OII LANDFILL MICROTURBINE POWER PLANT: CASE STUDY

Jeffrey L. Pierce, P.E.
Vice President
SCS Energy
Long Beach, California

Les LaFountain, Ph.D.
President
New Cure, Inc.
Monterey Park, California

Abstract

The Operating Industries, Inc. (OII) Landfill is a closed landfill located 12 miles east of downtown Los Angeles, California. It is now a USEPA Superfund site. Prior attempts to utilize the landfill gas at this site for energy generation had been hampered by a requirement for 99.99% destruction and removal efficiency (DRE) at the thermal oxidizer (flare) exhaust. A solution was proposed, and approved by USEPA, in which the exhaust from microturbines could be directed into the flare thereby meeting the DRE. In addition, other design issues had to be overcome, e.g., the typical methane percentage of OII's landfill gas is low, ranging from about 25% to 28%. Microturbines can only operate at methane contents as low as 30%. In order to overcome this, a dedicated pipeline carrying richer portions of the landfill gas was routed to the microturbines.

If permitted by the utility, excess power produced by the power generation equipment can flow into the utility's distribution system and several options were available. The option selected was to set a negotiated maximum amount of power that could be exported to the utility, but with the utility not required to pay for the power. Project financial risk was mitigated through risk sharing contracts with the constructor and the vendor. Prior to the initiation of construction, a $105,000 grant was secured from the California Energy Commission (CEC). A subsequent grant for $450,000 was obtained from the local electric utility. The power plant first produced electric power in late August 2002, approximately six months after execution of the turnkey contract. In January 2002, the plant was online nearly full time. In addition to recovering $555,000 in grants, savings have recently approached $30,000 per month in avoided electrical costs.

Project Genesis

The Operating Industries, Inc. (OII) Landfill is a closed landfill located 12 miles east of downtown Los Angeles, California. The site was opened in 1948 and continued in operation until 1984. Subsequently, it was placed on the National Priorities List in 1986 and designated a Superfund site whose remediation is currently under the direction of the United States Environmental Protection Agency. The landfill has remediation underway with regard to the landfill gas, stormwater, landfill cover and groundwater. It currently produces approximately 5,500 scfm of landfill gas which has been treated with a thermal oxidizer capable of a destruction and removal efficiency (DRE) of 99.99%. Any attempt to utilize the landfill gas for energy generation in the past was hampered by the requirement for 99.99% DRE.

In July 2001, the California Public Utility Commission (CaPUC) allowed the local utility serving OII, the Southern California Edison Company (SCE), to raise its retail rate from 10¢/kWh to 14¢/kWh. As a result of this increase, OII's annual power cost increased to $440,000. SCS Energy (SCS) proposed that a power generation feasibility study be undertaken, and New Cure, Inc. (NCI), the contractor for the Work Defendants, authorized SCS to undertake a feasibility study.

At the outset, the following boundaries were set on the study:

- Limit the Project's Size to the On-Site Load: SCE was not buying power, and even if SCE was buying power, a "retail deferral" type project would have a lower capital cost and a higher return on investment;

- Fuel the Project Exclusively on Landfill Gas; and
- Limit the Generation Technology to be Considered to Microturbines: Microturbines were considered to be the favored technology because: the landfill gas at OII has a low methane content; low NO_x emissions were a high priority with regulators; and a relatively small plant capacity was required.

A review of the power bills at OII showed that four major loads accounted for more than 95% of the landfill's power consumption:

- The landfill gas treatment system (LFGTS) itself;
- The leachate treatment plant (LTP);
- The office building at the landfill (known as the eight-wide); and
- The booster blower.

Table 1 summarizes the power loads and costs at each of these four locations (shown in Figure 1), each of which was served by a separate SCE meter. The LFGTS and LTP are adjacent to each other; however, the next nearest power load is the eight-wide, which is about 2,200 feet distant, and is located across the eight-lane Pomona Freeway. The final load, the booster blower, is an additional 1,900 feet away.

SCS's study recommended that the loads at the LTP and LFGTS be combined and be served by a 350 kW facility, that the eight-wide be served by a 70 kW facility, and that the booster blower be served by a 30 kW facility. The feasibility study indicated that all these projects were financially feasible. NCI submitted the SCS study to USEPA for funding approval in September of 2001.

