ISTANBUL LANDFILL GAS-TO-ENERGY PROJECT

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Abstract **- Ortadogu Enerji AS of Istanbul, Turkey has undertaken the Istanbul landfill gas-to-energy project after winning the tender held by the Istanbul Municipality company ISTAC AS in March 2007. This project includes two major landfill sites, the Odayeri site situated near the Kemerburgaz and the Komurcuoda site near the Sile districts of Istanbul. Ortadogu Enerji AS has made the investment for the design, construction and operation of the two plants, and ISTAC AS receives a portion of the income of the project. Electrical energy conversion has started in December 2008, currently totaling about 15 MW in both sites, expected to reach 25 to 35 MW depending on the gas generation and collection outcome of the sites. This report provides technical details and salient features of the project. Lessons learned during the execution of the project are also presented.**

Keywords - renewable energy, landfill gas-to-energy, waste-to-energy, public-private partnership.

1. Introduction

Istanbul Municipality has started two major landfill sites in 1995, one in the European and the other in the Asian part of Istanbul. These accept municipal (domestic) waste and are planned as sanitary landfills with the following features:

- An impermeable bottom layer preventing the contamination of the ground water.
- A system to drain and treat leachate water generated by the waste and accumulated at the bottom.
- Disposal of waste in planned deposit cells, compaction, and covering by earth.
- Collection and burning of the methane gas generated by the waste.

Odayeri landfill in the European side occupies about 0.5 million square meters of land and has accumulated about 32 million tons of waste. Komurcuoda landfill in the Asian side occupies about 0.4 million square meters of land and has about 15 million tons of waste. Both landfills were closed in 2009 after reaching their maximum capacity. Figure 1 placed at the end of the report shows their geographic location around the Bosphorus Strait.

The organic substances in any waste kept in a moist and oxygen free environment start to decompose and generate what is called "landfill gas". Landfill gas contains methane gas CH4 at a concentration of 40-55%, the remainder being carbon dioxide and small amounts of other gases. The gas generation peaks within a year and then decays exponentially over tens of years, depending on the rain fall and average temperature in the region. In Istanbul, it is estimated that the above mentioned landfills shall have an average gas production of about 79% of the peak value over a 23 year period. It is not possible to stop the generation of the landfill gas in organic waste except by drying it highly. The generation of the landfill gas occurs as a result of the biochemical decomposition action of the *anaerobic* bacteria which are always present and thrives in oxygen free environments. When waste is left in contact with oxygen, *aerobic* bacteria prosper, and decompose the organic material to generate only carbon dioxide and small amounts of other gases. Therefore, unless dried highly, organic waste should not be exposed to oxygen in order to preserve its methane potential.

During the decomposition process, water is formed in addition to various gases. As a result, a dark colored liquid called *leachate* drains from the waste. Leachate is very harmful if mixed with the ground water. Therefore, it must be carefully collected from the landfill, treated appropriately, and only then be discharged to the environment.

The methane gas has a *global warming potential* of 21 times that of carbon dioxide. It is then better (actually less worse) from an environmental point of view to release it to the atmosphere after burning it appropriately. Therefore, a properly constructed and maintained landfill should prevent the uncontrolled discharge of the methane gas by collecting and burning it under controlled conditions.

It is clear from the above discussion that constructing and operating a landfill is costly. Many municipalities in the world either cannot perform all these processes properly, or strain their budgets seriously.

On the other hand, since the landfill gas has about 50% methane, it can provide half the energy of natural gas. Therefore by burning the landfill gas in an engine coupled to an electrical generator, an otherwise wasted and harmful substance could be both a source of renewable energy and an environmental gain. This is why a landfill gas-to-energy system is a very meaningful concept and often quite a profitable project.

