Development of a 50 MW Landfill Gas Fired Power Plant at South Korea's Largest Landfill

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ABSTRACT

In 1999, SCS Engineers (SCS), Korea Power Engineering Company, Inc. (KOPEC), and two other firms were engaged by the Korean Ministry of the Environment (MOE) to conduct an energy recovery feasibility study for the Sudokwon Landfill.

The Sudokwon Landfill is South Korea's largest landfill. It opened in 1992 and currently has over 80 million tonnes (88 million tons) of waste in-place. It is expected that the landfill will be open beyond 2040. Substantial quantities of landfill gas are being produced at the Sudokwon Landfill. The Sudokwon Landfill's landfill gas presents a major energy recovery opportunity.

The feasibility study considered four power generation technologies: reciprocating engines; simple cycle combustion turbines; combined cycle combustion turbines; and a steam cycle power plant. The study also evaluated the feasibility of co-firing the landfill gas in an existing, utility-owned power plant and in a sludge combustion facility (with energy recovery), and producing pipeline quality gas.

The paper discusses:

- Long-term landfill gas recovery projections;
- The existing landfill gas collection and flare station facilities;
- The alternatives considered for landfill gas utilization;
- The economic and environmental evaluation of the alternatives; and
- Description of the recommended landfill gas utilization plan (a 50 MW steam cycle power plant), including interrelationships with the operation of the wellfield and flare station.

SUDOKWON LANDFILL

The Sudokwon Landfill is South Korea's largest municipal solid waste landfill. It began operation in 1992. It serves Seoul, Inchon and the surrounding metropolitan region. Sudokwon currently receives about 5.7 million tonnes (6.3 million tons) of solid waste per year. Waste disposal averages 18,000 tonnes (20,000 tons) per day.

Sudokwon is a modern sanitary landfill and is equipped with a synthetic liner, leachate collection and treatment facilities, and landfill gas collection and destruction facilities.

Sudokwon is the successor to the Sang Am Landfill (also known as Nanji Island). Sang Am closed in 1993. The author previously reported on SCS's involvement at a landfill gas to energy facility at Sang Am Landfill at this conference in May 2000[1]. The project produces hot water for off-site customers. The project is owned and operated by the Korea District Heating Company.

Sudokwon is located in Inchon, about 35 km (22 miles) west of Seoul. Sudokwon is adjacent to the Yellow Sea (West Sea). The site is flat and Sudokwon is a mound type landfill. The landfill consists of four areas. Area No. 1 was filled between 1992 and 2000. It occupies about 2.3 million m^2 (570 acres) and is about 40 m (130 feet) in depth. It contains about 65 million tonnes (71.5 million tons) of waste.

Area No. 2 is currently receiving waste, and is about 15 percent larger than Area No. 1. It is expected to be open to beyond 2010. Area Nos. 3 and 4 are larger than Area No. 2 and are each just under 4 million m^2 (990 acres) in size.

It is expected that about 260 million tonnes (286 million tons) of waste will be in place when the landfill closes at some point beyond 2040.

LANDFILL GAS COLLECTION AND CONTROL

The wellfield employs horizontal collectors and vertical wells. A layer of horizontal collectors is installed at every 10 m (33 feet) of vertical depth as waste is being placed. The horizontal collectors are located 100 m (330 feet) apart. In all, each area ultimately receives four layers of collectors. A 610 mm (24 inch) diameter HDPE header loops each area at each layer of horizontal collectors. Each collector is connected to the header at both of its ends. The horizontal collectors are up to 750 m (2,460 feet) in length. Vertical risers are installed every 250 m (825 feet) of horizontal length of the collectors. The risers are used for leachate pumping and supplemental landfill gas extraction.

After completion of filling of Area No. 1, vertical wells were drilled at about 60 m (200 feet) on center across the top deck. A total of 330 vertical wells were installed in Area No. 1 in 2003.

A single flare station serves the landfill. It incorporates four 85 Nm^3/min (3,000 scfm) enclosed flares and two 170 Nm^3/min (6,000 scfm) enclosed flares. Total capacity of the flare station is 680 Nm^3/min (24,000 scfm). The flare station is located adjacent to Area No. 1. The flare station's blowers directly draw a vacuum on Area No. 1.

