
In **The Netherlands** a LFG Advisory Center was set up in 1992 to promote and support energy recovery from LFG by providing advice to site owners and energy distribution companies on preparation, realization and operation of projects. The Advisory Center also run a contact group in which landfill owners and energy distribution companies exchanged knowledge and experience about landfill gas projects. Information dissemination was also important and the Center produced a periodic newsletter, a handbook and other publications. The Center also monitored the progress of projects and took action to act as a mediator when

a problem was recognized. The Advisory Center discontinued in 1996. During its operation, the number of Dutch LFG utilization plants climbed from 15 to more than 40.
In the **UK**, the Department of Trade and Industry, through ETSU, funds a program aimed at helping developers to overcome technical and non-technical barriers to use LFG. They have run a series of seminars on energy recovery from landfill gas, bringing together landfill owners and operators, consultants, suppliers, local authority and government staff.
These above mentioned advisory centers are mostly governmentally funded, and in the case of The Netherlands in a tri-party agreement between the governmental agency Novem, the utility association and the association of waste processors.

Successful information exchange activities
Based on international experience the following information exchange activities are successful:

1. A handbook (standard) for project developers, owners of landfill sites, regulators
2. Monitoring and reporting the progress of project development at the different sites
3. Successful demonstration projects are the best marketing tool for new projects
4. A newsletter to inform the market about progress in projects, legislation, financial support schemes and technologies (quarterly or biannual).
5. (Bi)annual meetings with all involved at the site of a new demonstration plant to discuss progress, problems, solutions and new technologies.
6. Training and Education of consultants, engineers from power companies, stakeholders from municipalities, operators from landfill sites

4. Barriers for introduction and implementation of landfill gas technologies

China is entering a new era with important developments in the introduction and implementation of LFG projects. As can be read in the previous chapters, different aspects may influence the success of landfill gas projects. Because of the complexity of the new, but challenging situation it is to be expected that at different levels in the government and society the level of information is insufficient to judge and follow the progress. It is however important at both national and municipal level that ample support is given to the development of LFG projects. From an administrational as well as a financial point of view projects must be supported to become successful.

In Europe the LFG project implementation in the last 20 years shows that several items hampering project development could be identified. With this experience the lessons learned in Europe should be used to improve the developments in China. In this respect possible barriers for the Chinese situation have been envisaged, with the help of Chinese experts from different levels. The perceived barriers can be divided in 4 main groups:

- Institutional level barriers;
- Financial barriers;
- Implementation obstacles;
- Organizational barriers.

These groups will be further discussed below. Based on the experience of the demonstration projects and one case study and the expert's discussion with the Netherlands Expert Group and the Chinese Expert Group, the importance of the different barriers were considered on a scale from urgent to less important items. It should be noted that the different main groups of barriers have close interrelationships.

4.1 Institutional level barriers

Until now hardly any information is available on the subject of LFG recovery and utilization at both technical and institutional level. Lack of technical knowledge or lack of information how to deal with the subject, makes it difficult to interest people and to convince them of the importance of the subject. Because the LFG issue is new and unknown there is a lack of awareness at political level. Confidence in the potential possibilities of LFG and the feasibility of projects is the main obstacle for obtaining the right awareness for further development at both institutional and industrial level. Financing and starting LFG projects is therefore very difficult.

Lack of awareness

Lack of awareness of the LFG subject is an important issue in the attitude towards LFG projects. Not only politicians and technicians should be aware of the LFG backgrounds, possibilities and limitations, but also the public (e.g. the citizens, neighboring the landfill site) must be informed about the LFG issue.

Legislation barriers

At different level legislation has been implemented. Standards for Sanitary Landfilling and for Environmental Monitoring are in force. Legislation in the field of landfill gas recovery and Utilization however has not yet been established. Although the construction issues of landfills has been covered with these standards, the development of well designed and environmentally sound LFG projects will only be enforced with own specific standards.

Insufficient legislation and awareness at national level will limit the developments at local level.

