Landfill Gas Utilization Project

RFP # 09-961-119

Union Mine Disposal Site

El Dorado County
Procurement and Contracts
330 Fair Lane
Placerville, California 95667

Project Proposal

Prepared by

STI Engineering, Inc.

Silverado, California

June 2009

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Union Mine Disposal Site

STI Engineering is pleased to submit this proposal to install a gas to energy project at the Union Mine Disposal Site located at 5700 Union Mine Road in El Dorado, California. STI has a patented process to enhance the generation of landfill gas (LFG) by injecting steam into the waste prism of landfills.

Introduction

It is understood that El Dorado County has issued a RFP for a landfill gas to energy project for the Union Mine Disposal Site. It is understood that the overall landfill site consists of 321 acres with 35 acres consisting of Class III refuse and is closed to the public. The site also contains 6 acres of Class II sludge cake.

The current intake of refuse is about 300 tons of sludge cake per day with and assumed 100 tons of organic material. According to the data provided it is assumed that approximately 350 scfm of landfill gas (LFG) is being extracted from the landfill at this time with 80 scfm going to 3 microturbines and the remaining 270 scfm with 34% methane is being flared on site

Basic Gas To Energy Project

Most gas to energy developers will submit bids estimating that this flow rate of LFG will produce about 525 Kw/hr. With 34% methane content the gas field will need substantial modifications to get the methane up to 50%+. Some developers may try to produce more power by installing extra gas collectors but this is a short term process and will shorten the life of the gas field.

It is assumed that are approximately 2,000,000 tons of refuse in the 2 cells of the landfill. If 50% of this waste is organic then there is about 1 million tons of organic material in place. With 350 scfm of LFG being generated this means 42 tons of organic material are being converted per day naturally. If this rate was consistent since 1969 then there may be 500,000 organic tons remaining in the landfill. At 42 tons being converted per day the gas field may last for another 30 years with enough moisture. With 100 tons of organic material coming into the landfill everyday this could extend the life of the gas field another 30 years unless the gas field is dried out from excessive gas extraction.

Although this appears to be a long time the revenues being generated will only amount to about $277,920.00 per year which does not compare to the cost of operating the landfill, which could run 3 to 5 million dollars per year plus post closure costs.

STI Approach

STI is proposing to install our patented Steam Injection process to enhance the LFG production in the two landfill cells. There are over 200 liquid injected bioreactor landfills in the U.S. These bioreactors have demonstrated that introducing moisture back into the waste prism increases LFG production.

Although it has been reported at SWANA Symposiums that only 5% of the water is retained in the refuse due to poor distribution, our steam process provides superior distribution.

In 2005-2006 STI performed a Pilot Study at the Miramar Landfill in San Diego, California (see SWANA paper attached). The study indicated that for every cubic foot of steam injected into the waste prism one cubic foot of LFG with 60%+ methane was created.

STI also has a patent pending process of Sequestering the CO_2 from the exhaust of the generators into the steam and then inject it to the landfill and convert it into additional methane. By recharging the waste prism with more carbon this allows twice as much methane gas to be produce without using up too much organic waste in the landfill thereby extending the life of the gas field.

Without using the CO_2 Sequester the steam injection process is sized to the amount of organic waste that is in place as well as how much organic waste is coming into the landfill everyday. This way we do not run out of organic material prematurely. Because this technology produces so much LFG the process has to be sized to the marketability of the products being produced. At larger landfills this process can produce more power than what the local grid can handle so other products such as CNG/LNG may have to be sold as well, which will increase revenues.

Basic Steam Injection Process

The Basic Steam Injection Process is based on the amount of refuse already in-place and the amount of refuse coming into the landfill each day. As stated above, there is an estimated 2.0 million tons of refuse in-place. Also there is about 100 organic tons of sludge cake coming into the landfill each day.

STI treats the number of acres that best match the parameters set above. Basically if we treat 3 acres or convert 267 organic tons per day it will take an estimated 15 years to stabilize the landfill. At this rate 6.3 Mw/hr. can be generated instead of just 525 Kw/hr. the natural way. This process will also be recovering valuable airspace and reducing post-closure costs since the environmental threat will be eliminated.

With pre-heating of the supply water (using waste heat recovery, solar, etc.) it will require less than 1% of the methane produced to fire the boiler for the steam.

According to the water board only potable water can be injected into the unlined portions of the landfill. Leachate and condensate can be injected into the lined portions of the landfill. STI usually converts 5,000 gallons of water into steam per acre per day. For 3 acres this means 15,000 gallons of water will be required for the cost of about $50.00 per day.

With 6.3 Mw/hr. being generated the annual revenue after expenses would be about $3,315,040.00 per year.

Advanced Steam Injection Process

Although the Basic Steam Injection Process is more productive than any other technology in the industry the one issue remains is that producing 6.3 Mw/hr of power produces a lot of exhaust that contains CO_2.

STI has a patent pending CO_2 Sequester that can sequester CO_2 from the generator exhaust into the steam stream. To prevent Nitrogen from being introduced to the gas field a membrane is used to separate the Nitrogen from the Oxygen in air prior to it entering the generator. Using this process the 6.3 Mw generators will produce about 5,000 scfm of CO_2. However there is not enough waste in the landfill to support this operation for more than 2 years. Another option is to use only 2,000 scfm of CO_2 and sequestering it into the steam. This is the same as adding another 180 tons of organic waste into the landfill everyday. (please see CO_2 conversion paper attached)

This means we can produce another 6.4 Mw/hr. and maintain the same 15 years of operation. This will produce another $3,300,000.00 per year.

For the methanogens in the waste prism to convert the CO_2 into methane they will require two times the water molecules to each CO_2 molecule.

To effectively inject this amount of enriched steam into the waste prism and allow the gas collectors to recover the LFG, 5 acres plots will have to be treated at a time. It requires about 1.2 years to treat each 5 acre plot and then another 5 acre plot is treated.

Future Expansion Approach

STI uses an instrument called the Piezo-Penetrometer Test (PPT) to profile landfills to determine their full gas potential. Until this process is performed at the Union Mine Disposal Site the actual life expectancy of the gas field is not known. (please see the SWANA paper attached.

Although the Steam Injection process can increase the amount of landfill gas produced the limiting factor is that eventually we will run out of organic waste in the landfill or airspace and the landfill will close.

As stated above the gas field may last for 30 years with mediocre revenues or 15 years with maximum revenues being generated. If 12 Mw/hr of generators are installed at the site it would not be practical to shut them down and remove them when the gas field dies. It would be more practical to install a 500 ton Steam Injection Biomass Reactor to receive the sludge cake from the water treatment plant as well other organic waste. The 500 tons converted to biogas will be enough to operate the 12Mw/hr. generators and will cost less to operate than the landfill.

If both operations are conducted at the same time then the revenues could be doubled. When the landfill gas field dies another 500 ton reactor would be installed to continue the gas generation.

Unlike wet bioreactors the steam process can convert green waste into biogas, which is an abundant source of organic waste. Another advantage of steam is that if H_2S is generated Ferric Chloride can be added to the steam and it will precipitate the H_2S out of the biogas before it leaves the reactor. This saves a lot of cost of filtering H_2S out of the biogas later.

Approach Summary

The following table displays the various approaches outlined above. The data below are based on the generators operating for 365 days per year although it is known that they will be down for maintenance for some unknown period of time. We prefer to use a known number instead of an unknown number.

Table 1
Approach Revenue Summary

Approach	Amount CH4	Revenue	Cost/Millions	Net Rev.
	Per Day	Per Day	Per Year	Per Year
525 Kw Gen.- $.08/kwhr	132,192cf	1,008.00	.02/kwhr=.09	$ 277,920
6.3 Mw Gen.- $.08/kwhr	1,602,000cf	12,096.00	.02/kwhr= 1.1	3,315,040
12 Mw Gen. - $.08/kwhr	3,204,000cf	23,040.00	.02/kwhr= 2.2	6,209,600
24 Mw, Gen. - $.08/kwhr	6,408,000cf	46,080.00	.02/kwhr= 4.4	12,419,200

not really an option
no return on invest
Trash
Trash + Co2
Trash + biofuel

Alternative Fuels

Although enough biogas could be produced to generate 24 Mw/hr the local grid wires may not be able to handle that much power or possibly the price for the power may not be enough to meet financial goals.

Table 2 is based on producing 13,824,000 cubic feet of methane and 9,216,000 cubic feet of CO_2 with 80% efficiency of the scrubber per day. If 3,204,000 cu.ft. of methane is used for 12 Mwhrs of power then 10,620,000 cu.ft. of methane can be sold as other products.

According to the PG&E Web site the next call for power bids will be in September 2009. Historically many power purchase agreements in California have been set at $.08 per kw/hr.

The other prices for products below are standard rates in the industry and are used here as examples for comparisons. The actual prices will be negotiated once a contract is awarded and the products selected.

Table 2
Estimated Net Revenue

Product	Amount Gas	Revenue	Cost/Millions	Net Rev.
	Per Day	Per Day	Per Year	Per Year
12 Mw Gen.- $.08/kwhr	3,204,000 cf Ch4	23,040.00	.02/kwhr=2.1	$6,307,200
CNG to Pipeline $5/mmBtu	10,620 mmBtu	53,100.00	1.50/mmbtu=5.8	13,567,050
CNG - $2.00/geg Retail	87,769 geg*	175,537.00	1.50/mmbtu=5.8	58,256,624
Liquefied CO2 - $40/Ton	569 Tons	22,756.00	5.00/ton = 1.0	7,267,515
Dry Ice - .50/Lb.	1,138,000 Lbs.	2,276,000.00	.05/lb = 20.7	809,971,500

* Gasoline Equivalent Gallon

The capital cost to produce the amount of dry ice presented above would be very high. Also developing the market for this much of the product would be challenging. It would be more practical to liquefy some of the CO_2 and make as much dry ice as the market will bear.

Cost Estimates For Various Approaches

The following table is a breakdown of the estimated cost for the **First Approach.** Due to the limited amount of information on the site, these cost estimates are rough and should be mainly used as a comparison.