2. The Istanbul Landfill Gas-to-Energy Project

Odayeri and Komurcuoda landfill sites are operated by the municipality owned company ISTAC AS. In 2007, ISTAC AS ran a tender for the design, construction, and operation of landfill gas-to-energy plants in these sites, and the private Ortadogu Group won the tender. This project is a kind of public-private partnership (PPP). The municipality assigns the energy generation rights to a private company and the private company does the investment. The income from the energy and carbon credit sales is shared by both parties through an appropriate contract which lasts for 23 years. Since Turkey has not yet joined the Kyoto Protocol in full, carbon credits generated in this project are traded in the voluntary emission reductions (VER) market.

The Ortadogu Group of companies started business in 1981. Today they have activities in land transportation, construction, renewable energy, and environmental technologies. For the energy projects, a subsidiary company called "Ortadogu Energy AS" has been established. The group is actively pursuing to start projects in other modalities of renewable energy in addition to new landfill projects.

3. How a Landfill Gas-to-Energy System Works

A landfill gas-to-energy system essentially collects the gas generated in a landfill through a gentle suction, treats it before sending to gas engines which are coupled to electrical generators, and conditions the electrical energy generated and conveys it to the national grid. These activities could be housed in steel transportation container type enclosures in small capacity systems, or in plant buildings for larger capacities. In the Istanbul project, pre-fabricated buildings having 20 gen-set (motor-generator set) and 10 gen-set capacity are employed for the Odayeri and Komurcuoda sites respectively.

Figure 2 presents a simplified schematic drawing of a typical landfill gas-to-energy plant.

A landfill gas-to-energy plant has the following main components:

A. Gas Collection

a. Gas collection well system
  i. Well bore
  ii. Perforated collection pipe
  iii. Settling resistant well structure
  iv. Well sealing
b. Leachate extraction system
  i. Pneumatic pumps
  ii. Pressurized air supply
  iii. Drain pipes
c. Gas transport system
  i. Well to manifold piping
  ii. Header pipes with redundant ring connection
  iii. By-pass valves
d. Condensate handling system
  i. Monotonous slope for all pipes
  ii. Siphon (U-tube) condensate traps
  iii. Condensate tanks and pumping system
e. Manifold stations
  i. Well pressure optimization system
  ii. Periodic gas analysis system
f. Compressed air system

B. Gas Conditioning

a. Blower system for suction and pressurization
b. Humidity removal system
c. Hydrogen Sulphide and Siloxane gas removal system
d. Flare system for burning the excess gas
e. Continuous gas analysis system
F. Gas collection SCADA System

C. Gas Storage

a. Gas storage balloons
b. Gas storage SCADA system
c. Lightning protection system

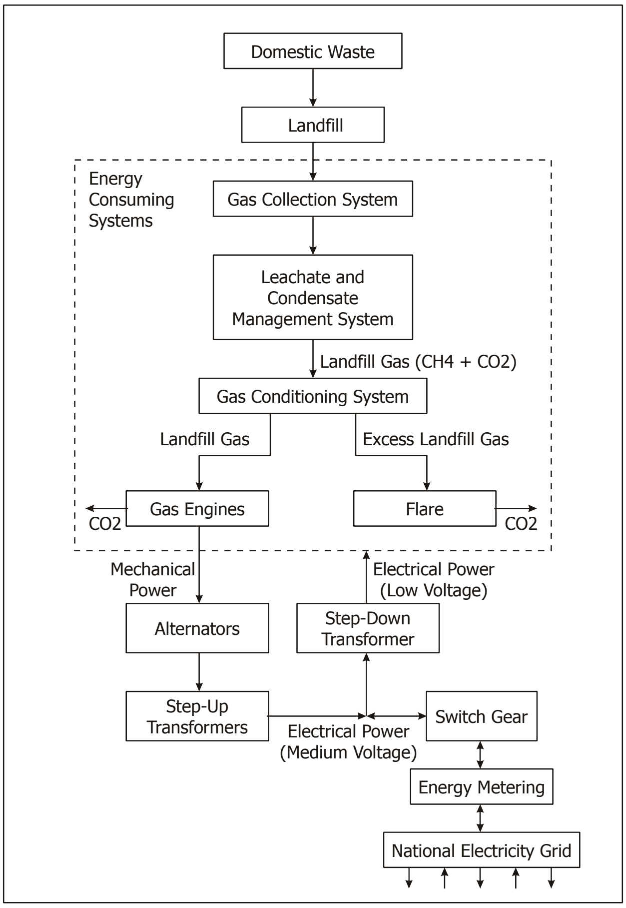

Figure 2. Simplified schematic drawing of a typical landfill gas-to-energy plant.