Planning
For planning and execution of projects the permission phase is very important. Unawareness of the importance of fast project initiation and mobilization may reduce the success of projects. Also here the education of the responsible officials is the main barrier for awareness. Cooperation of authorities at central and local level might be a limiting factor.

Résumé
The main barriers at institutional level are the limited awareness of the people involved, mainly caused by a lack of know-how, education and regulations.

4.2 Financial barriers

Financial support for landfill
A main barrier in the start of LFG projects, as well as sanitary landfilling is the lack of sufficient financial means. At present the waste removal activities are paid by a limited budget from the Department of Health and the Department of Construction. At this moment there is a lack of payment by the people (The waste removal costs in Beijing are 3 RMB/month per family, this only cover the removal costs and not the waste treatment costs).

In fact one of the reasons for the lack of finance is the absence of a direct relation between the polluter and the body responsible for waste treatment. For the future it is not clear yet how the waste management will be financed. Directives should solve this problem in the near future.

Financial support for energy from landfill
Because of the unawareness financial support for energy does not exist now, this is a main barrier for the further development of renewable energy in general and for LFG energy in particular. The structure for landfilling finance is not enforced so that it will be a major problem to collect finance specifically for LFG projects.

At this moment no structure of incentives for renewable energy (or energy from LFG) exists in China. A new system is being developed in the Worldbank Renewable Energy Scale Up project.

Résumé
The main barriers at financial level are the lack of financial structure for financing projects and the lack of financial support for renewable energy, caused by unawareness of the responsible people.

4.3 Implementation barriers

Estimation of gas production / lack of information on LFG
Reliable estimations of LFG yield are needed to show the LFG and energy potential. Since the local knowledge is limited and the background information has a limited reliability, the confidence in the LFG potential is also limited. Therefore the lack of knowledge is a major obstacle for reliable estimations and designs of LFG projects.

Lack of know-how

The lack of LFG projects implies a lack of experience. Because of specific technical and technological aspects, the lack of know-how may be a serious obstacle for the success of LFG projects.

Lack of local technology
Because of the totally new subject, hardly any information of technology or techniques is available in China. Especially the specific technology of gas treatment, gas cleaning and energy recovery is not widespread. Most of the technology must be imported, before enough information is available for the local market or developers.
Also knowledge of sanitary landfilling is missing at the involved levels of consultants, project developers and municipalities.

Lack of demonstration projects
At this moment 10 sanitary landfill projects are in operation in China. At three landfill sites demonstration plants for LFG recovery are built, only one demonstration project is equipped with LFG utilization, expected to start soon. Because of limited knowledge of the subject problems in the daily operation have occurred.
The limited amount of demonstration projects is a great barrier for the further development of new projects in near future.

Résumé
The main barriers at implementation level are the lack of knowledge at the people involved, the lack of possibilities of education and the demonstration of the LFG recovery and utilization in real projects.

4.4 Market / organizational barriers

Relation barriers
The complex relation between several parties involved in a project can be a restriction in the project development. Barriers can be foreseen due to contradictory interests of the project partners, caused by lack of knowledge .

Lack of information at parties involved
Because of lack of knowledge contract arrangements can be influenced negatively.
Unawareness and fear for unsuccessful projects could restrict project developments, as they will influence sale prices of the produced energy. At this moment no structure of obliged purchase of the produced energy exist.

Market barriers
The role of companies in the market is not clear at this moment because all activities are initiated and carried out by governmental bodies at national and local level. At this moment there is no insight in the developments to be expected that can give clear information to the market.
At one hand the government should however grant this entrepreneurs should take more responsibilities in the development of LFG projects. At the other hand government would like to have ample control so that projects are executed in an environmentally sound way.

Conflicts in the post closure situation

After the operational period of a landfill site conflicts are likely to occur if the situation of ownership, operation and maintenance is not clear.

Résumé

The main barriers on market or organizational level are identified as limited awareness caused by lack of knowledge at the parties involved and lack of a clear structure.
While it may be the fundamental reason. One cannot always point to the fact of lack of awareness. With a more thorough discussion for the various sub-sections, one should not need to draw some conclusions at this point for the reasons for the barriers.