Table 3

Task/Item	Cost
Overall Engineering & Permitting	$ 500,000.00
PPT Profiling, Gas Collection Installation	700,000.00
525Kwhr Generator & Interconnect	1,000,000.00
Total	**$2,200,000.00**

The following table is a breakdown of the estimated cost for the **Basic Steam Approach.**

Table 4

Task/Item	Cost
Overall Engineering & Permitting APCD UGA	$ 600,000.00
PPT Profiling, Steam Injection System, Gas Collect. Installation	1,000,000.00
6.3 Mw Generator & Interconnect	7,000,000.00
Total	**$8,600,000.00**

← 3-4 yr pay back ∴ phase

The following table is a breakdown of the estimated cost for the **Advanced Steam Approach.**

Table 5

Task/Item	Cost
Overall Engineering & Permitting	$ 600,000.00
PPT Profiling, Steam Injection System, Gas Collect. Installation	1,000,000.00
12 Mw Generator & Interconnect	13,000,000.00
Air Intake Membrane & Compressor	5,000,000.00
CO2 Sequester	500,000.00
Total	**$20,100,000.00**

The following table is a breakdown of the estimated cost for the **Advanced Steam Approach with Steam Injected Biomass Reactor.**

Table 6

Task/Item	Cost
Overall Engineering & Permitting	$1,600,000.00
PPT Profiling, Steam Injection System, Gas Collect. Installation	1,000,000.00
24 Mw Generator & Interconnect	25,000,000.00
Air Intake Membrane & Compressor	5,000,000.00
CO2 Sequester	500,000.00
Biomass Reactor	1,200,000.00
Grinder & Screen	700,000.00
Total	**$35,000,000.00**

STI uses state-of-art technology such as the PPT to develop gas recovery systems and to keep landfills in compliance with current regulations. Once a PPT Profile is performed at the landfill, a more intelligent decision as to which approach would best serve the County.

The STI approach can provide the landfill gas required to operate the 3 micro-turbines on site however once the large power plants are operational these may become obsolete.

Financial Considerations

STI has several funding sources to capitalize this gas to energy project once an approach is selected.

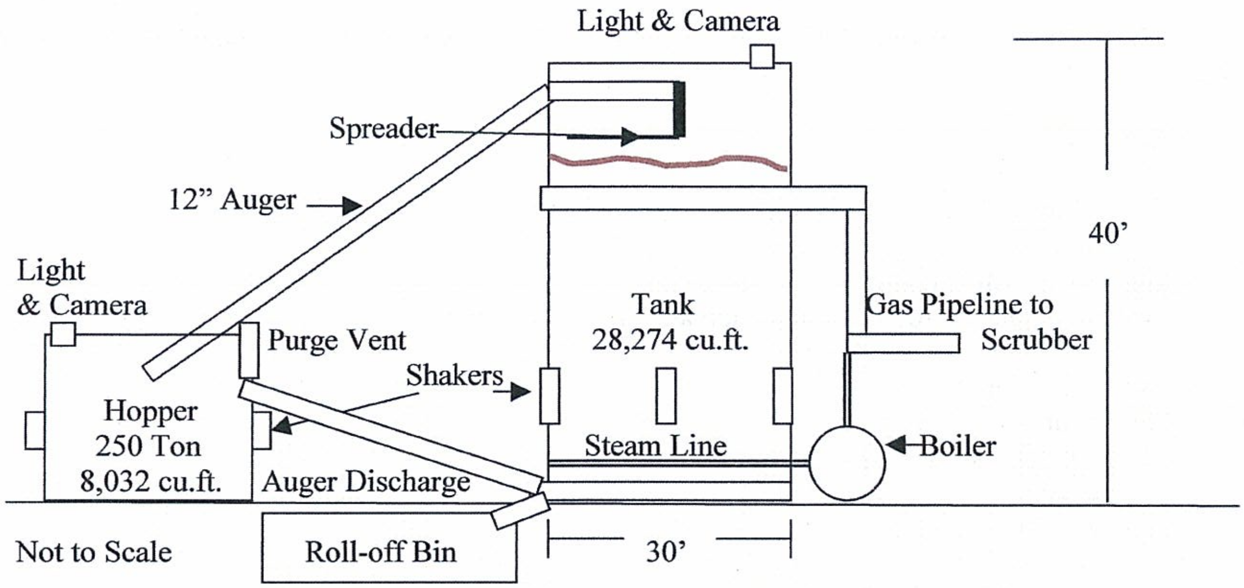
Depending on the approach selected and the financial requirements we are confident that the County will be pleased with the amount of royalty offered. Our approach produces so much more gas that even if we use the lowest percentage offered by our competitors the County will still make higher revenues with us. Some funding sources require a faster payback of funds than others, therefore the royalties may be lower in the beginning and then once the capitalization is recovered then the royalties can be increased.

There are only a few landfills in the country that produce enough LFG naturally that make gas to energy projects feasible. The steam injection process makes average to small landfill projects feasible and profitable.

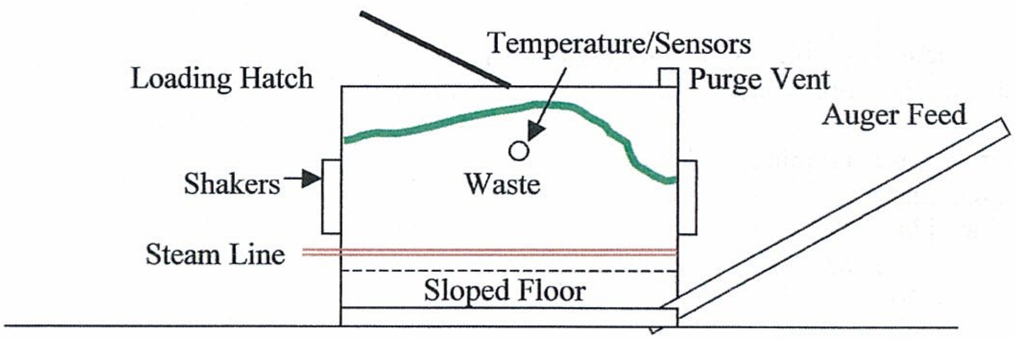
If there are any questions regarding this proposal please call at your earliest convenience.

Respectfully Submitted,

Reg Renaud
President



800 Ton Steam Biomass Reactor
Figure 1



Reactor Hopper
Figure 2

Insurance

STI maintains general liability and O&E insurance in the amount of $2,000,000.00 in good standing.

References

The following is a list of a few of the landfills STI has worked with in the past.

McCommas Bluff Landfill – Dallas, Texas
Evaluating landfill for steam injection and H_2S treatment.

Cambrian Energy
Mr. Tudor Williams
624 South Grand Ste.2420
Los Angeles, CA 90017
213-628-8312

Miramar Landfill – San Diego, California
Perform Steam Injection Pilot Study

City of San Diego
Mr. Chris Gonaver
9601 Ridgehaven CT. Ste. 310
San Diego, CA 92123
858-573-1212

Tierra Rejada Landfill, - Simi Valley, California
Install gas collection system.

Ventura Regional Sanitation District
Mr. Greg Grant
1001 Partridge Dr. Ste. 150
Ventura, CA 93003
805-658-4639

ENERGY BUGS Researchers are perfecting ways to turn algae—like the sargassum seaweed seen here—into biodiesel and to use *methylococcus* microbes (inset) to turn carbon dioxide into methane, the main ingredient in natural gas.

BIOFUELS

THE BIG PICTURE Ethanol is the most widely used biofuel today, but it's hardly a panacea to our energy woes. Researchers are scrambling to transform more-efficient organic materials—switchgrass, sugarcane, algae, sewage and even medical waste—into low-emission fuel for both transportation and electricity generation.

WHERE WE ARE: **643,000 BARRELS PER DAY**

WHAT WE NEED BY 2050: **34 MILLION PER DAY**

TECH TO WATCH: ALGAE

The canals of Venice, Italy, may soon provide a green power source for the city's seaport and prove that algae-derived energy can meet commercial electricity demand.

A $272.6-million plant is awaiting authorization to generate electricity by burning biodiesel fuel made from canal algae. To get the fuel for the plant, algae harvested from the canal will be cultivated in 26-foot plastic bioreactors (and fertilized with carbon dioxide from the plant itself), dried, expeller-pressed to squeeze oil-like lipids from the dried biomass, and turned into biodiesel through the addition of lye. By 2011, the plant could generate 40 megawatts, which would be used to power the city's seaport and channel the excess electricity—33 megawatts—to docked tankers and cruise ships, all with zero net carbon emissions.

The Venice project won't be cost-effective; it's designed as a technology demonstrator and to give the city a jump on expected stricter cap-and-trade legislation. In the meantime, however, other innovations promise to finally make algal power affordable. While centrifuges account for 34 percent of the total investment costs, there is now a cheaper way to separate the algae from the water they grow in. In March, AlgaeVenture Systems in Ohio announced a new method to "dewater" algae using capillary action: A superabsorbent polymer pulls water molecules through a membrane and leaves the algae dry. The company claims that the process reduces biofuel production costs from $875 per ton to just $1.92. Advances in algal oil extraction and the conversion to biodiesel should bring expenses down even further.

Although there are currently no plans for a commercial plant in the U.S., companies like BioProcess Algae are hoping to change that. BioProcess recently received a grant to build a pilot plant in Shenandoah, Iowa. If successful, prototype plants like this one could eventually help make domestic algae power more than a curiosity.

—AMBER SASSE

FROM TOP: NANCY SEFTON/PHOTO RESEARCHERS; DR. DENNIS KUNKEL/GETTY IMAGES

THE PERFECT BIOFUEL?

THE TECHNOLOGY is still experimental, but late last year researchers at Penn State University discovered how to make methane—a main ingredient in natural gas—from the very thing driving climate change: carbon dioxide. The key is microorganisms called methanogens. Engineer Bruce Logan discovered that the organisms produced methane with nothing but water and carbon dioxide when zapped with an electric current. Build a fuel cell around the microbes, and as long as the electricity that feeds into the device comes from a renewable source like wind or solar, the process can provide a carbon-neutral source of combustible fuel.—CATHERINE PRICE

09-1309.C.11

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28281 Silverado Canyon Road
Silverado, CA 92676-0792
714-649-4422 Fax 714-649-4423
www.landfillengineering.com

STI

August 4, 2009

Mr. Dave Johnston
EDC Environmental Management
County of El Dorado
330 Fair Lane
Placerville, CA 95667

RE: County of El Dorado
Royalty Proposal

Dear Mr. Johnston

STI is pleased to submit the following Royalty Proposal to the County of El Dorado for Landfill Gas Utilization Project in Placerville, California.

