ESMAP
Energy Sector Management Assistance Program

Energy Efficient Cities Initiative

GOOD PRACTICES IN CITY ENERGY EFFICIENCY:

Tianjin, China - Landfill Gas Capture for Electricity Generation

Project title	Tianjin Landfill Gas Capture Project
Sector	Solid Waste Management
Type of project	Landfill Gas Capture for Electricity Generation
City and country	Tianjin, China
City population	11.15 million
Capital cost/initial investment	CNY46.7 Million (US$6.9 Million)
Annual % energy reduction	N/A
Project status	Operational since May 2008

Project Summary

The city of Tianjin, the fifth largest city in China, has implemented a project to recover landfill gas (LFG), which was otherwise being released into the atmosphere, and burn pretreated LFG for electricity generation. The project was located at the Shuangkuo Landfill, one of five municipal waste landfills in Tianjin. The planned capacity of the project is 4.3 MW which is being installed in stages. The first generator, 1.03 MW, started operation in May 2008, currently utilizing 500-600 cubic meters of landfill gas. The electricity produced is being sold to the North China Power Grid under a long-term contract. Through the project, the city was able to use waste to generate revenues and gain local environmental benefits.

The project was initiated by the Tianjin Municipal Government, which has invested CNY46.7 million (US$6.9 million) in the project. The project has been implemented and is being operated by a specially created entity, the Tianjin Clean Energy and Environmental Engineering Co. Ltd. (TCEE). The project will obtain revenues from the sale of electricity which, over the project's life, will amount to CNY245.2 million (US$36.2 million). The project has been registered as a CDM project under the Kyoto protocol and reached an agreement with the World Bank to purchase the certified emission credits (CERs) from the project.

The successful implementation of the project provides an excellent demonstration of the technology and the institutional mechanisms for LFG recovery and electricity generation, which can be applied to many other large Chinese cities.

1. Introduction

Tianjin, the fifth largest city in China with a population of about 11.15 million residents, is located in eastern China near the coast, about 120 km southeast of Beijing. Tianjin is one of four cities in China under the direct administration of the central government, and it is the most important port city in northern China on the coast of the Bo Hai Sea. The Tianjin municipal government seeks to develop Tianjin as the key international port city to be integrated into the overall long-term economic and social development plans for northern China.

Based on 2004 data, solid waste management services were provided to about 6.5 million urban residents, collecting some 5,800 metric tons each day. The network of disposal sites includes five landfills and an incinerator. One of the landfills, in Shuangkou, is the most modern landfill in China.

The Shuangkou landfill occupies an area of 60 hectares and is approximately 35 km away from downtown Tianjin. It was designed with total waste disposal capability of 8.5 million cubic meters (7.4 million metric tons). The facility was constructed in 1999 and became operational in April 2001 to receive an average of 800-1000 tons of household waste per day. By the end of 2008, about 2 million tons of household waste had been landfilled. The waste mainly comes from four districts (Hongqiao, Hebei, Xiqing and Beichen) directly and two districts (Heping and Nankai) via Panlou transfer station.

The Tianjin Municipal Government implemented a Landfill Gas Recovery and Electricity Generation Project at Shuangkuo Landfill with the objective of supporting the city's improved solid waste disposal practices in a more environmentally friendly manner than has been the current practice, thereby leading to substantial greenhouse gas (GHG) emission reductions. Reduction of methane emissions and other non-methane organic compounds to the atmosphere are to be achieved through a LFG collection and treatment system, utilization of the biogas as fuel for electrical power generation, and a stand-by flare unit for destruction of the excess methane and other air pollutants. Without the project, the community surrounding the landfill would continue to be exposed to the odors from the waste, and landfill methane, a potent GHG. Through these improved site management and operating measures, the landfill site would also reduce its potential threats to local groundwater resources and soil contamination. In addition, the project contributed to improved safety because, if the methane concentration in the air rises up to 5~15% by volume within a confined space, the risk of explosion is very high.[1]

2. Project Description and Design

Background. The project will collect landfill gas, which primarily consists of methane (50%) and other gases (50%), such as carbon dioxide and additional gases including non-methane organic compounds, and generate electricity by installing LFG collection, electricity generation, and flaring systems on site. The generators will combust the methane in the LFG to produce electricity for sale to the North China Power Grid ("NCPG"). Excess LFG, as well as all gas collected during periods when electricity is not generated, will be flared. The state-of-the-art technology such as gas collection system, generating and flaring systems will be adopted by the project participant.