Area No. 2 is equipped with five booster blowers, which provide a vacuum on Area No. 2 and which slightly pressurize the landfill gas for delivery to the landfill gas beneficial uses and the Area No. 1 flare station.

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[1] "Landfill Gas Control and Utilization at the Sang Am Landfill," J. Pierce, YS. Cho and W.C. Joo, SWANA 23rd Annual Landfill Gas Symposium, San Diego, California, May 2000.

LANDFILL GAS RECOVERY PROJECTION

Figures 1, 2, 3 and 4 show landfill gas generation and recovery projections for Area Nos. 1, 2, 3 and 4. Figure Nos. 5 and 6 show the combined projections for Area Nos. 1 and 2, and the combined projections for Area Nos. 1, 2, 3 and 4, respectively.

The relatively sharp decay in the rate of landfill gas generation is due to the use of a composite, first-order model, with a single k equivalent of about 0.095. In future years, the decline rate is steep enough to just about offset additional landfill gas generation due to additional waste placement.

The significant gap between landfill gas generation and recovery, and the "saw tooth" pattern is due to reliance on horizontal collectors. The horizontal collectors are periodically brought online. Landfill gas recovery in each area is only optimized after the post-closure vertical extraction wells are installed.

FEASBILITY STUDY

In 1999, a consortium of four firms, including SCS Engineers (SCS) and Korea Power Engineering Company (KOPEC), was selected by the Korea Environmental Management Corporation (EMC) to conduct a landfill gas to energy feasibility study for Sudokwon Landfill. The study evaluated a range of alternatives, including:

- Reciprocating engines;
- Simple cycle combustion turbines;
- Combined cycle combustion turbines;
- Steam cycle power plant;
- Co-firing in a conventional electric power plant;
- Co-firing in a sludge combustion facility (with energy recovery); and
- Pipeline quality gas (molecular sieve and membrane process).

All of the alternatives were evaluated on the basis of:

- Net energy output potentially produced;
- Air emissions;
- Raw water requirements;
- Wastewater production (quantity and type);
- Construction cost;
- Operation/maintenance cost;
- Total energy product production cost; and

- Net annual revenue (based on energy product production cost versus energy product value).

Key market prices for energy products at the time of the feasibility study were as follows:

Electric power	48 won/kWh (4.4¢/kWh)
Medium Btu gas	78.5 won/Nm^3 ($3.76/mmBtu)
Pipeline quality gas	181.3 won/Nm^3 ($4.83/mmBtu)

The feasibility study concluded that a 50 MW steam cycle power plant should be constructed.

SELECTION OF DEVELOPER

After completion of the feasibility study, the EMC solicited proposals for private sector development of the landfill gas to energy project. After a formal proposal and evaluation process, a team led by Hyundai MOBIS won the right to develop the project. KOPEC and SCS were teamed with Hyundai MOBIS.

Hyundai MOBIS and its development partners formed a company named Eco Energy. KOPEC was retained as the design engineer and construction manager for the project. SCS was retained by KOPEC as a subcontractor. SCS was retained to provide advice on landfill gas management and power plant design.

The Sudokwon Landfill Site Management Corporation (SLC) installed a 6.5 MW reciprocating engine plant at the Sudokwon Landfill, as a demonstration project, in 2001, independent of the development of the main landfill gas to energy project.

LANDFILL GAS MANAGEMENT

Development of an overall landfill gas management scheme at Sudokwon Landfill is complicated by:

- The presence of two independent existing wellfields (Area No. 1 and Area No. 2), which are under the effect of two separate sources of vaccum;
- The simultaneous operation of two beneficial uses (the existing 6.5 MW reciprocating engine plant, and the under construction 50 MW steam cycle power plant);
- The presence of one flare station to satisfy the landfill gas destruction requirements of two wellfields (net of the demands of the beneficial uses);
- The different inlet pressure requirements of the flares, the reciprocating engine plant and the steam cycle power plant; and
- The significant investment in blowers and transmission piping that had already been made at the time that the design of the 50 MW plant had begun.