5. Strategy for removal of barriers and start implementation

The objective of this action plan is the promotion and widespread adoption of landfill gas recovery and utilization in China. Based on international best practices and a case study from an existing demonstration project an analysis of barrier results in a strategy to remove the barriers and start up the implementation. All the actions needed to start up the wide implementation are presented in the next paragraphs.
The target could be that all waste is treated in a sanitary way in all the major Chinese cities by 2015 and all the landfill sites will have landfill gas recovery and utilization.

The present situation is far away from this target and an immense change is required to achieve this goal. The previous chapter presented the barriers between this goal and the present situation. Because of the immense change to be made, a concerted approach with all actors at central governmental level, local governmental level, entrepreneurs in the market and all citizens of the cities is needed.

To make a strategy successful, the following conditions have to be met:

- **Want to do it**: the actors at all levels are willing to make a change from the current stage to a new approach. Awareness at a central level has to be obtained, as well as at the local community level.
- **Can do it**: From governmental level an environment has to be enabled where the sanitary treatment of waste and landfill gas utilization in a market oriented approach will be feasible. Both legislative actions and financial support are needed to raise the money to carry out the proper waste treatment. The know-how on landfill gas utilization has to be obtained and disseminated. The capacity for the implementation has to be build up.
- **Enforcement**: Once actors want to change and the government has enabled economically sanitary waste treatment, positive or negative feedback on actors should force them to behave in the right way.

In order to achieve a change, a top down approach and a bottom up approach can be combined. In the present situation the governments should act, realize legislation in a directive, and inform the citizens and the market about the danger of the present situation and the need to change. The bottom up approach is that the citizens could put pressure on governments in respect of proper waste treatment and landfilling through local environmental groups.

5.1. Governmental responsibility and entrepreneurial actions

In our view the best strategy would be that the central government takes the lead and involves regional governments and the entrepreneurs in the market to carry out the projects.
The primary responsibility is with the government, because China’s current way of managing municipal solid waste poses a great danger to the citizens and drinking water resources, and is a source of green house gas emissions.
SEPA is responsible for the introduction of this action plan and monitoring of the progress. The action plan should be executed together with the Ministry of Construction and the local governments as well as with the entrepreneurs in the market. The Government should set the rules and formulate the conditions for the entrepreneurs in the market.

The barriers, which have been distinguished before, need clear action in order to achieve the objectives of the action plan. Most barriers have occurred before in other countries, and the amount and results of the successful LFG projects prove that the barriers can be conquered!

Following paragraphs describe the actions advised to speed up the introduction of LFG projects and to improve the final results. The following questions will be answered to solve each barrier:
- Which actions are possible?
- Which action is considered best applicable?
- How should the action be implemented?
- At which level is action needed?
- Who is stakeholder and is responsible for implementation?
- What is the priority?
- When should the action be implemented?

Based on the priorities and importance for successful implementation, the actions are divided in:
- Institutional and legislation development
- Finance
- Technology and knowledge transfer
- Project implementation

5.2 Step wise introduction

The implementation of the strategy for the removal of barriers is challenging on one hand, but has to be realistic and achievable on the other hand. The market introduction will be divided in several steps, because the change China as a nation has to make, is so immense that only a stepwise approach will yield results.

The strategy should be to start with a preparatory phase. Afterwards the implementation in the large and economically developed cities in industrial or tourist area's, where resources are available and a fast transition can be achieved. And afterwards extend from that to the other cities. See Table 5 and paragraph 5.7.

Table 5: Step wise introduction

Phase		Actions
1	2002 – 2005	formulation of directive and legislation, demonstration projects, capacity building, regional action plans, international support, entrepreneurial involvement from the market
2	2005 – 2010	Implementation in the major industrial/tourist cities, financial support by renewable energy support and Clean Development Mechanism
3	2010 – 2015	Implementation in the other cities financed by the market

5.3 Institutional and legislation development

State directive on landfilling

A clear and uniform state policy is the basis for the improvement of landfill technology, including LFG collection and LFG utilization. Laws can be focused on the different aspects of landfilling, e.g. groundwater protection, waste treatment, clean air, etc. or it can focus on landfill specifically. It is advised that the policy will be written down in a directive/law at state level which covers the landfill of waste. The European Directive on landfill of waste, which is equivalent to laws/directives in other developed countries, is an example.