The methane from the LFG is recovered and used as a fuel for power generation which further off-sets the consumption of conventional fossil fuels for electricity production. The project includes the installation of four 1.03 MW generators in a staged manner over a period of 7 years (first generator was installed in May 2008).

Implementing Arrangements. To implement the project, the Tianjin Municipal Government established a new entity, the Tianjin Clean Energy and Environmental

[1] In China, landfill explosions have occurred as a result of the unsuccessful venting of landfill gas.

Engineering Company Ltd. (TCEE), a joint undertaking of the Tianjin Construction Commission and the Environmental Sanitation Commission. TCEE designed, constructed and operated the project using local resources, supported by international experts. TCEE selected a Chinese firm, Nanjing Long-Term Environment Technology Development Company Ltd. (NJETDC) as a build, operate, transfer (BOT) contractor to develop and operate the gas collection and power generation systems.

NJETDC was established by Chinese nationals who had worked as staff members at an Australian firm that was active in Chinese LFG market. The firm had two other LFG projects under development. Project activities at the landfill include the reconstruction of the landfill and set-up of LFG recovery systems in its working cells, including such systems as LFG collection, pre-treatment, electricity generation and grid connection, flaring, monitoring and protection system, data recording and archiving.

Technology. In China, the technology to use landfill gas to produce electricity or heat is in its infancy. Therefore, existing landfills with gas utilization systems generally employ foreign technology. The Tianjin project uses the state-of-the-art technology from overseas to assure that the emission reductions from the project are real, measurable and qualified. Generators and auxiliary facilities are being installed in different stages based on the available LFG flow so that the most modern and suitable technology will be employed during the project operating period.

The project includes the following systems:

- **Gas collection system -** At present, a total of 42 vertical gas-venting wells are installed at the site in a rectangular formation. The interval between two wells is 99 m in length and 88 m in width. These wells were constructed in 1000mm diameter with Φ200mm high density polyethylene (HDPE) pipes inside, which are raised as waste fills up. The proposed project will install a gas collection network with additional wells, where appropriate, and connect each wellhead to lateral piping, which transports the gas to a main collection header.
- **Gas pretreatment system -** Prior to electricity generation and flaring, LFG must be pre-treated to remove its impurities. Pre-treatment is important as it will help to prevent corrosion in the generators and flaring system. The pre-treatment process consists of: 1) separation of leachate condensation; 2)

filtration, dewatering and removal of solid impurities and moisture; and, 3) drying and pressurization.

- **Electricity generation and grid connection system -** The project will include four Caterpillar electricity generators (1.03 MW each) installed in different stages of the project. The generated electricity is being sold to NCPG under a long-term power purchase agreement.
- **Flaring system -** LFG not used for electricity generation is flared. When methane is converted into carbon dioxide, the greenhouse effect caused by LFG is substantially reduced. The main pre-operation component of this project element includes the installation of enclosed auto-ignition flare platforms.
- **Monitoring and protection system -** The monitoring and protection of the project is firmly based on the CDM monitoring methodologies[2]. This project provides monitoring and protection facilities for landfill gas pre-treatment, power generation, and public grid connection. Since LFG collection and utilization is a new field in the operation of Chinese landfills, the technology used in the project is imported and meets international standards.

3. Cost, Financing, Benefits, and Effects

Project Cost

The total investment cost for the LFG recovery and power generation project is 46.7 million CNY (US$6.9 million), and the operation and maintenance costs over the lifetime of the project are estimated to be 163.7 million CNY (US$24.1 million). The project will obtain revenues from the sale of electricity to NCPG at 0.50 CNY/kWh (US$0.074/kWh), which over the project life will amount to 245.2 million CNY (US$36.2 million). The pre-tax net profit (after other local taxes) is 34.4 million CNY (US$5.1 million).

[2] The CDM methodologies used for this project are ACM0001 (ver.05) - Landfill Gas Capture, and AMS I.D. (ver.10) - Grid-Connected Power Generation (Small-scale).

Based on these costs and revenues (which do not include revenues from the sale of the CERs), the internal rate of return (IRR) for the project (pre-tax) is 5.9%. If the CERs are sold at $10 per unit, the pre-tax IRR improves to 15.2%.