D. Energy Conversion

a. Gen-Set System
   i. Gas Engine
   ii. Electrical generator (Alternator)
   iii. Gen-set protection switch
   iv. Gen-set control system
   v. Island mode gen-sets
   vi. Gen-sets SCADA system
b. Plant internal consumption system
   i. Step-down transformer (34.5/0.4 kV)
   ii. Emergency stand-by diesel generator

E. Electrical Grid Connection

a. Step-up transformer (0.4/34.5 kV)
b. Medium voltage switch gear
c. Energy metering system
d. Grid coupling system
e. Underground cable
f. Overhead transmission line
g. Coupling to the national grid (Feeder cell)
h. Transmission line bird protection system

F. Plant Housing

a. Container system for a small number of gen-sets and building system for a larger number
b. Gen-set cooling air system

G. Support Systems

a. Gas field maintenance system
b. Gen-set maintenance system
c. Electrical switch-gear maintenance system
d. Transmission line maintenance system
e. Fire protection system
f. Personnel safety system

4. Salient features of the Istanbul Landfill Gas-to-Energy Project

- The project management and system integration for this project has been realized by Ortadogu Enerji A S, and not contracted out to an international company. In this way, a significant accumulation of local expertise has been realized.
- Imports of equipment from other countries have been kept at the minimum and the resulting local contribution to the project has been realized at about 50%.
- Throughout the project design, high energy efficiency and minimum total life cost have been the top priority, resulting in about 11.5 % more energy being delivered to the national electric grid as compared to typical project implementations. (See Figure 3 at the end of the report.)
- A contract management consultant has been employed, resulting in the signature of purchase and service contracts prepared by the buyer but not by the sellers.
- The following are some data about the project:
  - Conclusion of the tender and start of the project date: March 2007.
  - Start of energy conversion: December 2008.
  - Public-Private Partnership project duration: 23 years.
  - Total power generated on both sites as of July 2010: 15 MW.
  - Total peak power estimated from both sites: Between 25 to 35 MW, depending on the gas generation and collection outcome of the sites.
  - Ratio of the 23 year average to the peak output: Estimated at about 79%.
  - Total estimated carbon credits from both sites: About one million ton/year CO2eq. for the first 7 years.
  - Gas collection wells: Odayeri site 133, Komurcuoda 111 wells, 80 cm dia., up to 43 m deep. New wells of 60 meter deep are planned.
  - Total length of gas, leachate and compressed air pipes: Odayeri site 50 km, Komurcuoda 38 km.
  - Blower system capacities: Suction side -120 mbar, Pressure side +130 mbar, Odayeri site 17,500 Nm3/h, Komurcuoda 7,500 Nm3/h.
  - Flare capacities: Odayeri site 5,000 Nm3/h,
  - Komurcuoda 2,500 Nm3/h.
  - Gen-Sets: Each with 1.4 MW power, a total of 18-25 units depending on the gas production and collection outcome of the landfill sites.
  - Gas storage: Two balloons made of cloth-reinforced plastic, each with 15,000 Nm3 capacity, utilized to accumulate landfill gas during night hours of low buying tariff and consume during the day.
  - Plant enclosure: Enclosed in pre-fabricated concrete power houses with 20 and 10 gen-set capacity, respectively for the Odayeri and Komurcuoda sites.
  - Total investment cost: Approximately 35 million Euros. (1.4 to 1.0 Million Euros per MW.)
  - Pay-back period: Dependent upon the Renewable Energy Purchase Price of the government, and the gas production/collection performance of the landfill.
  - Figures 4 through 14 at the end of the report show various views from the plants.