The State directive has to focus on landfill classes, waste acceptance, permits, operational monitoring and control, costs, closure and after care procedures. A transitional arrangement for existing landfills is necessary to fulfil the requirements in a reasonable period of time. Monitoring of LFG emission, LFG collection and utilization have to be laid down in the directive, for landfills at which organic material will be disposed.

SEPA, which is (recommended to be) responsible for development of the proposed directive, should give high priority to the Directive. A draft directive should be available for local governmental departments in 1 year, in order to support the drafting of local action plans. The final directive has to be ready in phase 1.

Legislation development
Regulations are the basis for sound and effective LFG collection and utilization projects. These should be developed in phase 1 analogous with the directive. The regulations have to be developed by SEPA, in consultation with the Ministry of Construction and other ministries and should focus on:

- Government regulation, which request all landfills have to be designed, constructed and maintained based on the national standards.
- National standard system for sanitary landfill design, construction and maintenance, including LFG collection and utilization;
- Mandatory LFG collection and control for landfills of over a certain size.
- National regulation, which requests the utility has to purchase the electricity, gas, thermal or other renewable energy products, produced by sanitary landfills
- To set up legislation, which allows private sector to own sanitary landfills and LFG collection and utilization.

Enforcement of regulations

Enforcement of the implementation of the legislation and regulations has to be carried by SEPA, who is stakeholder of introduction of LFG collection and utilization at State level. The enforcement of sanitary landfills and landfill gas treatment will build on the existing procedures of enforcement for waste management. Aspects that have to be covered in an enforcement plan are:

- Definition of essential points of enforcement (e.g. an essential point for SEPA is the minimization of emission of greenhouse gases and odour);
- Objectives: the enforcement and monitoring of essential points;
- Evaluation of yearly reporting by local governments;
- Progress check and progress control;

- Registration of progress at local and national level;
- Feed back to local governments.

The enforcement plan has to be drafted in phase 1 simultaneously to the National landfill directive.

New landfill projects and rehabilitation of existing landfills have to be initiated by local governments. The enforcement measures at a local level should include the following items:
- Landfill design and operation have to be permitted by local government authorities (Environmental Protection Bureau), to ensure the landfill meets technical and environmental requirements;
- Landfill operation has to be checked by local government authorities at a regular basis
- Evaluation of yearly reporting by landfill operators;
- Registration of progress at local level;
- Reporting of results to SEPA.

These enforcement measures at local level have to be taken in phase 2 and shall be continued in phase 3.

Planning of LFG projects

At state level, the implementation of LFG projects has to be inserted in the next long-range plan (5 year plan) by SEPA and the State Economic Planning Commission.

The actual planning of the implementation of LFG projects is the responsibility of the local governments. The urban clearance committee and the local construction department shall insert LFG collection and utilization in the local landfill development and/or waste treatment schemes. The local planning commission can insert the projects in the next local long-range plan. The local action plan on landfill gas utilization will be the cornerstone for actions at a local level. Drafting of local action plans should start in 2002 (phase 1). SEPA should lay the foundation for the local action plans by issuing a draft National Directive for the landfill of waste.

Market enterprise involvement

The implementation progress of LFG projects can be accelerated at the moment that free enterprises are able to invest in and operate landfill projects and/or LFG projects. In this way external money is made available and (international) knowledge and experience will be introduced at a local level.

To enable private investments and operation, institutional reform from government to privatization is necessary, and has to begin at State level. At a state level SEPA and ministries of finance, trade and economical affairs have to change legislation to introduce privatization and remove import barriers. The action is to include the free market in the new legislation and develop tender procedures to invite and select private companies, and in this way to attract national and foreign investors.

Institutional reform actions shall be started in phase 1 and have to be continued in phase 2 and phase 3.