The following philosophy of operation was adopted:

- A constant vacuum would be continuously maintained on both wellfields, regardless of the quantity of landfill gas being produced, and regardless of the variability of the demands of the beneficial uses;
- The quantity of landfill gas extracted from the wellfields would be governed by the sum of the individual valve adjustments on the hundreds of landfill gas collectors and wells. Landfill gas extraction would be optimized on a valve-by-valve basis;
- The order of landfill gas commitment would be -- first to the reciprocating engine plant, second, to the steam cycle power plant, and third, the flares; and
- If the beneficial uses consumed less landfill gas than was available at any time, then only the excess landfill gas will be flared. In the event of total non-availability of the beneficial uses, then all of the landfill gas will be flared. If the beneficial uses demand more landfill gas than is available, then the demand of the beneficial uses must be constrained to avoid overpulling the wellfield.

The landfill gas management scheme developed by SCS uses pressure monitoring and pressure regulation, through use of strategically located flow control valves, to automatically allocate landfill gas flow and to satisfy the above described philosophy of operation.

STEAM CYCLE POWER PLANT

The steam cycle power plant is currently under construction. Upon completion in March 2006, it will employ the following components:

- Three 425 Nm^3/min (14,000 scfm) landfill gas compressors;
- Two high pressure/high temperature steam boilers;
- One 50 MW system turbine; and
- One natural draft cooling tower.

CONCLUSION

The Sudokwon Landfill landfill gas fired steam cycle power plant will equal the size of the landfill gas fired steam cycle power plant now in operation at the County Sanitation Districts of Los Angeles' Puente Hills Landfill. The Puente Hills project has been in operation for over 17 years. The Sudokwon Landfill project demonstrates the worldwide applicability of landfill gas to energy and the concept of public/private sector project development.