As outline in our proposal we intent to develop the LFG Utilization project in a phased approach to minimize capital investment and to create cash flow as soon as possible.

In conversations with SMUD they have stated their interest in purchasing the power that would be generated at the site. (Please see attached letter) However the interconnect will still have to be through PG&E and they will charge a wheeling charge for transporting the power from the landfill to the high power lines. A request for the interconnect charge and the wheeling charge has to be submitted to PG&E and there may be a deposit required.

According to SMUD a term sheet has to be submitted to them with the price per kilowatt/hour that is required by the project to be profitable. The SMUD personnel would not quote the going rate for power but I did get him to suggest that $.08 per kw/hr is in the ballpark. However, with the Renewable Energy Credits included we may get $.10 per kw/hr average.

With these requirements and costs from PG&E and SMUD, STI is going to require some form of commitment from the County to use our technology and approach to this project. We would also require authority from the County to submit a term sheet to possible purchasers of the power.

It is understood that the County wastewater treatment plant requires about 133 kw/hr of power. STI will supply the necessary power to operate this plant saving the County about $175,000.00 per year

The following chart will provide an estimate of the potential revenues that may be generated if the purchase price of the power is $.10 per kw/hr. At this time we do not know what the wheeling charge will be from PG&E although we will be offering them the opportunity to purchase the power as well, but they will not accept a purchase offer until September. This could offset the wheeling charge.

The following table presents the 10% royalty being offered by STI for the various power-generating levels. If the landfill is re-opened this will allow the full potential of the generating capabilities of our technology such as the CO2 Sequester and the Biomass Reactor Tank.

Product	**Amount Gas Per Day**	**Cost/Millions Per Year**	**Net Rev. Per Year**	**To County Per Year**
6 Mw/hr Gen.- $.10/kwhr	1,602,000cf Ch4	.03/kwhr=1.6	3,656,000	$365,600
12 Mw/hr Gen.- $.10/kwhr	3,204,000cf Ch4	.03/kwhr=3.2	7,312,000	731,200
24 Mw/hr Gen.- $.10/kwhr	6,408,000cf Ch4	.03/kwhr=6.4	14,624,000	1,462,400

It is estimated that it may cost the County about $800,000.00 a year to operate the closed landfill. If STI takes over the development and operation of the gas field, the cost to the County should reduce to about $400,000.00 per year. With the power being provided to the treatment plant saving this cost and the above royalties to the County this should cover most of the remaining landfill costs. If the landfill is re-opened then extra revenue for the County should be made from the power project as well as tipping fees and the savings to disposal fleets from not shipping the refuse out of the County.

STI hopes the County finds the above proposed royalty percentage to be acceptable. The sooner an agreement can be reached the sooner we can obtain more definitive information on the power purchase and start the permitting process. Also STI can begin obtaining the necessary funding to begin the project.

Respectfully Submitted,

Reg Renaud
President

greenersolutions ENVIRONMENTAL

Awareness. Advocacy. Action.

Mr. Reg Renaud
President
STI Engineering
P.O. Box 792
Silverado, CA 92676-0792

July 13, 2009

Letter Of Intent

Dear Mr. Renaud,

Greener Solutions is very interested in raising capital for the Landfill Gas Utilization project at the Union Mine Disposal Site in El Dorado County, California. Upon review of the project proposal we feel the project goals meet our investor's requirements.

Once the approach and the project management structure has been finalized we are prepared to move forward to determine the level of capital invest required. We are prepared to fund in the range of $35,000,000 to $40,000,000 for materials and working capital.

This Letter of Intent represents a non-binding agreement to acquire the necessary funding for this project. Greener Solutions does not, nor does this LOI guarantee or present any liability to either party for project funding. Funding will be available once all requirements of the investors are met.

Respectfully Submitted,

Steve Herzog
President
Greener Solutions

By

Accepted By:

Reg Renaud
President
STI Engineering

U.S. SCIENCE & TECHNOLOGY

Mr. Reg Renaud
President, STI Engineering, Inc. (STI)
28281 Silverado Canyon Rd.
Silverado, CA 92676-0792

July 9, 2009

LETTER OF INTENT

Dear Mr. Renaud,

We at USST are writing today to express our interest to provide financial support through our investment partners for the El Dorado County Landfill Gas to Energy project for the Union Mine Disposal Site. We have reviewed the high-level project specifics and agree that the proposed project meets our investor's interests. Assuming you are able to procure the necessary contracts and agreements within our funding requirements, we are ready to move forward to the due diligence stage for this specific transaction.

We understand the project details as follows:

- It is understood that El Dorado County has issued a RFP for a landfill gas to energy project for the Union Mine Disposal Site.
- The overall landfill site consists of 321 acres with 35 acres consisting of Class III refuse and is closed to the public. The site also contains 6 acres of Class II sludge cake.
- The current intake of refuse is approximately 300 tons of sludge cake per day with an assumed 100 tons of organic material. According to the data provided it is assumed that approximately 350 scfm of landfill gas (LFG) is being extracted from the landfill at this time with 80 scfm going to 3 microturbines and the remaining 270 scfm with 34% methane is being flared on site.
- Funding requested for equipment and working capital is $40,000,000.
- We will provide up to 100% project funding with an option for a two-year interest-only option for pay-back during project construction and deployment

Once you have secured the necessary feed stock agreements and off-take purchase agreements; inclusive of our investment criteria we will issue a term sheet for the specific transaction, through our funding partners. Upon your execution of the term sheet we will proceed to the next steps of the funding process.

4366 Auburn Blvd, Sacramento, CA 95841
Bus (916) 978-9900 • Fax (916) 978-9904

This LOI represents a non-binding agreement to pursue project funding on behalf of the parties on a "best efforts" basis. USST does not, nor does this LOI guarantee or present any liability to either party for project funding. Funding will be available subject to definitive "due diligence" of the transaction and the qualifications and abilities of the parties and further subject to financial market conditions at the time of execution of a project contract. Further, this transaction is fully subject to the presentation of necessary feed-stock and off-take agreements with credit worthy third parties prior to any transaction execution.

Respectfully,

William Ludwig
President/CEO
USST
Tel: 916-978-9900

Accepted By:

Reg Renaud
President/CEO
STI
Tel: (714) 649-4422

Executive Summary

Union Mine Disposal Site

STI Engineering is pleased to submit this proposal to install a gas to energy project at the Union Mine Disposal Site located at 5700 Union Mine Road in El Dorado, California. STI has a patented process to enhance the generation of landfill gas (LFG) by injecting steam into the waste prism of landfills.

Introduction

It is understood that El Dorado County has issued a RFP for a landfill gas to energy project for the Union Mine Disposal Site. It is understood that the overall landfill site consists of 321 with 35 acres consisting of Class III refuse and is closed to the public. The site also contains 6 acres of Class II sludge cake.

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STI Approaches

STI uses several approaches to Gas to Energy and Waste to Energy projects.

- **Basic Gas to Energy Project** – Accept the natural production of landfill gas and design a power package that best utilizes these resources.
- **Basic Steam Injection Project** – Use Steam Injection to enhance the gas production of the gas field and produce many times of power.
- **Advanced Steam Injection Project** – By Sequestering the CO_2 from generators or from the landfill gas into the steam stream and injecting it back into the landfill the methanogens will convert it back into methane hence extending the life of the gas field and producing much more methane.
- **Steam Injected Biomass Reactor** – An alternative to disposing organic waste into a landfill the waste is conveyed into a reactor tank and apply steam as in a landfill and convert organic waste into biogas at a fraction of the cost of operating a landfill.
- **Alternative Bio-fuels** - The steam processes can produce more gas than what can be used on the local grid. This extra fuel and CO_2 can be converted to CNG/LNG, Pipeline Gas, Ammonium Nitrate as will as carbon dioxide and dry ice.

This project can have an annual revenue of $277,920.00 to $12,419,200.00 with power only or more than $64,000,000.00 with power and alternative fuels.

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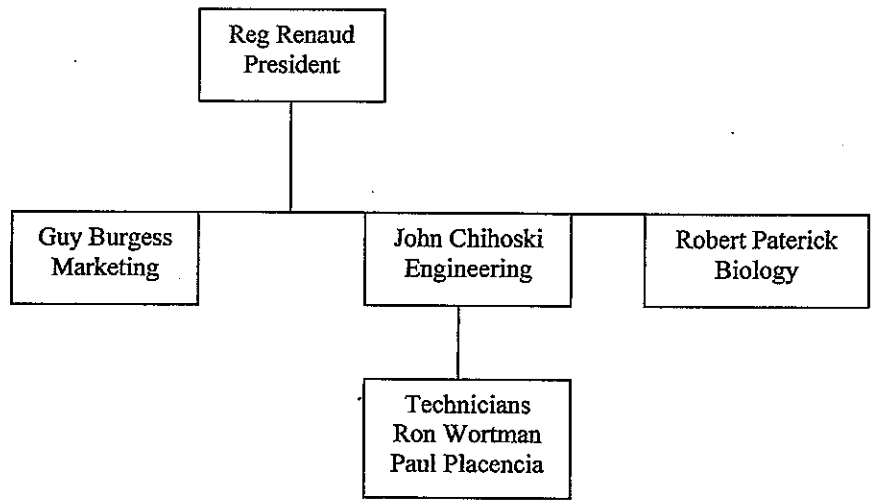
Project Management Flow Diagram



Resume of Reg Renaud

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e-mail regsti@msn.com

Statement

This resume will outline the employment evolution of Reg Renaud. He began his career in the geotechnical offshore drilling industry, then transitioned into the onshore geotechnical industry. Following ten years of field experience in site investigation and development of geotechnical test equipment, Reg entered the environmental industry. Here the skills developed in the geotechnical field became instrumental in his success in the following eleven years in the environmental field.

Employment History

October, 1996 - Smartworm Technology, Inc. (STI), aka STI Engineering President and owner. Developed landfill gas and liquid profiling system, using piezo-penetrometer test (PPT). Developed Steam Injection method for Landfill Bioreactors and Co-Gen. operations. Has developed a Steam Biomass Reactor for organic waste as well as a CO2 Sequester for recycling CO2 & CO back into landfills. He has recently developed a process to treat H_2S in landfills and biomass reactors. He has been awarded several US patents and has other patents pending. Web site: www.landfillengineering.com

1991 - 1996 - TRC Environmental Solutions, Inc., Manager of Innovative Technology. Evaluated and developed techniques for remediation of soil, water and air. Participated in the implementation of remedial work plans at several superfund sites and landfills. Developed landfill-mapping techniques for trash and gas extraction systems using the PPT system. Developed mobile air monitoring system for Health & Safety monitoring during site operations at a superfund site.