5.4 Finance

Financial support LFG collection
Sanitary landfilling is of vital importance for the success of LFG collection and utilization. The 'polluter-pays' principle is the one and only sound economic approach for financing modern and well-sized sanitary landfills. Introduction of the principle is not part of this action plan, but has to be realized within the overall waste treatment policy. The income differences and social between rural and urban areas in China are large. Implementation of the 'polluter-pays' principle cannot be forced by this National Action Plan, but has to be based on a general waste treatment policy. The LFG collection system and treatment (flaring) plant is standard equipment at a sanitary landfill with organic substances. The action is to include the cost of standard equipment in the costs of landfilling. The costs of this standard equipment should be earned back by the gate fee. The investment costs of utilization equipment can be earned back by selling the energy.

Introduction of a LFG extraction budget in the standard landfill costs estimates shall be started in phase 1 and have to be continued in phase 2 and phase 3.

Financial support for LFG utilization
Incentives are needed to speed up the implementation process. It is advised to clear the way for LFG projects by building in a form of competition (during phase 1), in which premiums or other stimuli are given by the Central government for a limited number of 'starters/pioneers'.

Economic incentives are the major driving force for inducement of enterprises to adopt the landfill gas utilization. The major incentives could include:

- **Sales price incentives:** utilities are obliged to buy LFG energy (mandated share). To reach a sound price level (a price above the cost price), a certificate system will be introduced by the World Bank, in the Renewable Scale Up Program in China.
- **Tax incentives:** The landfill gas recovery and utilization company could get a long-term income tax dispensation and/or exemption for operation taxes. Therefor a State Council regulation should be drawn up;
- **Duty free incentives:** The imported high-tech equipment for landfill gas recovery and utilization can be a duty free, which has applied for other high-tech equipment system. SEPA should initiate duty free incentives, based at the available regulations of the Ministry of Finance.
- **Investment incentives:** put landfill system construction and landfill gas recovery and utilization projects into the priorities of the national development bank, bilateral government loan and other conssessional investment catalogue.
- **Equipment production incentives:** Encourage enterprises to develop industries related to landfill gas recovery and utilization, such as biogas power generation equipment, biogas refinery and compress equipment by reduction taxation and other economic incentives, which applied for the high-tech equipment R&D and manufacture.

Worldbank demonstration projects, in the framework of the Renewable Scale up Program in the specific provinces to be related with LFG demonstration projects.

The highest priority (phase 1) should be given to sales price and investment incentives, in order to make projects clearly feasible in a short way. Responsible authorities for sales price and investment incentives are at State level.
Long term priority (phase 2 and 3) should be given to duty free incentives, tax incentives and equipment incentives.

Financial resources for implementation of the action plan
The sufficient financial arrangement can ensure the successful of the national action plan. The financial flows for the action plan can come from:
- Central, Governmental and Municipal financial budget, which has been put for the municipal solid waste management;
- International financial support;
- GEF grant financing;
- National development bank;
- Commercial banks; and
- Private investments.

In the rough calculation, the total cost for the national action planing implementation will be more than billions of RMB. The multiple financial channels will be helpful for the implementation during phases 1, 2 and 3. Especially, international assistance is needed for short term activities in phase 1 and phase 2.

5.5 Technology and transfer of knowledge

LFG prognoses
LFG generation models might give an uncertain feeling LFG utilization projects. LFG prognoses models are based on firm input of waste data. Only when waste data (past and future) are correct (preferably long-term data), a model can give average LFG production prognoses.
Several models can be used, and all those models show a range of inaccuracy. On one hand, this inaccuracy depends on the waste data input. On the other hand, influences in the waste body (e.g. moisture content), collection efficiency, etc. are not fully predictable.
To obtain actual waste data, it is advised to introduce waste registration systems at all landfills. Waste data to be registered are quantity and type of waste (depending on organic substance content and the origin).
It is advised that the Anshan LFG advisory Center selects one typical LFG prognoses model, during phase 1, which shall be used in China for the short term (phase 1 and 2). The Center should also start (in phase 1) to build up a database for verification of the model, using data of the demonstration projects (phases 1 and 2). Based on verification decisions can be made for the following implementation phase 3.