5. Lessons Learned From This Project

- **Problem encountered:** During the project development phase, the landfill gas was analyzed for trace amounts of gases which could be harmful for the engines, such as hydrogen sulphide (H2S) and siloxanes. Gas samples were collected by competent experts and analyses were performed in competent labs in Europe. The test results were considered satisfactory by engine manufacturers and a hydrogen sulphide or siloxane gas removal system was not indicated. However, after running only a few thousand hours the engines developed excessive deposits in their combustion chamber. Their manufacturer claimed that the landfill gas contained excessive amount of siloxanes and this caused the deposits. They declared measuring siloxanes by analyzing the gas samples as being unsatisfactory for evaluating the quality of a landfill gas, and stated that what counts is what happens in the engines, but not what the gas analyses say.

Lesson learned: Evaluation of landfill gas for siloxanes is a very difficult task. Preferably install a siloxane removal system even if the engine manufacturer does not require. But, siloxane removal is a costly process. Better, choose an engine truly guaranteed by its manufacturer to be tolerant to the siloxane levels existing in the landfill gas. Also, keep in mind that landfill gas is not a very stable product; the siloxane content may change over years, even months. Carefully study the siloxane problem in the literature before the plant design is finalized.

- **Problem encountered:** System integration performed locally was not hundred percent successful, such as an insufficient thermal insulation in a sub-system, which needed some re-work for correction. Design of the insulation done by local experts was not satisfactory.

  Lesson learned: Make sure that the balance of the plant left to the system integrator is specified in full detail, and that local expertise is available to design and manufacture it satisfactorily. Balance of the plant is that part of a plant not provided by major suppliers such as gen-set manufacturers. Insist that all system suppliers provide detailed production blue-prints for anything they do not supply but is needed for their system to operate properly.

- **Problem encountered:** Landfill gas collection wells proved to be not long-lasting. Some of them got clogged by hard deposits inside the perforated pipe. Some wells became deformed as a result of the settling and horizontal movements in the landfill. This resulted in reduced gas output and the need for opening and furnishing new wells.

  Lesson learned: Use multi segmented gas well piping with telescope-like joints. If required, use larger diameter gas well pipes. Set aside budget and be technically prepared to re-work on gas wells and open new wells.

- **Problem encountered:** Medium voltage overhead transmission lines utilized to connect to the electric grid had many short circuits due to storks and other big birds perking on the towers located near the landfill.

  Lesson learned: Active landfills attract birds in big flocks. Take bird protection measures on the transmission lines around the towers, such as extra insulation sleeves, bird repellants, etc.

- **Problem encountered:** A lot of unexpected manufacturing defects in capital equipment, and dissatisfaction with suppliers in correcting the problems were encountered. This led to major disagreements over the contractual obligations of the parties.

  Lesson learned: Luckily, comprehensive and prudent purchase contracts was drafted and negotiated by a contract management consultant for this project, instead of the buyer blindly signing the standard contract of the suppliers. If it were not for this contract, the project owner would have been totally helpless and unable to protect its rights and countermove for the survival of the project in a just way. Therefore, refrain from signing the standard contracts of suppliers. Do not even try to modify and improve on their contract drafts. Instead, write your own version of the contracts from scratch, by following the steps below:

  - Study and analyze the processes, obligations of the buyer and the seller, and risks involved in the business deal to be covered by the contract.
  - Distribute the obligations and risks between the buyer and seller in proportion to their ability to undertake and manage them.
  - Specify the goods and services to be provided accurately, set measurable performance levels, and define penalties when set performance levels are not met. This is known as the Service Level Agreement in the information technology field. This methodology is needed in contracts in all fields.
  - Study and clearly put in writing the obligations of the buyer and supplier during commissioning, acceptance and warranty periods.
  - Include in the purchase contract, a legally binding offer from the supplier for an “After Warranty Maintenance Contract” with reasonable terms.
  - Include in the purchase contract, a legally binding offer from the supplier for the provision of durable and limited-life (consumable) maintenance supplies. Attach to the contract guaranteed price lists for all these supplies, and clearly state the guaranteed service life for the limited-life supplies.