1990 - 1991 - Tank Protect Engineering, Inc., General Manager. Managed day to day operations of site Remediation Company. Obtained the first permit from the City of L.A. for operating a thermal oxidizer at a soil remediation site. Conducted Phase I, II, III investigations and remediations on various sites in southern California.

1988 - 1990 - Schaefer Dixon Associates, Inc., Senior Field Technician. Transitioned from geotechnical to environmental investigation and remediation. Managed the remediation of a 35-acre site in Los Angeles. Installed groundwater monitoring wells and pulled underground storage tanks at several gas stations in southern California.

1978 - 1988 - The Earth Technology Corporation, Inc., Offshore Technician and CPT Operator. Introduced the electronic cone penetrometer test to the American market. Involved in modifying the cone penetrometer for North American soils. Demonstrated and taught the principals and operation of the cone penetrometer at several universities around the U.S. Participated in several full-scale pile load tests for offshore platform design. Was trained for drilling and sampling techniques, mass and precision grading, compaction testing, geophysical testing, QA/QC testing. Installed instrumentation to monitor movement parameters of an oil production gravel island offshore of the North Slope of Alaska. Field supervisor for MX Missile project.

Recent Completed Projects

Two parking lots for Disneyland
Completed 6 million cubic yard mass grading, PA-11 in Mission Viejo, for Shea Homes
Completed precise grading, PA-12 in Mission Viejo, for Shea Homes
Storage tank, removal and backfill for S.C. Edison
CPT project for L.A. School District
West Basin Pipeline, Backfill QA/QC, Excavation of contaminated soil
Palos Verdes Landfill, PPT Landfill Gas 3-D Profile and install 10 push-in collectors
Santiago Landfill, PPT Landfill Gas Profile and install 8 push-in LFG collectors
Horsethief Booster Water Station, Grading and Concrete inspection
Olinda Alpha Landfill, PPT Landfill Gas 3-D Profile
EPA Buffer Zone, Neighborhood Park, Fill Control and Grading Inspection
Southbay 6 Drive-in Landfill, Carson, Ca. PPT and installation of LFG collectors
Tajiguas Landfill, Santa Barbara, Ca. 3-D Profile from PPT investigation
Calabasas Landfill, Calabasas, Ca. PPT and installation of 15 push-in LFG collectors
Tierra Rejata Landfill, Ventura, Ca. PPT & installed 31 push-in LFG collectors
Miramar Landfill, San Diego, Ca. PPT & installed collectors and steam injectors and operated Steam Injected Bioreactor Pilot Study
Cal Compact Landfill, Carson, Ca. PPT investigation
Hay Road Landfill, Vacaville, Ca. PPT & installed 10 LFG vents
Cal Compact Landfill, Carson, Ca. PPT Profile of 168 acre landfill.
McCommas Bluff Landfill, Dallas, Tx. Installed 6 Push-in gas collectors, evaluates landfill for steam injection and H_2S treatment.

Education, Certifications and Licenses

Schoolcraft College, One year Business Management Courses
University of Houston- Principles of Purchasing Course
Phillip Morris Co.- 3 Years Management Training
Instructed In-situ technology at Univ. of Houston, Louisiana State Univ., Long Beach State, Univ. of Washington, Seattle.
Paul Munroe Hydraulic Certification
CPN Nuclear Testing Certification
40 Hour Hazmat Training and 8 Hour Supervisor Hazmat Training
General Contractor - Class B California
Former President of Inventors Forum

Published:
Sixteenth International Conference on Solid Waste Technology
"Innovative Approach to Landfill Gas Profiling & Extraction"
Steam Injection Landfill Bioreactors- GFR Magazine January 2001
Report on Multi-Chamber Short Comings – Waste News- June 2001
PPT Profiling & Steam Injection – SWANA- Los Vegas, NV.
Steam Injection Bioreactors & Multi-Chamber Short Comings- World Congress, San Diego
An Innovative Approach To Landfill Engineering: (Trafford Publishing 2008) Author of a technical book based on 30 years in the engineering and landfill industry.
Presented at SWANA and LEA conferences.

JONATHAN T. CHIHOSKI

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• Cell (401) 499-6759 • JChihoski@gmail.com

EDUCATION

Georgia Institute of Technology
Bachelor of Science in Mechanical Engineering — December 2005
E.I.T. Certification — October 2005

WORK EXPERIENCE

Delta Airlines - Atlanta, GA — May 2005-current
Ramp Agent
• Responsible for taxiing aircraft in and out of the concourse area.
• Loaded bags and cargo.
• Assisted customers onto the aircraft and helped to resolve any complaints in a timely manner.
• Kept the concourse safe by following strict safety guidelines.

Barrett, Woodyard, and Associates - Norcross, GA — May 2005-Aug 2005
Engineering Intern
• Responsible for creating CAD drawings in accordance with building codes.
• Did on-site inspections and evaluations of customers' facilities.
• Used various computer programs in order to run loads on buildings in order to determine needs.
• Conducted research and called inspectors to determine any changes in building codes.

Parker Hannifin Corp. - Lynchburg, VA — May 2004-Aug 2004
Engineering Intern
• Responsible for editing CAD drawings to customer's requirements.
• Built and improved various testing equipment for an engine test lab.
• Conducted numerous lab tests in order to evaluate current gaskets and prototypes.
• Analyzed data and made presentations to supervisors.

Rhode Island Department of Transportation - Warwick, RI — May 2003-Aug 2003
Engineering Intern
• Responsible for generating and editing CAD drawings in accordance with state projects
• Assisted in on-site inspections of contractors' progress to ensure compliance with contract documents

Cotton Jubilee Catering - Atlanta, GA — Aug 2002-Dec 2002
Customer Service Representative
• Investigated and satisfied customer complaints
• Prepared the press box suites prior to home football games

RELATED SKILLS

• Proficient in C++ • MATLAB • QBasic • PBasic • AutoCAD • Solid Edge • Microsoft Office • Plumbing
• Carpentry • Minor Electrical repair • Automotive repair • Marine repair • Certified Scuba diver

RELEVANT COURSES

• Internal Combustion Engines • Machine Design • Engineering Graphics • Fluid Mechanics

EXTRACURRICULAR ACTIVITIES

• Georgia Tech Varsity Track and Field Team, Letter winner • Triathlete • Volunteer Track & Field Coach

Guy Burgess

Experience

2008 – Present

-STI Engineering, Silverado, CA – Responsible for identifying potential landfill and biogas to renewable energy opportunities for STI's patented steam injection process. Successfully introduced their technology and facilitated a pilot test project to an interested local refuse company – Rainbow Disposal.

-Enviro-Energies, Ontario, Canada – Responsible for promoting Enviro-Energies' Mag-Wind system to various businesses and home owners. Their innovative patented magnetic vertical axis wind turbine is roof mounted and spins around much like a merry-go-round rather than a windmill.

-FirmGreen Inc., Newport Beach, CA – Responsible for promoting FirmGreens' proprietary and R&D 100 Award winning CO2 Wash clean-up technology to potential landfill and biogas to renewable energy opportunities world wide. Renewable energy products produced include: pipeline quality gas, hydrogen, methanol and liquid CO2.

2007- 2008 Applied LNG Technologies Dallas, TX
Sales Manager Western Region

- Responsible for building and maintaining the company's largest sales territory – the Western United States.
- Products include: vehicle grade LNG and LCNG fuel and delivery systems. These systems include: turnkey fuel solutions, equipment leasing, station installations, safety and training, natural gas production, low BTU gas processing, temporary fueling stations, and consulting in the LNG and LCNG markets.
- Scope of the market focuses on large size refuse, mass transit and trucking fleets.
- Consistently exceeds the sale quotas.

2006-2007 Self Employed (Various Consulting Projects)

-Mack Trucks, Allentown, PA – Responsible for identifying potential landfill to renewable energy opportunities in the state of CA for the Mack/Acrion Technology. Successfully introduced the Mack/Acrion Technology to an interested local refuse company – CR&R.

-Chart Industries, New Prague, MN – Responsible for the continued gathering and interpretation of market intelligence in the Alternative Fuels Industry.

-Weaver Inc., Anaheim, CA – Responsible for assisting in all aspects of a major RFP project in CA for a large LNG/LCNG station – the City of San Bernardino.

1998–2006 **Chart Industries, Inc.** **New Prague, MN**

Business Development Manager

- Responsible for building and maintaining the company's largest sales territory through new market development and sales management of liquefied natural gas (LNG) applications and other related niche markets for the Western United States.
- Products include: LNG and LCNG (compressed) fueling stations, vehicle tanks, hydrogen fueling stations, hybrids, gensets, liquefiers and purifiers.
- Scope of the market includes: mass transit, trucking, refuse, marine, airport and other industries; both public and private, foreign and domestic.
- Proven leader at introducing new ideas and technology to the market.

1993–1998 **Arrow Truck Sales, Inc.** **Atlanta, GA**

National Accounts Manager

- Top performer, consistently sold over 100 tractor-trailer trucks per year.
- Responsible for selling medium to heavy duty trucks for all applications.
- Customers ranged from single truck owners to large national fleets.
- Specific duties on a national basis included: extensive prospecting, developing and maintaining a strong customer base.

1986–1993 **Burgess Enterprises, Inc.** **Melbourne, FL**

President

- Invented new automotive after market product, designed prototype, obtained U.S. Patent, raised venture capital, brought in manufacturer and ultimately sold the product line to the manufacturer.
- Specific duties included: market analysis, price determination, test marketing and overall business plan.
- Product is still on the market with sales in excess of $10 million.

Education

1982–1986 **University of Florida** **Gainesville, FL**

- Bachelor of Science in Advertising / Minor in Business Administration

James Robert Paterek, Ph.D.