FIGURE 1
LANDFILL GAS GENERATION AND RECOVERY
SUDOKWON LANDFILL - AREA 1

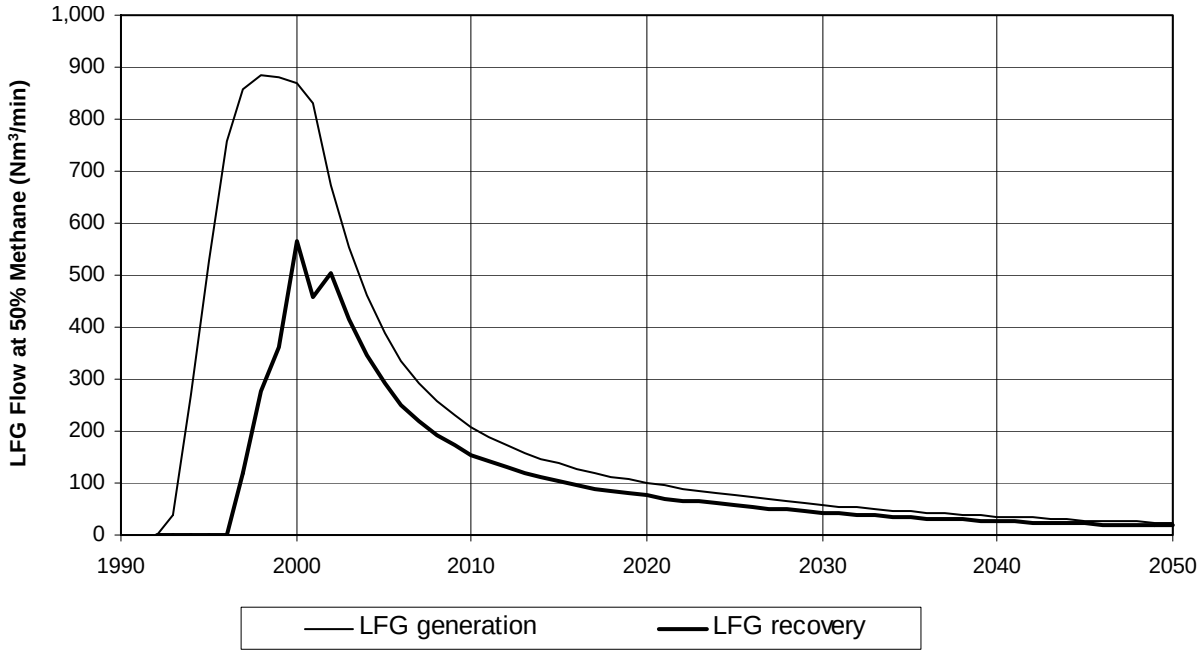

FIGURE 2
LANDFILL GAS GENERATION AND RECOVERY POTENTIAL
SUDOKWON LANDFILL - AREA 2

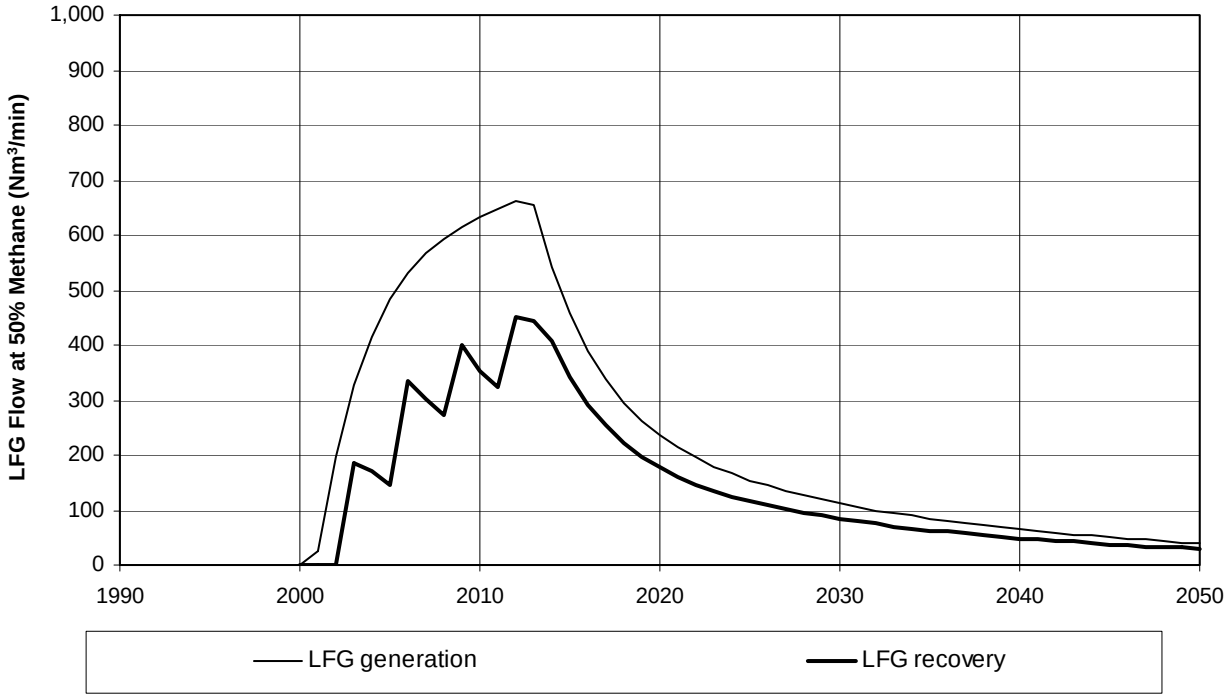