Technology
Technology improvement is a major objective to overcome the lack of local technology. The improvement is necessary not only because lower investment costs might be achieved, but also to upgrade the quantity and quality of local supplies.
It is advised to start in phase 1 with the stimulation of joint ventures and twinning arrangements, financed by international funds. Technology improvement might also be introduced in specific procedures for the procurement of goods in demonstration projects.

Transfer of knowledge

During the period in which the legislation and regulations are being developed, a program for awareness and education has to be developed and executed. The program has to focus on all actors involved, including (not limited) decision makers (city mayors, local planning committee, etc.), public servants of different departments, local officials, banks, landfill operators, suppliers, design and construction engineers, public utilities, labour and public in general.

Transfer of knowledge should focus on:

1. Improvement of sanitary landfill operation;
2. LFG collection and utilization technology, implementation and financing;
3. Communication, quality assurance, social welfare, health & safety and social economic aspects.

Several steps have to be taken to assure the effectiveness of transfer of knowledge, awareness and education. Advisory centers should be created in several central situated cities to initiate and facilitate all necessary activities related to awareness and transfer of knowledge. The Anshan Advisory Center can take the lead in creating regional advisory centers. But before this action takes place, it is necessary to make up the mind on how to communicate and educate. It is advised to start with a quick scan of knowledge needed, and based on that to assign communication advisors to make within a period of half a year from now:

- a communication plan,
- an education plan,
- a public relations plan (e.g. media involvement)

All plans including an analysis of actors, objectives, and communication means, monitoring and evaluation procedures. SEPA is the obvious agency to initiate these actions, to improve the effectiveness of SEPA's efforts at implementation of LFG legislation.

The following activities might be included in the transfer of knowledge program:

- A (international) study tour or congress on LFG recovery and utilization in terms of environmental protection and human health and the overall benefits, in terms of emerging environmental, social and economic issues domestically and internationally.
- The introduction of a Chinese LFG extraction and utilization Guidebook, based on the best international practices.
- A training program to educate on new national standards.
- Training of local public servants, public utilities, landfill operators and companies to increase their capability for the approval and monitoring the landfill system design, construction and maintenance.
- Technical support of landfill operators and companies;
- Organization of exhibitions on the landfill gas recovery and utilization;
- Promotion of private and public participation;
- Education at primary schools and universities.

Demonstration projects

Demonstration projects are an effective way of promoting LFG projects, of course combined with transfer of knowledge. Therefor the amount of actual demonstration projects is not enough to reach the objectives. It is advised to:

- Facilitate the existing demonstration projects in order to increase the knowledge transfer;

- Set up a framework to invite other local governments to implement LFG demonstration projects. Selection criteria are needed, such as level of waste treatment, geographical spreading, etc. It is advised to start a selection competition in order to reach a higher level of commitment and landfill operation by the selected local governments.

SEPA is the stakeholder of the demonstration projects. Both actions should be finished within one year, to reach the goal of upgrading the amount and quality of demonstration projects in phase 1.

The demonstration items should include following:
- Implementation of standards for landfill system design, construction and maintenance;
- Institutional arrangement for landfill gas recovery and utilization;
- Power purchase agreement (PPA) development and enforcement;
- Information dissemination and awareness program both for landfill gas recovery and municipal waste management.

5.6 LFG Project implementation

Complex relationships
In every LFG project, complex relationships are to be expected. A lot of departments, companies, financiers and authorities are involved in the project planning and implementation. Close contacts and communication are needed to overcome this barrier. A developer of a project should ensure to contact planning and permitting authorities in an early stage. On the other hand, local-planning commissions should prepare themselves on incorporating LFG projects in their strategic policies.

Besides the knowledge transfer who is needed at all levels, it is advised to SEPA to draft:
- planning guidance documents;
- a program to scrutinize and streamline regulations affecting LFG projects (e.g. emission standards)

Both shall be executed in phase 1. For successful implementation, international experience and local input are needed. International funding might be necessary.