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BIOENERGY SCIENCE AND ENGINEERING℠

Principal Consultant and Technology Director

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bioenergy@att.net

More than $50,000,000 of earnings has resulted directly from Dr. J. Robert (Bob) Paterek's responsibilities, activities, and experience in his career of 25+ years. Renewable, sustainable energy and "green" projects have included:

- Anaerobic biogas (methane) production from agricultural biosolids, agri-business wastes, and energy crops
- Biogenic hydrogen production from biosolids, wastes, and energy crops
- Bioreactor and Digester design
- Landfill bioreactors design & operation
- Greenhouse Gases abatement
- Carbon footprint reduction
- Water & wastewater treatment with energy and water re-cycle
- Oil and natural gas exploration & recovery
- Corrosion detection & control
- Other "green" technologies

Dr. Paterek is the Principal Consultant / Advisor and Technology Director for *Bioenergy Science & Engineering*℠. His renewable energy, biofuels, and "green" technologies' responsibilities include:

- Design, & implementation of anaerobic digestion
- Biomass audit and assessment
- Feasibility and assessment studies
- Energy analyses and audits
- Planning biosolids, solar, wind, ethanol/methanol, and other combined facilities
- Proposal generation for grants and loans
- Presentation and Report generation
- Site assessment for agricultural and urban waste disposal and energy resources
- Technology assessment for business development and venture capital investment

Prior to his present position, Dr. Paterek served as Technology Director for *Bison Renewable Energy, LLC*. His responsibilities included technical responsibility for the design, construction, and operational planning for a multimillion dollar regional anaerobic digester facility, i.e. Cornerstone Biogas Regional Anaerobic Digester (BRAD) in northwestern Iowa. This digester was designed to convert animal manures, rendering byproducts, food processing and other agri-business wastes to methane to be injected into a high-pressure natural gas pipeline.

Dr. Paterek was a Senior Environmental Microbiologist with the *Gas Technology Institute* in Chicago. He was responsible for and managed projects valued at >$15M in his 12-year tenure. Funding for these projects came from the U.S. EPA, U.S. DOE, U.S. Department of Defense, Gas Research Institute, Southern California Gas Company, and other natural gas distribution and transmission utilities funding singly or in consortia. Other senior positions included as a Senior Scientist with the *Salk Institute Biotechnology Associates* in La Jolla, CA, and Vice President for Technology with *Oxford Environmental Corporation*, an US EPA certified laboratory in New Orleans.

Career History

Organization	Position	Dates
Bioenergy Science & Engineering Naperville, IL	Principal Advisor & Technology Director	Oct 2008 through present
Bison Renewable Energy, LLC Minneapolis, MN	Technology Director	Mar. 2006 through Sept 2008
Bioenergy Science and Technology Naperville, IL	President & Technology Director	Sept 2004 through Feb 2006
Gas Technology Institute Chicago, IL	Senior Environmental Microbiologist	Mar 1992 to Oct 2004
Salk Institute Biotechnology Associates San Diego, CA	Senior Environmental Scientist	1988 through Feb. 1992
Oxford Environmental Corporation New Orleans, LA	Vice President	1984 through 1988

Professional Preparation

Institution	Major Study Areas	Degree / Year Awarded
Clemson University Clemson, S.C.	Microbiology	B.S. / 1974
Clemson University Clemson, S.C.	Microbiology	M.S. / 1977
University of Florida Gainesville, FL	Microbiology & Cell Science	Ph.D. / 1983
Marine Biological Laboratory Woods Hole, MA	Microbial Ecology	Education & Research Certificate / 1980

Representative Publications, Patents, and Presentations

Dr. Paterek has generated more than 100 publications, presentations, and reports. He holds 4 US patents, with 2 in renewable biofuels production technologies. A brief list of representative documents is listed below. Additional information and copies of the papers or presentations are available upon request.

Title	Location	Type	Year
Ecological Engineering of Methanogenic Anaerobic Digesters and its Application to Naturally-occurring Shallow Biogenic Gas Sources	American Association of Petroleum Geologists' Annual Convention and Exposition, Denver	Co-Chair and Presenter	June 2009
Bioenergy and Biochemicals from	Iowa Farm Bureau's	Presenter	Feb 2007

Title	Location	Type	Year
Agricultural Wastes and Biosolids	Conference on Anaerobic Digestion for Agriculture		
Method for Hydrogen Production from Organic Wastes Using a Two-phase Bioreactor System	U.S. Patent Number: 7,083,956 B2	Patent	Aug 2006
Energy and Chemical Precursors from Manures and other Agricultural Wastes Using Novel Digesters and Configurations	Water Environment Foundation & USEPA Conference, "Innovative Uses of Biosolids and Animal and Industrial Residuals", Chicago	Presenter	June 2005
Method and Apparatus for Hydrogen Production from Organic Wastes and Manure	U.S. Patent Number: 6,887,692 B2	Patent	May 2005
Biogenic Hydrogen Production from Animal Production Biosolids	Savannah River DOE Nat'l Laboratory, Aiken, SC	Presenter	July 2004
Biogenic Hydrogen Production by *Thermotoga* Species Cultivated in Hollow-Fiber Membrane Reactors (HFMR)	National Hydrogen Association Conference on "Hydrogen – A Clean Energy Source", Los Angeles	Presentation and Technology Report	April 2004
Anaerobic Digestion of Brewery Wastes for Fuel-Grade Methane	Gas Technology Institute, Chicago	Feasibility Report	April 2003
"Humic Coverage Index" as a Determining Factor Governing Strain-Specific Hydrocarbon Availability to Contaminant-Degrading Bacteria in Soils	Environ. Sci. Technol. 37: 5168-5174.	Publication: Chemistry on bioavailabilit y of organic contaminants	2003
Biogenic Hydrogen Production from Biosolids and Renewable Biomass Applying Bacteria Grown in Hollow Fiber bioreactors	Hydrogen Production & Storage Forum Washington, DC	Presentation: Biofilm formation and controlling factors	2003
Prevention and Control of Microbiologically Corrosion using Environmentally Benign Components Isolated from *Capsicum* sp.	SERDP/ESTCP Partners in Environmental Technology Symposium	Presentation: Biofilm in corrosion and metal-biofilm interactions	2001

Reg Renaud

From: "Michael Eaves" <meaves@cleanenergyfuels.com>
To: "Reg Renaud" <regsti@msn.com>; <guy.burgess@yahoo.com>
Sent: Friday, June 19, 2009 5:09 PM
Subject: Thanks for talking today

Reg and Guy,

Clean Energy is very interested in your digester in Chino. We'd be interested in buying all the gas you can produce. We'd also be interested in building a retail station at your facility for CNG/LNG operations - but that of course would depend on how close the site is to major traffic patterns.

Given our discussion, I would like to arrange a meeting with you at our offices to further explore benefits of steam injection as well as CO2 reinjection.

Please let me know when you might be available.

Again, a pleasure to talk to you today - and thanks for your persistence in contacting me!! (I have been obviously swamped!)

Mike

Clean Energy
North America's leader in clean transportation

Michael L. Eaves
Assistant Vice President of Technology Advancement
Clean Energy
Phone: 562/493-2804
Cell: 562/370-7226
Email: meaves@cleanenergyfuels.com

STEAM INJECTION LANDFILL BIOREACTORS

Reg Renaud
President
STI Engineering
Silverado, California

ABSTRACT: The goal of a Landfill Bioreactor is to increase the humidity of the landfill not to saturate the refuse. Based on several case studies of Landfill Bioreactors involving leachate recirculation it has been confirmed that increasing the humidity of the landfill will produce as much as seven to ten times more methane in a shorter period of time than normal MSW landfills with no leachate recirculation. Steam injection will increase the humidity to 100% with excellent temperature control and should produce the maximum amount of methane based on the amount of organic material available. Not only will Steam Injection create the maximum amount of LFG but recover the most air space in the shortest amount of time. Once leachate/condensate is converted to steam and is injected into the landfill, it is converted to LFG and extracted, there is no recirculation of the leachate/condensate.

This paper will outline the advantages of using steam injection versus water addition in landfills. Many of these advantages are enhanced by the use of the in situ data obtained by the Piezo-Penetrometer Test (PPT) to properly design and construct the system and evaluate the progress of the Steam Injection Landfill Bioreactor. The PPT is also used to install the push-in gas collectors and steam injectors at a fraction of the cost of drilled in collectors.

This paper will discuss the basic theory of Steam Injection Bioreactors based on the physics of the process involved and then confirm them with the results of a pilot study performed at the Miramar Landfill in San Diego, California in 2005 and 2006. All of the project goals were achieved.

INTRODUCTION

In August, 2003 STI Engineering presented a proposal to the City of San Diego, Refuse Disposal Division to perform a Steam Injection Pilot Study at the Miramar Landfill, located in San Diego, California.

On May 5, 2005 STI Engineering received the Right of Entry from the City of San Diego to perform the Steam Injection Pilot Study.

On May 16, 2005 STI Engineering mobilized a PPT rig and a Geoprobe unit to the subject site.

The 30 ton PPT rig that was available at the time of the start date did not have a large enough center hole to accommodate the 2" diameter pipe used for the injectors and collectors, therefore a Geoprobe was used to install the pipes. No drilling was conducted to install any of the instruments in the test area, only push-in technology.

FIGURE 1
PPT RIG & GEOPROBE

The following outlines the project scope of work, and describes the field operations.

SCOPE OF WORK

The scope of work completed consisted of the following tasks:

- Developed a Health and Safety Plan for the proposed work on the subject site.
- Pre-qualified selected locations on the landfill using the PPT prior to installing 2-inch diameter steel push-in injectors and collectors. The PPT data was used to indicate the following:
- Verify the presence and density of refuse.
- Determine the presence of LFG pressure.
- Determine the optimal depths to install the screen sections of the injectors and collectors.
- Verify that no liquid layers were present that could impact the injectors or collectors.

- Installed 6 schedule 80 black steel 2" diameter collectors-extraction wells (EW) with (1/8-inch mill slot screen) for gas in the test area.
- Installed 2 schedule 80 black steel 2" diameter extraction wells (EW) for gas in the control area.
- All extraction wells were connected to a 2" diameter Landtec well heads and then to the vacuum header.
- Installed 3 steam injectors using 2" diameter steel schedule 80 black pipe.
- Installed 9 thermocouples into the refuse at various depths and at various locations in the test area. Installed 1 thermocouple on each of the 3 steam injectors.
- Installed 2 Static Piezometers in the test area.
- Install 5 settlement monuments in the test area and one in the control area.
- Prepared and submitted a progress report.