FIGURE 3
LANDFILL GAS GENERATION AND RECOVERY
SUDOKWON LANDFILL - AREA 3

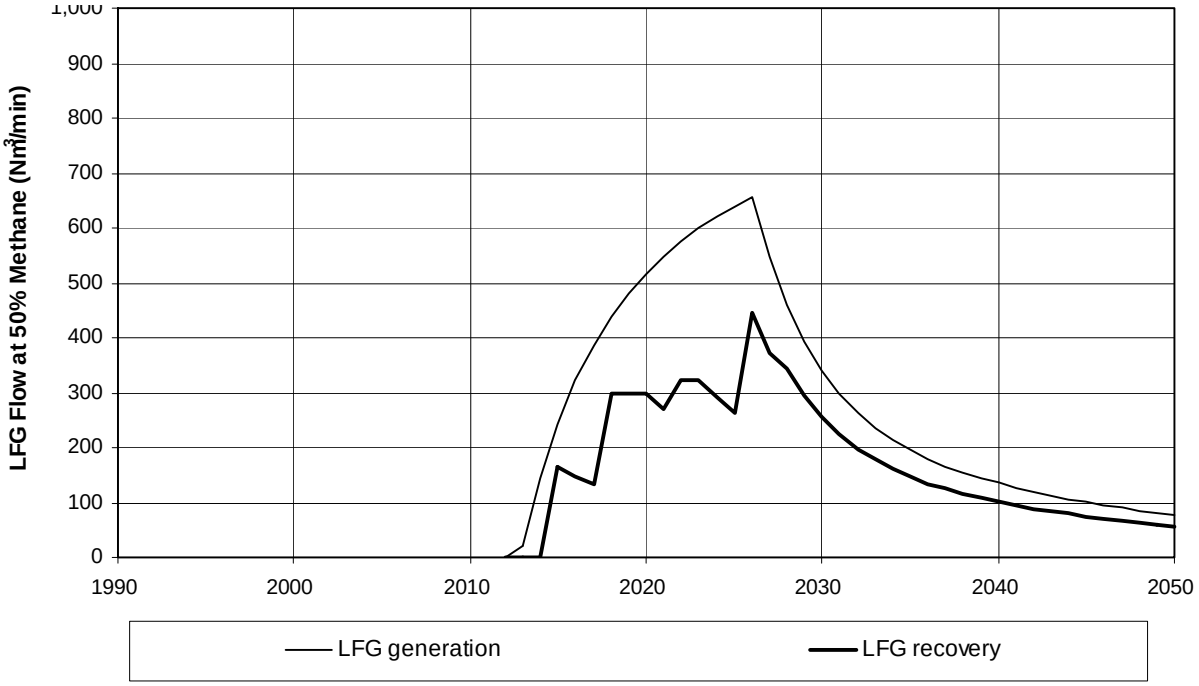

FIGURE 4
LANDFILL GAS GENERATION AND RECOVERY
SUDOKWON LANDFILL - AREA 4

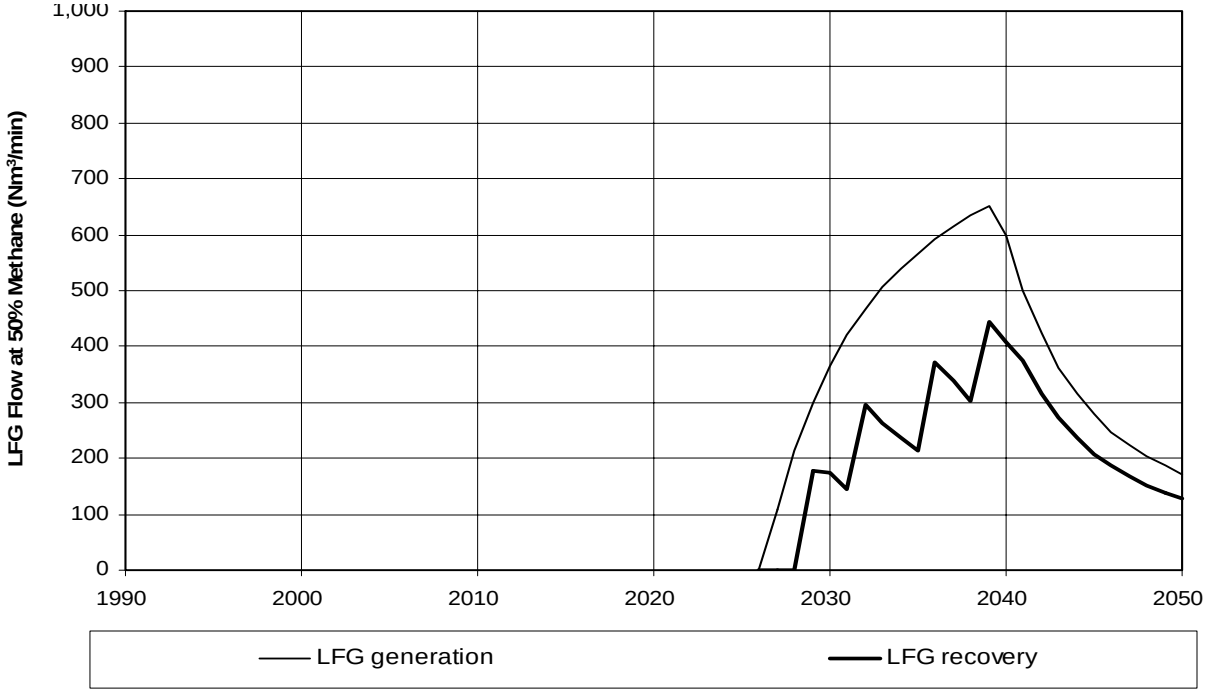