TABLE 1
OII
ANNUAL POWER LOADS AND COSTS

	Peak	**Average**	**¢/kW**	**Annual Cost**
LFGTS	232 kW	205 kW	14.5	$260,000
LTP	130 kW	63 kW	14.6	$81,000
Eight-Wide	86 kW	43 kW	14.6	$56,000
Booster Blower	40 kW	33 kW	14.4	$42,000
	448 kW	**344 kW**		**$439,000**

Project Refinement

Upon review of the proposed project, USEPA decided that, for consistency, a DRE of 99.99% would be required for any landfill gas burned in the microturbines (i.e., the 99.99% DRE requirement would apply whether the landfill gas was flared or was beneficially used). It was expected that microturbines could achieve at least a 99.5% DRE, but this was short of USEPA's requirement. SCS proposed a solution in which the exhaust from the microturbines could be directed into the LFGTS thereby meeting the DRE of 99.99%. The microturbines would consume only about 5% of the total landfill gas burned in the LFGTS, and the introduction of the microturbine exhaust would not disturb LFGTS operation. USEPA approved this solution; however, the recommendation to install 70 kW and 30 kW microturbines on the other side of the Pomona freeway had to be abandoned because of the requirement to route the exhaust gas to the LFGTS.

SCS evaluated the possibility of extending an NCI-owned power line across the Pomona freeway. The payback on this incremental investment was marginally acceptable, but the self-owned power line crossing a public highway introduced complications in securing an interconnection approval from SCE. While attempting to deal with obstacles imposed by SCE, SCS offered a partial solution to the problem. A review of the subloads at the eight-wide revealed that more than 60% of the power consumed at this location was due to air compressors, which served site-wide compressed air requirements. SCS proposed that a sixth microturbine be added to the LFGTS/LTP and that the air compressors be relocated to the LFGTS/LTP. This was possible because available piping would allow the compressed air needs of the landfill to be served from the LFGTS/LTP with relatively minor system modifications and additions. In this solution, the load was brought to the power supply, rather than bringing the power supply to the load.

As mentioned above, the typical methane percentage at the LFGTS is low. It ranges from about 25% to 28%, but microturbines can successfully operate only at methane contents as low as 30%. The low methane percentage at the LFGTS is primarily due to an extensive in-soil, perimeter extraction well system, which largely pulls air. The perimeter well and interior well gas is intermingled before crossing the Pomona freeway and reaching the LFGTS. Initially, it was thought that the perimeter wells could be less conservatively tuned thereby raising the methane content at the LFGTS to 30%+. Compliance with regard to offsite migration of methane is of paramount importance at OII, and it is preferred to be able to operate the landfill gas extraction system unencumbered by issues other than compliance. SCS proposed that a 4-inch dedicated pipeline be installed from the LFGTS/LTP, paralleling the main landfill gas transmission line, crossing the Pomona freeway, and then intercepting a landfill gas header in the landfill unaffected by the perimeter extraction well system. Implementation of this approach was aided by the existence of a spare pipe within the bridge crossing the Pomona freeway.

Landfill Gas Quality

The methane content in the landfill gas at OII is somewhat variable due to the presence and operation of the perimeter extraction well system. The basis for microturbine design was 35 percent methane content; however, in actual operation the methane content has varied from 29 percent to 47 percent.

Hydrogen sulfide concentration at OII is relatively low at 19 ppmv. Siloxane is also relatively low at 0.690 ppmv. Siloxane on a speciated basis is shown on Table 2.

TABLE 2
SPECIATED SILOXANE CONTENTS

Siloxane	Siloxane (ppmv)	Silicon (mg/m^3)	Silicon (g/MMBtu)
D4	0.145	0.52	0.05
D5	0.112	0.52	0.05
L2	0.256	0.48	0.05
L3	0.177	0.49	0.05
	0.690	**2.02**	**0.19**

Plant Description

The above-described evolution led to the installation of the following plant configuration:

- A dedicated landfill gas transmission line;
- Piping interconnection with the flare station and condensate collection system;
- A 40 hp, 250 scfm landfill gas blower which raises gas pressure from -80 in. wc to 10 psig;
- A refrigeration system which chilled the compressed landfill gas to 40º F, coupled with a heat exchanger to reheat the chilled gas to 20º F+ above the dew point;
- Six 70 kW Ingersoll-Rand (I-R) PowerWorks microturbines;
- 30 ft x 30 ft metal deck cover over the turbines;
- Exhaust ducting;
- Switchgear and utility equipment;
- Continuous fuel gas quality analyzer (methane and oxygen);
- Motor control center for the motors on the compressor skid; and
- Plant control computer with touch screen interface and off-site wireless access.