A Health and Safety Plan was developed prior to the start of the field operations and submitted to the City of San Diego. A Health & Safety meeting was conducted with all parties involved in the field activities on May 15, prior to the start of the work. A Rae Q-Rae Lower Explosive Limit (LEL) meter was used to monitor the air inside the PPT rig during operations. The readings never went beyond the background levels at the landfill site. Operations were conducted in Level D protection.

FIELD OPERATIONS

The field operations began by performing several PPT soundings on a 200-foot grid to determine the overall conditions of the landfill waste prism. The grid was reduced to 100 feet and then to 50-feet to obtain enough data in the selected test area to properly design the steam injection and gas collection system.

The PPT was developed in the late 1970s and early 1980s. At the time, the primary purpose of this device was to measure the pore pressure in the soil to determine the level of the ground water. The PPT cone is pushed into the landfill by hydraulic rams mounted on a 20-ton truck. The cone is advanced by adding 1-meter long push rods pre-threaded with a cable connecting the cone to a computer, which digitally records and displays in real time several parameters continuously during the sounding. The PPT cone measures tip resistance and sleeve resistance (useful data for soil type, strength and foundation design) the same as a standard CPT (ASTM 1988). The instrument has inclinometers to ensure that the cone is staying vertical during advancement through the subsurface or landfill, which adds to the accuracy of the depth control. The depth control of the sounding is very exact (via a wire-line from an encoder attached to each advanced push rod segment). Figure 2 presents a typical PPT sounding log and describes how to read the log.

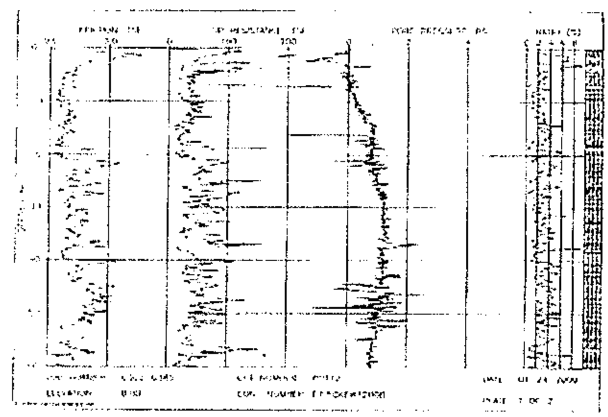

FIGURE 2
TYPICAL PPT LOG

The following is a brief description of each column displayed on the log:

__Column 1__ – Depth of sounding in ten foot intervals.

__Column 2__ – Friction sleeve values as the PPT cone is advanced through the landfill. The values are presented in tons per square foot (tsf). The friction values are useful in determining a friction ratio, which is used to identify the type of material the cone is passing through. It is also an indicator of moist conditions in the landfill.

__Column 3__ – Tip Resistance or End Bearing (tsf) values indicate the relative density of the material the cone is penetrating. This value is also used in the friction ratio calculation. The high tip resistance readings can indicate dense layers or daily cover layers and the low tip values usually indicate refuse.

__Column 4__ – Pore Pressure values (psi) measure landfill gas pressures, vacuum and liquid head pressure. On the above PPT log, the Pore Pressure values begin to increase in pressure at a depth of 5 feet below ground surface (bgs) and continue to increase to about 1 psi of gas pressure down to 60 feet bgs.

__Column 5__ – Friction ratio (%) is calculated by dividing the friction sleeve value by the tip resistance and is presented in a percent. In soils, friction ratios of less than 2% typically indicate sandy or gravelly soil behavior types, while the higher the friction ratio, indicates a more "clay-like" the material (Robertson and Campanella 1988). Moist municipal solid waste has been found to generally have friction ratios greater than 2%.

The pore-pressure transducer in the PPT cone can differentiate between hydrostatic head pressure and gas pressure as indicated in Figure 3 below. This sounding was not performed at the Miramar Site but is used to clearly demonstrate the capability of the PPT cone. No substantial liquid layers were indicated in the test area.

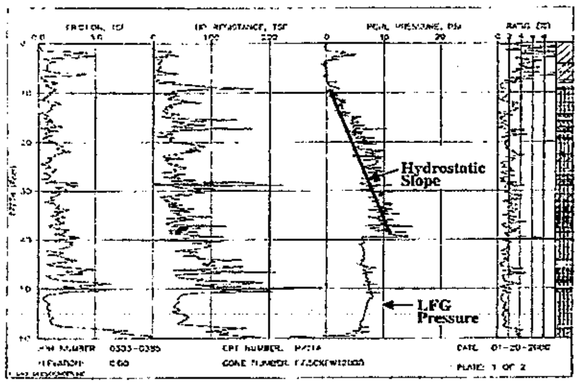

FIGURE 3
TYPICAL PPT LOG

SITE CHARACTURIZATION

The study area was in a 12-acre portion of the landfill that had not been disturbed by LFG collection. The waste was approximately 150 feet thick in a lined portion of the landfill. About 8 feet of cover soil/stockpile was placed over the whole area. This landfill receives only 4-8 inches of rain per year. A dense layer was indicated by the PPT at 52 feet below ground surface, which acted as a false bottom so only the top 50 feet of the landfill was treated with steam.

The PPT locations were designated as EW (extraction well) if a collector was installed following the PPT sounding. The PPT locations were designated as SI (steam injector) if a steam injector was installed at that location. Also the PPT locations were designated as Piezo if a static Piezometer was installed at that location. (see Site Layout, Figure 12)

Seven large diameter gas collectors were already installed at the northern end of the test area. To determine their range of vacuum influence PPT soundings were performed at 50', 40' and 25' from the existing collectors adjacent to the test area. Significant vacuum was only indicated in the sounding that was only 25 feet from the collector. Based on this data the test area was placed at least 100 feet away from the line of existing collectors to minimize their influence on the test area.

PROGRESS OF OBJECTIVES AND GOALS

The following bullet items are the initial objectives for this Pilot Study and the current performance results for each objective, based on the progress achieved:

1. Increase the moisture content of the refuse

   Based on temperature increases noted from thermocouple points (see Table, Figure 8), the moisture content of the refuse appears to be increasing within a 75-foot radius around each injector. The moisture increase comes from steam moisture and bio-degradation of refuse, both related to the increase in refuse temperature.

2. Increase the temperature of the refuse

   The temperature data also indicates that there are areas within the test site that have increased in temperature by as much as 69° F. Additional information regarding temperature increases in specific areas will be analyzed during the upcoming PPT investigation performed near the completion of the Study.

3. Monitor the migration of the steam through the refuse horizontally and vertically

   The steam migration through the refuse, both horizontally and vertically, has been continually monitored during the Study period. Temperature increases have been detected at 15 and 35 feet below ground surface.

4. Control the steam migration by using LFG collectors

   It has been demonstrated that increasing or decreasing vacuum flow at the LFG collectors can control steam migration through the refuse.

5. Monitor any excess liquid at bottom of test site

   Piezometer readings do not indicate the presence of any liquid collecting beneath the refuse layer and comes in contact with the impervious fill cap soils, which is 50ft below ground surface.

6 Evaluate whether or not landfill leachate and condensate can be used in this process

   This has been the greatest challenge and appears to have been resolved. At this point, *the leachate and condensate from the landfill can be used in this process assuming the landfill can provide a sufficient amount of leachate and the filtration operation can maintain production. Since the leachate is no longer being re-circulated the daily output of leachate has diminished rapidly.*

7. Increase the LFG quality and quantity output within the test site

The primary goal of this Pilot Study is to control the flow of the collectors to manage steam migration, and is not intended to obtain the highest flow rate of LFG. However, as a positive addition, some of the LFG collectors have indicated a 10% increase in methane concentrations. This appears promising, although each time the collector valves are closed to retain the heat generated because water inflow has ceased, either due to insufficient water provided or system down time for repairs/maintenance, flow rates become difficult to accurately calculate. As production times become stable and longer, more consistent measurements can be made. More definitive information will be available at the time of the Final Report.

8. Increase the settlement of the refuse

There is visible evidence along the line of steam injectors of about 18" to 24" of settlement. Soil settlement has not yet been detected at the settlement monuments; however, the Study was focused on the viability of the process and the potential environmental impact of moisture added to the refuse. The reduced volume of leachate water available for the Study prevented settlement from spreading out far from the injection wells at this time. Additionally, the existing surface soil cap is likely bridging over the refuse. Significant settlement is anticipated when surface compaction efforts collapse the soils.

9. Obtain material quantities and costs per acre for treatment

A cost analysis will be presented after the study is concluded. Initially, the additional costs for larger boilers and filtration systems to overcome the high solids content of the leachate water, and, the recent substantial increase in fuel costs have had an impact on the initial cost estimates for the Study.

10. Obtain landfill surface settlement values during a 3 to 6 month period.

Due to filtering of the leachate water, the Study is about two months behind schedule. As long as there is insufficient water to convert to steam, the Study will not achieve its desired potential. Surface settlement values will not be accurate or significant if the Study cannot continue as planned with appropriate supply of water. Monitoring will continue and be reported at the completion of the Study.

1ST PROGRESS REPORT CONCLUSIONS

As stated above, despite production issues and delays, most of the Study's objectives have been achieved. With the modest amount of water injected and settlement achieved, the initial results are still encouraging. Once there is enough water to operate 24-hours a day for several of weeks, another PPT Profile will be performed to evaluate actual subsurface conditions relative to the anticipated results.

It is becoming apparent that the soil layers used to cap the landfill at various times, are bridging over the underlying refuse layers and inhibiting settlement despite the increase in void space within the refuse zones. Therefore, in order to fully realize the actual volume reduction potential, some form of mechanical compaction may be necessary to break through the soil layer and allow total settlement to occur. Evaluation of the impact of this condition will be conducted as production is increased and the system is operating at full capacity.

CONTINUING OPERATIONS

In order to optimize conditions for landfill volume reduction by bio-degradation, it is imperative to provide sufficient steam to the test prism such that virtually all voids can be filled with moisture. The steam injection operations began at the site using a 360,000 btu boiler capable of delivering over 4,000 gallons of steam per 24-hour period. The boiler performance was considered optimal based on calculations regarding the amount of void space estimates within the total waste volume, approximately 20%.