Figure 1. Geographic location of the landfill sites around the Bosphorus Strait.

(**Figure 2** is embedded in the text)

Breakdown of the Extra Energy Efficiency Obtained in the Project

	Energy Efficiency Obtained in the Project	Energy Efficiency in a Typical Project	Efficiency Gain in the Project
Thermal Energy Input	**100,00**	**100,00**	
Gen-Set Efficiency	**41,60%**	**39,17%**	**2,43%**
Transformer Efficiency	**98,90%**	**98,20%**	**0,70%**
Transmission Line Efficiency	**96,04%**	**92,08%**	**3,96%**
Electrical Energy Output	**39,51**	**35,42**	

Additional Energy Supplied to the Grid	(39,51 - 35,42) / 35,42 = **11,56%**

Figure 3. In this project, 11.56 % more energy is being delivered to the national electric grid as compared to typical project implementations.

Figure 4. An aerial view of the Odayeri site. Maximum depth of waste is 90 m, average 30 m.

Figure 5. An aerial view of the Komurcuoda site. Maximum depth of waste is 70 m, average 19 m.

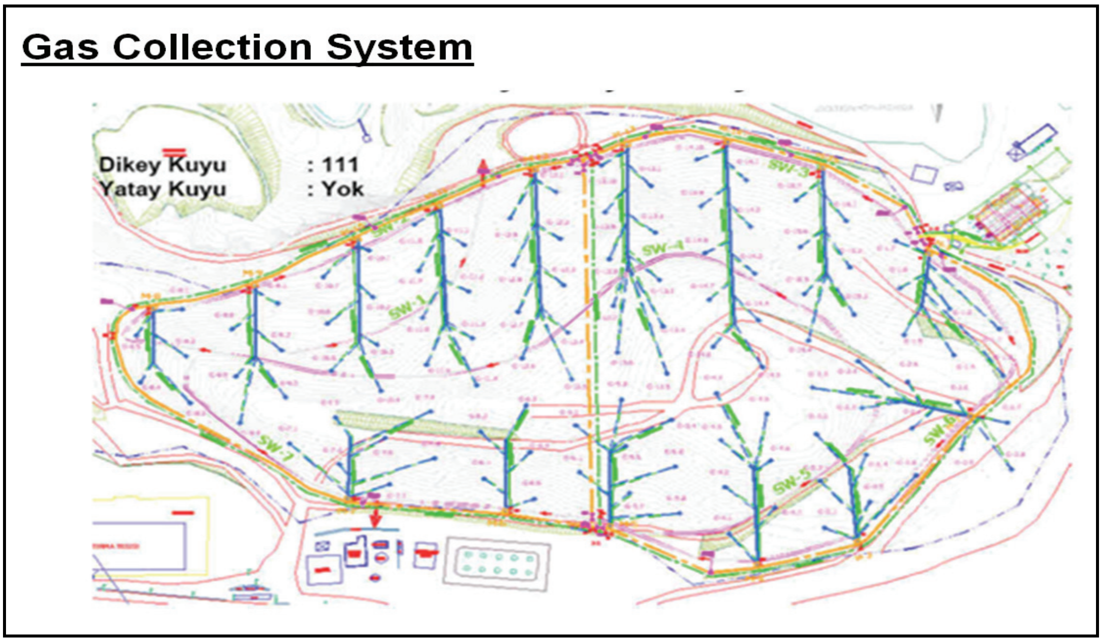

Figure 6. Positioning of the gas collection wells on the Komurcuoda site. Wells are located 50 m apart from each other and are piped separately to a collector station (manifold), where the vacuum applied to each well is adjusted periodically for maximizing the methane concentration and flow rate.

Figure 7. The plant building in the Odayeri site.

Figure 8. The gas conditioning system and flares.