The landfill gas extraction system at OII includes a large in-soil, perimeter well extraction system that dilutes the gas delivered to the flare station to less than 30% methane. The dedicated collection header taps into the existing collection system where the gas quality is typically 35% to 40%.

The I-R microturbines require 80 psig gas. They incorporate a factory-supplied on-board compressor, but the compressor could not be factory-upsized to raise the required quantity of landfill gas from -80 in. to 80 psig. To overcome this problem, a positive displacement blower was used to "pre-pressurize" the landfill gas to 10 psig. A chiller and heat exchanger were provided for moisture removal.

The pre-treatment equipment, including all non-utility electrical and control equipment, was designed and constructed on one skid. This allowed for assembly and initial testing of the skid to be completed off-site.

In order to meet the 99.99% DRE requirement, for flared landfill gas, the LFGTS is equipped with combustion air fans to enhance the fuel mixing and combustion. It was possible to meet the 99.99% DRE requirement with microturbine exhaust gas routed into the combustion air blowers because:

- The oxygen content in the exhaust of the microturbines is very high, and is high enough to not impact mixing and combustion in the flare;
- The air temperature from the microturbine exhaust would be acceptable to the combustion air fans (after pre-mixing and dilution with ambient temperature combustion air); and
- Control of the microturbines would be interlocked with the operation of the LFGTS in order to avoid back-flowing the microturbine exhaust out the combustion air inlets (which could occur if the LFGTS was offline and the microturbines were on).

SCE Interconnection Issues

Virtually every distributed generation project, which has the ability to access a utility electric power distribution system, operates in parallel with the utility. The power generation equipment and the on-site power loads are continuously connected to the utility through a closed main breaker. Standby and supplemental power from the utility is instantaneously fed by the utility if there is a problem with the power generation equipment and/or if on-site power demand spikes above power generation capacity. If permitted by the utility, excess power produced by the power generation equipment can flow into the utility's distribution system.

Three options are available when excess power generation capacity is available:

1) Match Power Production to On-site Load -- Under this scenario, power is not exported to the utility and is commonly called the "no export" option. If an applicant accepts this option, the utility generally requires strict adherence to this condition. The utility requires the installation of a reverse power relay which detects when any export of power occurs and which immediately calls upon the main breaker to the utility to open. When the main breaker opens, it is not possible to close it without shutdown and restart of the power generation facilities. Obviously, this undermines the advantages of parallel operation. Activation of the reverse power relay would generally occur when the power generation equipment cannot reduce its rate of power production fast enough to follow dips in on-site power demand. A solution to this problem is to operate the power generation facility at an output below the actual on-site load, allowing some utility power to be backfed at all times, despite the availability of adequate power generation capacity. The obvious disadvantage to this arrangement is that power is being unnecessarily purchased;
2) Inadvertent, Uncompensated Export of Power -- Under this scenario, a negotiated maximum amount of power can be exported to the utility, but the utility does not pay for the power. The problem of matching power generation to on-site load can be eliminated by always generating a little more power than is needed. If the distributed generation facility is fired on conventional fuel, the fuel is an expense, and an unnecessary cost is incurred to generate the "unneeded" excess power. At OII, the fuel is available at no cost and fuel cost is not an issue. A second disadvantage to the inadvertent export scenario is, at least in California, that the utility review of the interconnection application takes longer, is more costly, and can result in more extensive and costly utility-installed equipment on the utility side of the meter. The applicant is required to pay these costs in full at the time of installation; and
3) Export of Power With Sale of Power -- California utilities are currently required to buy power, at their avoided cost, only for projects less than 100 kW in size. At the present time, there is virtually no market for sale of electric power in California.

It was clear that Scenario 2 was the preferred scenario, provided that SCE's requirements did not become unacceptably onerous in terms of lost time and money. Identification of the interconnection cost difference between Scenarios 1 and 2 was not the only open issue to be addressed during the review process. The above-discussed question of extending service across the Pomona freeway (impacting plant size) and the question of the most cost-effective way to combine the two service points at the LFGTS/LTP into a single service point were also factors. Several meetings involving almost a dozen SCE representatives (technical, financial and regulatory) ultimately led to SCE's acceptance of Scenario 2 with an export limitation of 150 kW.