The water supplied for the steam injection comes from the landfill leachate collection system and, as a result, has a very high amount of both particulate and dissolved solid matter suspended within. This water introduced solids into the boiler and injection system causing significant mechanical problems, machinery clogs, and resulting down time needed to clean and repair the equipment. The degree of filtration was not apparent or planned for in the initial design of the system.

Filtering the water is the only viable solution, but has been hampered by extremely high, suspended solids over-loading all devised filtration systems. The system could not operate for the planned extended periods due to the maintenance of filtration and injection equipment. However, the majority of filtration problems have been overcome and the system is functioning more reliably.

Only about 350,000 gallons of water was injected as steam, which is well below the 800,000 gallons initially planned. At the start of the study the landfill leachate collection system was recovering about 13,000 gallons per day, which the landfill operators were re-circulating at the active face. Once the leachate was being delivered to the study site and converted to steam, the daily leachate rate went down to approximately 500 gallons per day. Condensate from landfill gas was used to supplement water needs. The condensate actually became more of an asset than just being additional water, as its lower pH cleaned the boiler coils and steam pipeline.

With this addition the landfill was only producing an average of about 1,500 gallons of leachate and condensate per day, insufficient to achieve the planned objectives, whereas, the planned steam injection process was permitted for 3,400 gallons per day minimum, yielding a water shortage of 1,900 gallons per day. A request was submitted to the City to use locally available recycled water as a supplement to the leachate and condensate water. This would allow for production goals to be achieved. This request was rejected by the Regional Water Quality Control Board, due to the short term of the pilot study. The Board stated that the application would be considered if or when the project went to full scale.

Our experience with the smaller boiler indicated increasing the temperature (375°F) in order to expand the steam influence in the waste prism was not the way to increase coverage. By increasing the temperature we were creating particular matter and carbonate deposits inside the boiler. By lowering the temperature to 250°F the boiler stopped fouling.

When the temperature was lowered, which consequently reduced steam pressure in the small boiler it was necessary to increase the size of the boiler and water flow, as to increase the steam influence in the test site. A 660,000 BTU unit was ordered but had a 1 month lead time, so a used 440,000 BTU unit was used until the larger unit arrived. The larger unit did increase the steam influence.

FIGURE 4
660,000 BTU BOILER

During the study, temperature and piezometer readings were recorded and LFG readings were measured using a Landtec Gem 2000. Generally, all aspects showed favorable increases during the monitoring period, despite the delays and inconsistent operation times.

WINTER OPERATIONS

Problems encountered due to high concentrations of solid particles within the landfill leachate being used resulted in significant cost increases and delays. Due to these delays the Pilot Study was about 2-months behind the planned schedule. This delay forced the continuation of the study into the rainy season. As a result, earthen berms were constructed around the test site to control surface water drainage. On a positive note this delay allowed us to operate through a full cycle of weather changes. Fortunately the weather was a typical rainy season with only a few heavy rain events. There were only a few days when water tanker trucks could not get to the site due to muddy conditions. No adverse impacts occurred to the landfill or the environment due to the Pilot Study winter operation.

PUSH-IN COLLECTORS/INJECTORS

One of the goals of the study was to evaluate the use of push-in steel collectors and injectors with oilfield mill slot screens, which have been used in oilfields for over 100 years. Five-foot long, schedule 80 black steel pipe 2" in diameter was used for the injectors. Over ten years ago stainless steel was used but it was discovered that stainless steel does not stay stainless outside the atmosphere. Therefore it will corrode just as fast as black steel, but black steel is less expensive than stainless steel and has become the material of choice.

Schedule 80 black pipe is thick enough to allow a patina of rust to form and inhibit corrosion and still maintain its integrity. This is the same principal used when building bridges, the gauge of the steel beams are increased to allow for surface rust. The pipes were threaded and coupled.

Following a PPT sounding to verify that the selected location is suitable for a collector/injector, a 3" diameter mandrel is pushed down the pilot hole to expand it. Once the mandrel is removed, the 2" diameter black steel oilfield mill slot screens and blank risers were lowered down the expanded hole. Since no drilling was performed no cuttings were created. Within a day the refuse consolidated around the collectors/injectors and was ready for operations.

FIGURE 5
OILFIELD MILL SLOT SCREEN

The purpose of using this system is to allow the collectors to be converted into injection wells if necessary and conversely allow injectors to be used as collectors. Two of the smaller steam boilers were connected to EW-2 and EW-5, making those two collector wells into steam injection points. Steam was injected into these injectors for a short time but the lack of water minimized the length of this operation. However, the injectors did perform as planned proving that this system can be used as injectors or collectors. There was no evidence that steam leaked from around the injectors and no oxygen was ever indicated in the gas collectors.

Another reason the collectors EW-2 and EW-5 were converted into injectors was to simulate the current LFG collection system found at the site by operating only the 4 corner collectors at the test cell.

In a full-scale scenario the plan would be to install a steam injector in the middle of each acre with a collector at each corner. The corner collectors would pull the steam across the treated acre. The current test scenario is proving to be effective. However, we injected steam from 3 injectors instead of one to make up for lost time.

FIGURE 6
BOILER FOR EW-2 AND EW-5

There has always been some controversy about large diameter drilled in collectors and push-in steel 2" diameter collectors. This study showed that the smaller push-in collectors/injectors worked. However, another virtue of these wells is that if they should get plugged (and even drilled-in wells plug), steam can be used to clear them instead of installing another well. They also cost about a third of drilled in collectors. If a drilled-in well plugs, it must be abandoned and a new well installed. This can be very costly especially when a landfill has been developed after closing and there is hardcover around a LFG collector.

MONITORING

As back-up monitoring devices, 2 static piezometers were installed in the study area using the PPT rig. The bottom 5 feet of the ¾" PVC pipe was slotted with the bottom sitting on a dense layer at the 52-foot depth indicated by the PPT. No liquid was ever detected in either piezometer during the study.

One major advantage of using steam instead of water is that is warms the waste instead of cooling it. This makes monitoring the migration of the steam through the waste prism much easier and effective.

Using the PPT rig, 9 thermocouples were installed in the test area. Four of the thermocouples were installed at a depth of 22 feet below ground surface (bgs) and at 25-foot intervals between SI-2 and EW-2. (see Site Layout,

Figure 12) These thermocouples were used primarily to monitor the migration of the steam from the injectors to the collectors.

The other thermocouples were installed at various locations throughout the test area to monitor the coverage of steam. At 50 feet from injector 1 and 2 two thermocouples were installed, one at 15 feet bgs and another below it at 35 feet bgs. These thermocouples were used to monitor the steam migration in the vertical plane. The steam did heat the waste from just below the cover soil and to a depth of 35 feet bgs.

A thermocouple was attached to the top of each of the 3 steam injectors. All of the thermocouples were connected to an Omega data logger located inside a data acquisition trailer on site.

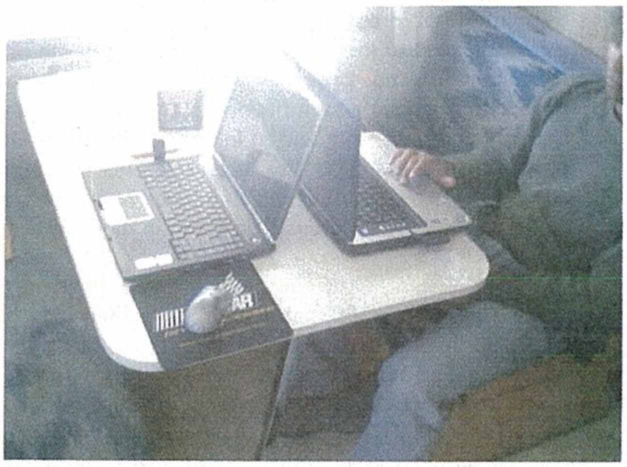

FIGURE 7
THERMOCOUPLE DATA LOGGER

Thermocouple # 9 was over 100 feet from injector #2 but was influenced by this injector and not injector #3, which was only 50 feet away. This was verified by turning each injector on and noting which injector increased the temperature. This indicates that channeling can occur on a horizontal plane. This can be controlled by installing Internal Conduits (3/4" PVC pipes used to connect vacuum and pressure layers inside the waste prism using the PPT rig) to prevent steam from channeling to a gas collector before it has a chance to convert to LFG. This will be discussed later in this paper.

Location	Probe Depth	Start Temp.	End Temp.	Total Increase
	Feet	June 2005	March 2006	Deg. F.
T-1	22	97	116	19
T-2	22	94	95	1
T-3	22	96	97	1
T-4	22	93	95	2
T-5	31	96	126	30
T-6	15	88	157	69
T-7	35	95	100	5
T-8	15	86	98	12
T-9	31	96	108	12

FIGURE 8
TEMPERATURE TABLE

The thermocouples were fast and easy to install and worked as intended.

SETTLEMENT

The main purpose of performing this study at Miramar was to recover airspace since the landfill is due to close in 2012.

The steam injection pipeline was a good reference point to monitor settlement across the study site. As the ground lowered, the pipeline had to periodically be re-supported along its length. In the photo below, the wood stake is where the pipeline was supported when the test first started. The measuring tape shows over 24 inches of airspace recovered. The settlement created a bowl in the center of the study site. The most settlement occurred around the injectors and fanned out about 75 feet from the centerline. The settlement monuments were 50 feet from the centerline and only indicated a few tenths of a foot settlement.

FIGURE 9
RECOVERED AIRSPACE

Another lesson learned is that using a steel pipeline is not the best way to convey steam to the injectors. Due to settlement, the steam line had to be continuously re-supported to prevent damage to the steam pipe. Birds also enjoyed ripping off the insulation, which often had to be repaired. To eliminate these problems future operations will use steam hose, buried in the cover soil for protection and insulation. A coiled 5' long pigtail lateral would be connected to the injectors and would uncoil as the landfill settles and the injector pipe rises above the landfill surface. Once the next joint of injector pipe (at each 5-foot segment) the pipe segment would be removed and the pigtail would be reconnected at the ground surface.

As the landfill settled, injector pipes became exposed as they stuck up out of the cover soil. Soil was mounded up around them to insulate them from ambient cooling. This is only effective up to about 2.5 feet and then pipe insulation will have to be used. When the injector pipe is 5 feet above the landfill surface another joint will be exposed therefore allowing the pipe to be removed and the steam hose reconnected to the injector.