Figure 9. Drilling of a gas well. Because of the methane gas explosion danger, fire extinguishing equipment is kept nearby.

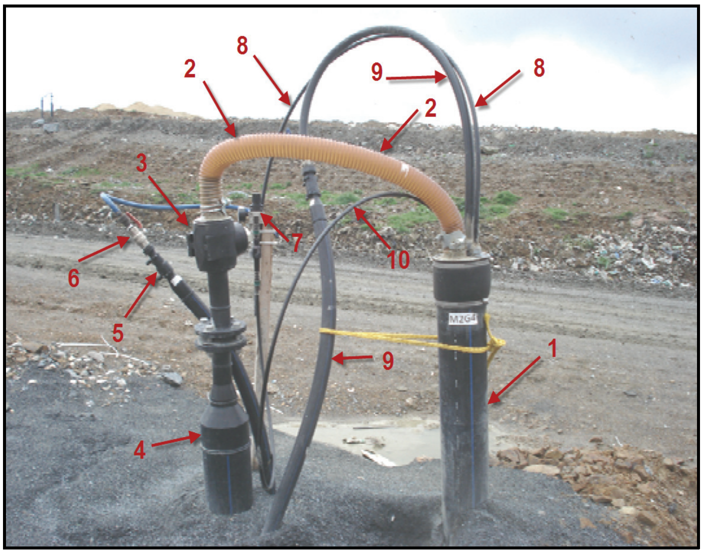

Figure 10. Well head detail.

(1) High Density Poly Ethylene plastic 160 mm diameter well pipe (2) Flexible tube (3) Gas valve (4) HDPE plastic 160 mm dia. gas transmission pipe (5) Pressurized air supply line (6) Air supply valve (7) Pressure regulator and pulse counter (8) Pressurized air supply to the pneumatic leachate pump inside the well (9) Leachate discharge line from the pump (10) Exhaust air discharge line from the pump to the atmosphere.

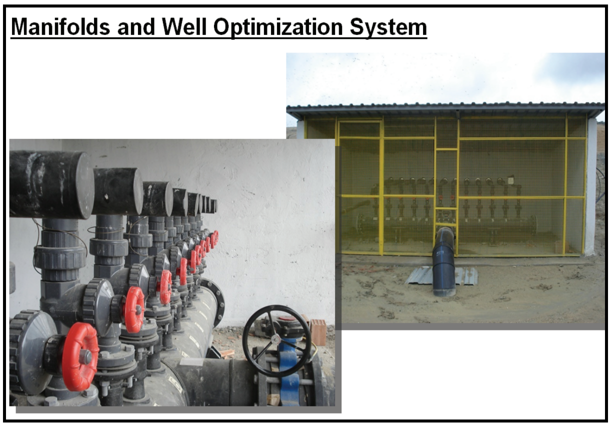

Figure 11. Well pressure regulators and manifold enclosure.

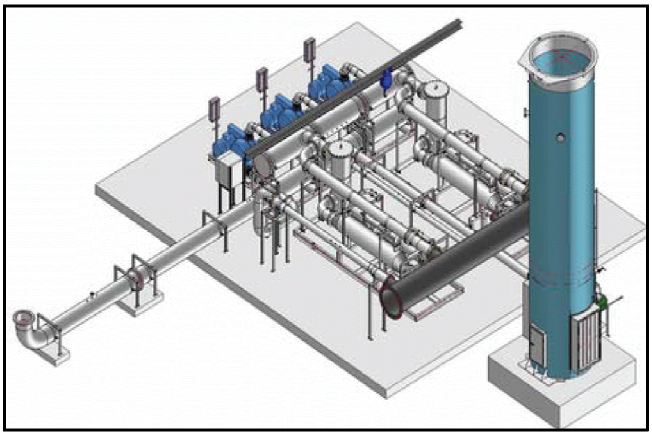

Figure 12. A schematic diagram of the blowers, the moisture removal system, and the flare.

Figure 13. A view from the gen-set hall.

Figure 14. One of the step-up transformers, and the overhead transmission line.