At the conclusion of this process, NCI marveled at how difficult it was to give free power to a utility in a state which less than a year before was facing power blackouts and soaring wholesale prices.

It took 86 days from the date our interconnection application was filed through the day it was approved. In hindsight, the rather complicated application was processed in a reasonable amount of time. SCE ultimately charged NCI $105,000 for upgrades on the utility side of the meter. The upgraded facilities included a new main transformer, a ground bank and wiring modifications.

Financial Considerations

NCI minimized its financial risk through risk sharing contracts with SCS and I-R. NCI signed a turnkey construction contract with SCS, which called upon SCS to provide design, permitting, equipment installation and start-up on a time-and-materials basis for a guaranteed maximum price of $1,080,000. The turnkey contract placed construction cost risk on SCS, prior to the plant being designed.

NCI signed a five-year, fixed price microturbine maintenance contract with I-R. Under this contract, I-R provides all scheduled and unscheduled maintenance required by the microturbines for $8,000 per microturbine per year (about 1.5¢/kWh). Microturbine maintenance is expected to represent about 70% of the plant's overall operation/maintenance cost. As a result, NCI has a fixed operation/maintenance cost for the plant at a guaranteed price for a five-year period. More importantly, the cost risk from the plant component that had what was believed to represent the greatest risk, was virtually eliminated by the I-R contract.

SCS was able to bring additional financial benefits to the project in the form of grants. Prior to the initiation of construction, SCS secured a $105,000 grant from the California Energy Commission (CEC). The grant was paid to NCI through SCS at project completion. The grant represented $250/kW and was offered under CEC's Innovative Peak Load Reduction Program.

As construction of the plant was nearing completion, SCS identified another opportunity for a grant. The California Public Utility Commission (CAPUC) directed investor-owned utilities in California to modify the then existing eligibility criteria for the Self-Generation Incentive Program. The program was extended from what was a cogeneration-based eligibility criterion to add non-cogeneration projects which were fired on at least 75% renewable fuel. SCS prepared an application for funding under the Self-Generation Incentive Program and submitted it to SCE within days of the CAPUC action. SCE's Program Administrator first learned of the change in criteria when he received the application from NCI.

Rapid application for the grant was paramount because grants are awarded under on a first-come, first-qualify basis with a limited pool of funds was available. NCI's application was the first filed under the program's new criteria and was the first project funded. The grant was in the amount of $450,000 and SCE directly paid the grant to NCI.

After full consideration of construction costs and ongoing operation/maintenance costs, the projected payback on the original investment is expected to be about 2 years.

Initial Operation

The power plant first produced electric power in late August 2002, approximately six months after NCI's execution of the turnkey contract with SCS.

By October 2002, most start-up and debugging activities were complete. During October 2002 through January 2003, the plant was online 86% of the available hours. In January 2002, the last full month of operation completed at the time this paper was prepared, the plant was online 95% of the available hours. Savings in avoided electrical costs have recently approached $30,000 per month.

As mentioned above, a dedicated transmission line was run from the power plant to the wellfield to improve the methane content of the landfill gas fired to the microturbines. Landfill gas quality is, nevertheless, somewhat variable. The microturbines have demonstrated the ability to operate at methane contents as low as 29 percent.

Selection of the inadvertent export interconnection option has proven to be a wise choice. The power demand at the site has significant swings. Figure 2 shows a five-day plot of power production (top line) and power demand (bottom line). The gap between the two represents "over production" or export. It can also be seen on Figure 2 that there is a diurnal variation in power plant output. The capacity of a combustion turbine is affected by ambient air temperature, because air temperature affects the density of the combustion air. Power output is greater when the ambient air is cooler. The electric power demand is higher at OII at night, since the air blowers associated with the LTP's batch treatment process are run at night, in a conscious decision to match maximum load with maximum power output.

Summary

Converting landfill gas to electricity seems only logical at OII given the large amount of landfill gas available and the Southern California need for energy. However, regulatory requirements regarding landfill gas DRE seemed to be a fatal flaw in any consideration for landfill gas to energy projects at OII. When energy prices began to escalate, seemingly out of sight, as a result of California’s energy crisis, a harder look was taken at the concept.