Ownership

Preparing draft contracts for various agreements can solve the problem of ownership of LFG collection and utilization equipment, during the exploitation and after care period. The Anshan Advisory center could be stakeholder of this item. A document with draft contracts should be published in phase 1.

The rights of using gas as a resource should be a local government right solely, because local government bodies have the responsibility of waste treatment and are owner of the land in most occasions.

5.7 Time schedule NAP implementation

Above mentioned actions have to be implemented in a logical sequence. Table 5 gives the outline for the stepwise approach, related to the actions that are described in paragraphs 5.3, 5.4, 5.5 and 5.6. The following paragraphs give a clarification of the implementation of the actions per phase.

5.7.1 Phase 1: Market preparation (2002 – 2005)

The market preparation phase is a 3-year period (2002 – 2005) in which the market for waste treatment and gas recovery has to be established.

1. Policy support

At a central level policies have to be formulated on the waste treatment that should become obligatory after 2005. This policy should include legislation and standards for a landfill site (State directive), financial arrangements, institutional reform of the waste market with clear description of responsibilities, enforcement procedures.

At a local level the cities have to formulate a local action plan for the years 2005 – 2015 on waste treatment, the size and location of new landfills, including gas recovery system and utilization gas plant.

2. Economic support

At a central level a renewable energy policy should be formulated to stimulate the production and utilization of renewable energy. This should include:

- priority access of renewable energy to the grid;
- either a obligatory demand for renewable energy for utilities or the market;
- sales of renewable certificates nationally and internationally;
- sales of CO2 credits through the CDM as part of the Kyoto agreements.

3. Capacity building and technical support

This work can be build on the UNDP/GEF project on landfill gas utilization, where a start with 3 demonstration projects and a landfill gas advisory center was made. However to enable the market this needs to be a much more extensive activity and disseminated all over China.

On a *national scale* the following capacity building strategy is proposed:
The goal should be the strengthening of the position and capacity of the Anshan center on landfill and landfill gas management as an intermediate organization in the execution of landfill gas policy. Enhancing the Anshan centers' capacity for promoting and stimulating LFG projects, for information dissemination and for technical support towards regional actors.

On a *local or regional level*:
Special attention should be given to the embedding of a regional institute that will be responsible for the implementation of the policy through: (i) information dissemination; (ii) networking; (iii) training and programming; and (iv) monitoring actions.
On regional level well-trained and well-embedded organizations are crucial in the implementation of policies, in this case on landfill gas.
The "Anshan center on landfill and landfill gas management" should be a model for such a regional institute. The centers' staff has to be trained on technical, economical and policy aspects of landfill gas utilization. Next, together with these staff members training activities

should be organized for relevant actors like municipalities, industry, energy companies, banks, etc. The center should be trained in programming and monitoring skills in order to enhance its sustainability and to successfully fulfill its role as an intermediate organization between national government and local actors.

Demonstration of the landfill gas technology is seen as a key factor for success and the number of demonstration projects should be increased to 30 by 2005. The present 10 projects should all have energy recovery by 2005. The additional 20 projects should be selected in a bidding process where the town with the best proposition gets a demonstration project with a financial support from the central government and e.g. a free education of one or two engineers in the Anshan Landfill gas advisory centre.

4. Market involvement

When both policies and economic drivers are established the market will become interested in the treatment of waste, landfills and landfill gas utilization. These drivers can gradually be introduced and the work can be moved from the present governmental/municipal bodies. But even when the market carries out the work the governmental bodies remain responsible for waste management and have to control the companies.

5.7.2 Phase 2: Project implementation in priority cities (2005 – 2010)

In phase 2 the economically developed cities should start with the implementation of landfills and landfill gas extraction. On a regional level the cities should execute their own action plan and implement landfill sites, where the finance is based on the polluter pays principle. The gas extraction and utilization have to be supported by a specific renewable energy scheme drafted by SEPC. The central government should monitor the progress at all levels.