FIGURE 5
LANDFILL GAS GENERATION AND RECOVERY
SUDOKWON LANDFILL - AREAS 1 AND 2

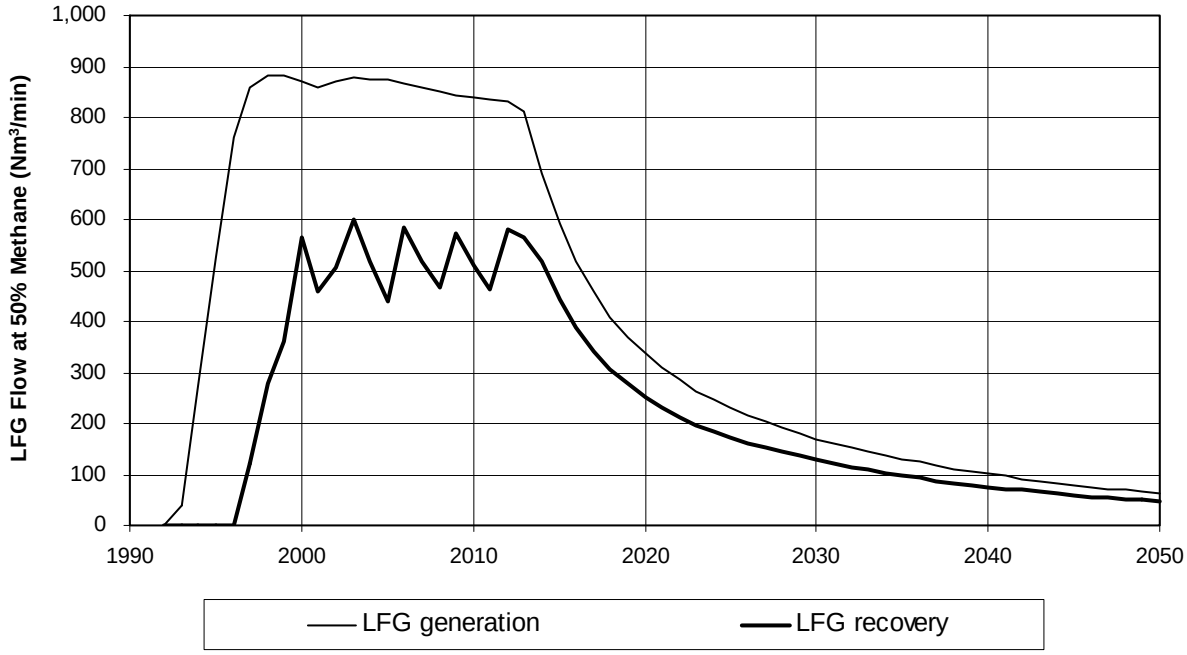

FIGURE 6
LANDFILL GAS GENERATION AND RECOVERY
SUDOKWON LANDFILL - AREAS 1, 2, 3 AND 4