The design innovation brought to this project that made it feasible was the routing of the exhaust gas from microturbines to the thermal oxidizers burning the landfill gas at a DRE of 99.99%. The project’s initial cost analysis showed that it could reduce energy bills by approximately $30,000 per month. Both the feasibility of the design and the anticipated cost savings were recognized in the units after construction and operation.

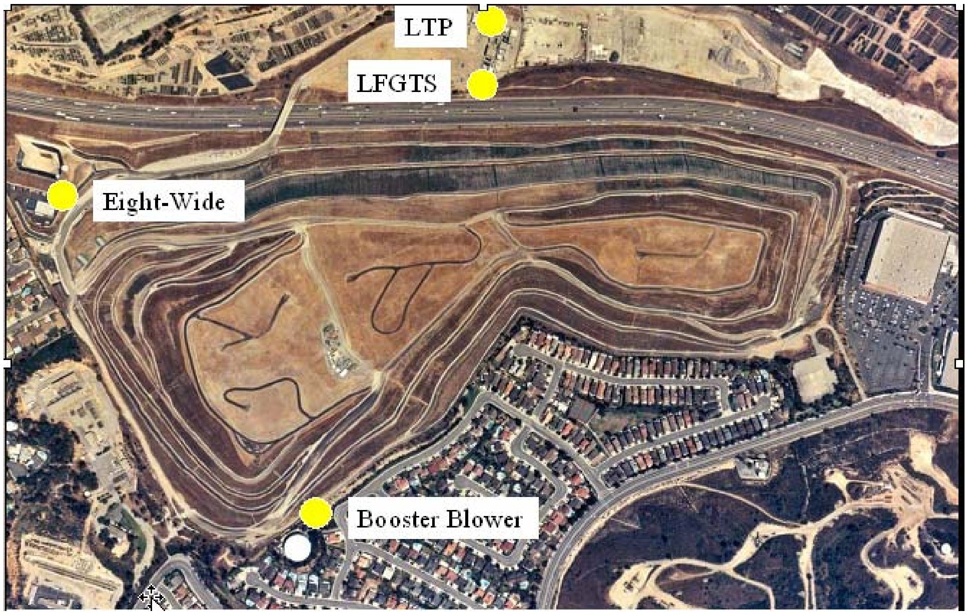

FIGURE 1 – OII SITE PLAN

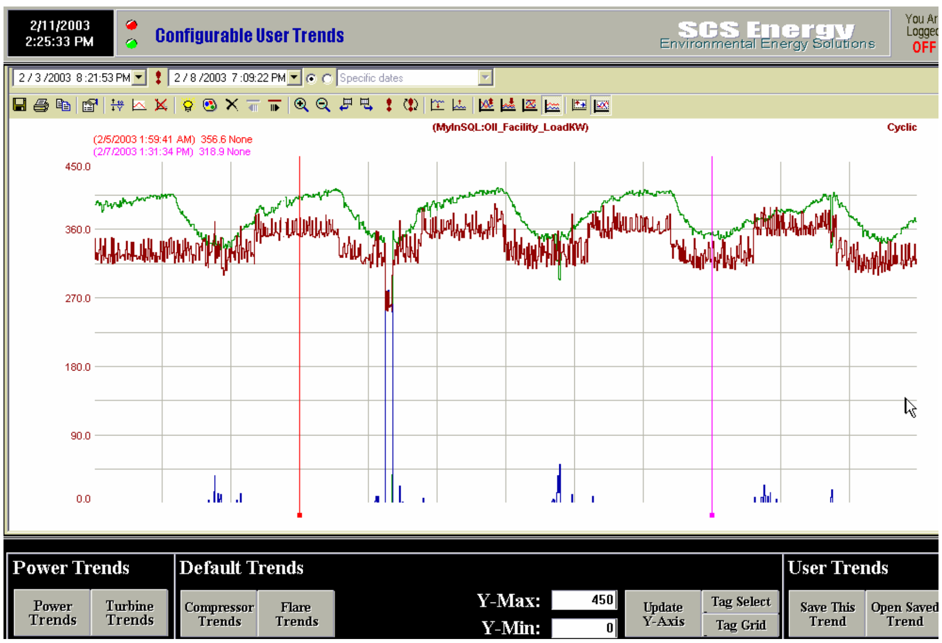

FIGURE 2 - PLOT OF MICROTURBINE OUTPUT VERSUS ACTUAL DEMAND

FIGURE 3 - OII MICROTURBINE POWER PLANT