It is suggested to have a midterm evaluation to see if the policies, regulations, financial support, knowledge support, technology applied and local action plans yield the appropriate results, or need adjustments during this period.

The landfill and landfill gas market should become organized in a body like an association that has power to negotiate with the governments and suppliers of know how and equipment.

5.7.3 Phase 3: Project implementation in other cities (2010 – 2015)

In phase 3 a well-established market for landfills and landfill gas extraction should be implemented. This market should extend its activities to towns with less capital and money. It is the responsibility of governments to control the operations of these companies. Monitoring of the progress should be continued and a continuous evaluation of financial support and profits of the companies should take place. In case financial support of the government becomes too high it should be lowered.

5.8 Targets in a Scenario for possible implementation

Forecasting

The forecast on the amounts of waste to be treated and landfilled in China (chapter 2), show that though in the future larger amounts will be reused and incinerated with energy recovery, the amount to be disposed of will increase. (see Table 6)

Table 6: Prediction of municipal solid waste in China for landfill sites

Year	MSW (Million tons/year)	To Dumpsite or Landfill (Million tons/yr)	For Reuse or Incineration with energy recovery
1996	108	108	0
2001	162	150	12
2010	289	200	89
2020	408	200	208

As explained in chapter 2, most of the waste comes from the large cities, where disposal has to be replaced by sanitary landfilling including landfill gas recovery. It is expected that the number of landfill sites will increase to 600.
Based on this stepwise approach rapid increasing number of landfills and landfill gas recovery projects to be established can be expected (Table 7).

Table 7: Expectation of municipal solid waste treatment and landfill gas recovery in China

Year	MSW (Million tons/year)	To Sanitary Landfill (Million tons/yr)	Number of Sanitary landfills	Landfills with gas utilization	Energy recovery from landfill [PJ/yr]
1996	108	0	0	0	0
2001	162	3	10	1	0
2005	223	9	30	30	10
2010	289	100	300	300	120
2015	350	200	600	600	240
2020	408	200	600	600	240

This scenario shows that in order to achieve such a massive implementation the market has to be ready by the year 2005 and that only in the year 2015 a situation is achieved where all the Municipal Solid Waste is either reused, incinerated, or landfilled.

5.9 Implementation and monitoring of the progress of the action plan

The implementation of this National Action Plan has to be supported by the following activities:

- A monitoring plan for the implementation activities by SEPA, including detailed benchmarks for all actions. The monitoring plan should be finished within three months after publication of this report;
- Realization of financial support for the actions. SEPA (and Ministry of Construction) should start with introducing the costs of the actions of the NAP in the yearly budget. The

costs have to be estimated by SEPA in close cooperation with other ministries and international experts.

- Monitor the progress of actions (including preparation and financing);
- Assess the annual results of the NAP every year. The evaluation report has to be made available for stakeholders, and should advise on adjustments of the National Action Plan.

Abbreviations

CDM	Clean Development Mechanism
CERE2000	China International Environment, Renewable energy and Energy Efficiency Exhibition and Conference
CHP	Combined Heat and Power
EC, EU	European Commission, European Union
ERI	Energy Research Institute
EXBIC	Export Support Energy Technologies Indonesia, China and South-Africa
GEF	Global Energy Fund
MOC	Ministry of Construction
NFFO	Non-Fossil Fuel Obligation
PPA	Power purchase agreement
SDPC	State Development Planning Commission
SEPA	State Environmental Protection Administration
SEPC	State Environmental Protection Committee
UN-DESA	United Nations Department of Economic and Social Affairs

CH4	Methane
CO2	Carbon dioxide
HCl	Hydrogen chloride
LFG	Landfill Gas
MSW	Municipal Solid Waste
PE	Polyethylene
SO2	Sulfur dioxide

LHV	Lower Heating Value
MJ	MegaJoule, (10^9 J)
PJ/yr	Peta Joule per year (10^{15} J per year)
MWe	MegaWatt electric(1000 kWe)
GWh	Giga Watthour (10^6 kWh, 10^9 Wh)

Annexes

Available from ERI, see colophon