Financing

The project is financed by the Tianjin Municipal Government using proceeds from a broader World Bank loan for environmental projects. The Bank's Carbon Finance Unit is arranging for the purchase of the project CERs under the CDM.

Results and Benefits

The project was successfully launched in May 2008. The current LFG utilization is 500-600 m^3/hour (50% of which is methane). The project was registered as a CDM project on August 27, 2008 and has been able to earn CERs since that date.[3] Under the purchase agreement with the World Bank, the Bank will purchase 635,000 tons of CO_2e from TCEE and has an option to purchase an additional 470,000 tons.

Overall, the project benefits include the following:

- Increased revenues to the municipality from electricity sold to the grid and CERs
- Reduction of local and regional pollution
- Reduction of GHG emissions from the landfill and electricity production
- Enhanced safety from reduced risks of explosion from high methane concentrations
- Creation of local jobs, since the project was designed, constructed and operated using local resources; while jobs were created during both the project construction and operation periods, they were not quantified
- Improved site management and reduction of potential threat to local groundwater resources and soil contamination.

4. Project Innovation

The innovative aspects of this project include the creation of a special entity, TCEE, for project implementation and operation and the successful application for registration as a CDM project.

5. Lessons Learned

As with most development projects, the success of this project had less to do with technology than with institutional and financial arrangements. Concerns over investment requirements, project management and operating experience, long-term financial viability, energy utilization options and marketability, and environmental benefits were thoroughly considered. The creation of TCEE and its ability to retain competent local engineering

[3] For specific information on the CDM project design document and registration history, see http://cdm.unfccc.int/Projects/DB/JQA1193375340.58/view.

organizations to prepare its feasibility studies and environmental assessment reports, helped ensure a satisfactory implementation of the project.

The project also demonstrated that the technology for LFG recovery and electricity generation is currently available and can be applied in China for such projects. Also the project has demonstrated that LFG projects can be registered as CDM projects and can obtain revenues from the sale of carbon credits. However, as LFG recovery and electricity generation is complex and is still new to China, some technical challenges remained during the operating stage of the facility.

6. Financial Sustainability, Transferability, and Scalability

Financial Sustainability

The project is financially sustainable because it generates revenues from two sources - the sale of electricity to NCPG and the sale of CERs. The total revenues exceed the total expanses for operation, maintenance and local taxes, thereby providing a profit for TCEE. Unless there is an unexpected reduction in emission reductions and thus CER payments, the project should be financially sustainable.

Transferability and Scalability

Currently Tianjin has four other landfills in operation, in addition to the Shuangkou landfill. None of these have an LFG recovery and utilization system, and the success of this project is likely to be replicated at these landfills by the Tianjin Municipal Government.

China has about 100 cities with a population of one million or more plus numerous other larger urban areas. Therefore, there is a significant potential for similar LFG capture and electricity generation projects in China, and such projects represent an important part of China's efforts to reduce GHG emissions. The innovative elements of this project, particularly the carbon financing, can be readily transferred to the other Chinese cities to scale up China's efforts to reduce GHG emissions.

References

1. World Bank, 2006. "Tianjin Landfill Gas Recovery Project Information Document." World Bank, April 1, 2006.
2. World Bank, 2007. "Tianjin Shuangkou Landfill Gas Recovery and Gas Utilization Project." World Bank CDM Project Design Document, May 18, 2007. (See http://cdm.unfccc.int/Projects/DB/JQA1193375340.58/view.)
3. Peterson, Charles (World Bank), Personal communication, 2009.

ANNEX: CITY AND PROJECT PROFILE

CITY PROFILE

1. Name of the City	**Tianjin**
2. Area	**8,772 Square Kilometers**
3. Population	**11,760,000**
4. Population Growth Rate	**1.43%**
5. GDP of the City	**US$ 501.8 Billion**
6. GDP Growth Rate	**12%**
7. GDP per Capita	**US$ 55,473**

PROJECT PROFILE

1. Project Title	**Tianjin Landfill Gas Capture Project**
2. Sector	**Solid Waste Management**
3. Project Type	**Landfill Gas Capture for Electricity Generation**
4. Total Project Capital Cost	**CNY 46.7 Million; US$ 6.9 Million**
5. Energy/Cost Savings	**128.3 GWH of electricity**
6. Internal Rate of Return	**5.9 % without CERs** **15.2% with CERs**
7. Project Start Date	**2008**
8. Project End Date	**Ongoing**
9. % of Project Completed	**Operational**

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