NATURAL GAS PRODUCTION

One acre of landfill, 50 feet deep will naturally produce about 50 scfm of LFG, which is a conversion rate of 50 x 1440 = 72,000 cu. ft. LFG/day / 12,000 = 6 tons of organic waste converted per day.

Usually LFG is used to produce electrical power so 1 cubic foot of methane contains 1012 BTU and a typical engine with an efficiency of 30% will generate power at 10,500 Btus/kwhr.

Therefore, 72,000 cu. ft. of LFG contains 50% methane or 36,000 cu. ft. x 1012 = 36,432,000 BTU / 10,500 = 3,470 kwhr per day per acre. This assumes 50% methane, but this rate will drop (to about 40 to 45%) as the moisture is removed from the waste during LFG extraction. Landfill co-gens usually do not generate 3.5 megawatts per acre. At 40% methane each acre would produce 2.8 megawatts. The one other thing that may be causing the shortfall in the real world is the amount of cover soil being used daily. The following will show how steam injection can make a difference in LFG production in quality and quantity.

ORGANIC POTENTIAL

In published articles, 1 ton or 3.5 feet cubed or (42.9 cu. ft. or 47 pcf) of waste with 50% organic material will produce about 6,000 cubic feet of methane gas and 6,000 cu. ft. of carbon dioxide (CO_2) (Bolton, 2007).

If 1 acre - 50 feet deep of fresh waste with a field density equal to 42.9 cu. ft/ton, it will contain an estimated 25,212 tons of organic material. Using 50% methane as the conversion rate 25,212 x 12,000 x .50 = 151,272,000 cu. ft. of CH_4. Then 151,272,000 x 1012 BTU / 10,500 = an estimated energy potential of 14,579,739 kwhrs per acre. Of course the amount of cover soil used in filling this acre will ultimately determine the actual energy potential.

ENHANCED LANDFILL GAS GENERATION

Although this Pilot Study was primarily concerned about recovering airspace it also verified that the addition of moisture and heat increased the quality and quantity of the LFG generation.

Unfortunately since the gas generation was not the main goal, the control valves on the gas collectors were not opened fully to recover the maximum amount of gas but were restricted to keep the steam inside the waste prism long enough to be converted to LFG. The valves were opened just enough to influence the steam to migrate laterally across the site and to keep up with the positive pressure being generated by increased LFG production. All of the gas collectors in the study area became gushers so the vacuum was increased to keep up the flow rate to the header.

An average of 1,500 gallons of water per day was converted to steam and injected into the landfill during the study. The following demonstrates the gas potential of an acre of waste 50 feet deep using steam injection.

A reminder our goal is to fill the void spaces in the waste not to saturate the waste. One acre 208 x 208 feet x 50 feet deep = 2,163,200 cubic feet of refuse x .20 percent void space = 432,640 cubic feet. 2,000 gallons of water converted to steam would fill the void spaces. However, we were 500 gallons per day short of this target and the dry waste, prevented full void coverage.

Even with this shortfall let's see what the gas potential was, using the steam process. If 1,500 gallons / 7.5 gal. per cubic foot = 200 cubic feet x 1,600 expansion factor of steam = 320,000 cubic feet of steam. The steam vapor is the mechanism that enhances the anaerobic conversions occurring in a landfill to produce LFG. It is known that the organic material in the landfill contains the necessary components (hydrogen and carbon) to produce methane. However, additional heat and moisture accelerates this process. It is an industry standard that most municipal solid waste (MSW) contains 50% organic and 50% inorganic material. Therefore, it is assumed by some in the industry that one volume of steam will facilitate creating 1/2 volume of LFG with some of the steam lost in the inorganic waste.

Therefore, 320,000 cu. ft. of steam created 160,000 cubic feet of LFG, which usually contains .50 percent methane = 80,000 cu. ft. methane (CH_4) /day. Although, we actually produced 62% to 66% methane in the Pilot Study while the nearby collectors in the landfill were only producing 45% methane. For the following calculations we will use an average conversion rate of 64% or 102,400 cu. ft./day. Therefore, 102,400 cu. ft/day x 1012 BTU/ cu. ft (methane) / 10,500 Btus/kwhr has the potential to produce 9,869 kwhrs per day per acre.

There was a 3-day delay until the dry conditions of the refuse were overcome and the bioreaction was sustainable. As the bioreaction increased so did the temperature and continued even without steam for 1-2 days when we ran out of water.

These conclusions were based on 1 volume of steam creating ½ volume of LFG. However the test site was producing an average gas extraction rate of 229 scfm of LFG. Therefore, 229 x 1440 min. = 329,760 / 12,000 = 27.5 tons/day converted.

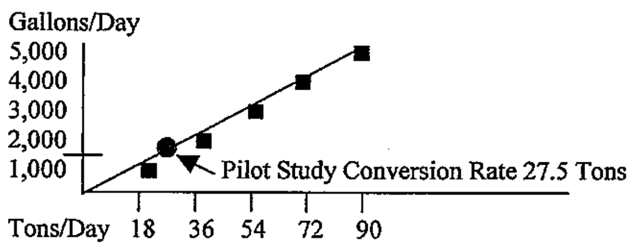

FIGURE 10
ORGANIC TONS CONVERSION TABLE

As the chart above indicates, the rate of organic conversion for the pilot study falls on the 1:1 conversion line. This conversion rate will be verified when a full-scale operation can adjust the collectors and monitor the gas flow for maximum affect. Therefore the 9,869 kwhrs stated above could be 19,738 kwhrs instead. Again the amount of cover soil used will affect the final potential.

With the above natural daily production rate 6 tons of organic waste were being converted per day. At this rate the acre would be stabilized in 25,212 / 6 = 4,202 days or 11.5 years. With steam injection, 27.5 tons of organic waste were being converted, it will take 25,212 / 27.5 = 917 days or 2.5 years to stabilize the one-acre.

If 5,000 gallons of water converted to steam were injected into the same acre it would convert 89 tons of organic waste per day. At this rate it will only take 9 months to stabilize the acre.

STEAM BIOREACTOR COSTS

One of the goals of the pilot study was to obtain some idea of the cost to perform a Steam Injection Bioreactor. The initial cost to perform the PPT Profile and to install the first 5-acre treatment plot is estimated at $140,000.00. The mobilization charges will vary depending on the location of the landfill. Most of the equipment used in the initial installation is re-useable for the continuation of the process to other acres. Approximately 10 scfm of methane from LFG per acre will be used to make the steam if it does not come from the power plant or LFG conversion technology. Less than 1% of the LFG generated by the steam process would be used to create the steam leaving 99% of the fuel for energy or fuel. If additional water is necessary beyond the leachate and condensate from the site this will be an additional cost. However, with water selling for about $2.00 per 1,000 gallons this equates to about $50.00 per 25,000 gallons per day to treat 5-acres 75 feet deep per day. At about every 1.5 years the treatment site will have to be moved as the treated acres stabilized and gas production declines. The PPT rig will have to be mobilized to the site and another 5-acres set-up for treatment using the equipment from the previous acres lowering the overall cost of the process. Overtime and the more acres treated the lower the costs. To treat a 100 acre landfill it is estimated to cost about $4,500.00 per acre to treat.

PILOT STUDY FINDINGS

On February 24, 2006 a 30-ton PPT rig was mobilized to the study site. A series of post-study PPT soundings were performed across the control area and the test site.

- The refuse in the study cell was very dry preventing the entire void space to be filled with steam. The refuse absorbed most of the moisture as it was injected unless the vacuum was increased to a level that caused the steam to migrate though the waste prism. The lack of water prevented a prolonged injection surge to overcome the dryness and reach the full 100-foot radius of the study cell.

- As the ambient temperature at the study site cooled, the water-cooled and propane usage increased by about 5% during the winter months. Pre-heating the water by using solar panels as much as 50% could be saved on LFG usage. For colder regions, a geothermal well is being developed. This is to be installed in landfills using the warm waste heat to pre-heat the water. This could save as much as 30% on the amount of fuel used. For more constant preheating at night, both methods should be used in tandem. Using pre-heating technology it has been estimated that 50 scfm of LFG with 50% methane would be required to steam 5 acres of landfill to a depth of 50 to 75 feet.

- The leachate can be filtered and converted to steam although the level of filtration is not as important as first thought. With the temperature reduced to 250°F most of the dissolved solids will pass with the steam and not plug the boiler coils. Condensate, with lower pH actually cleans any deposits that may build up in the boiler coils.

- An average of 3 inches of settlement per month was measured at some of the survey points near the injectors on the study site. However, other observations around the site indicated that the settlement was not uniform across the site. It is also believed that the thick cover soil, as much as 8 feet, may have inhibited the rate of surface settlement by bridging. The post-study PPT logs indicate low-density layers under the cover soil, which may indicate that a large amount of organic waste has biodegraded. We asked the landfill operator if they would drive their loaded 12,000-gallon water tow over the site to break the bridging and compact the test area. They agreed to do so but on the day before the PPT rig was to arrive on the site to perform the post PPT Profile the landfill operators changed their minds and refused. They were concerned that the water tow would drop into a large hole. There was not enough time to mobilize another vehicle to the site so no post-compaction was performed. Fortunately the PPT rig weighed only half as much as the water tow and did not sink into a large hole.

- At the start of the study the methane concentration was 54% in the test site collectors. Within a couple of months the methane concentration increased to about 62 to 66%. During the summer months the existing collectors outside the study area showed that the methane decreased to 45%. At this same time as steam was replenishing the moisture in the study area the methane concentration remained at 62 to 66%.

- Installing and maintaining the steam pipeline was labor intensive and costly. To improve future operations a rubber coated steam hose should be used instead. Birds constantly tore off the insulation, which required constant repairing. To insulate and protect it, the hose will be buried under the cover soil. This will also reduce corrosion and UV damage.

- The collectors and injectors performed as planned and they are inter-changeable, which may be useful during full scale areas along the edges of the landfill that may need to have steam injected in small pockets of refuse that were not affected during the main injection process.

- Thermocouples were effective in detecting the migrating steam. Occasionally where the wires were spliced together the contacts would corrode and would be shorted. Once they were repaired they operated as expected.

- Steam injection does significantly enhance LFG production. Natural gas production will usually convert 6 tons/day/acre of organic waste. The pilot study with 1,500 gallons of water/day converted to steam and injected converted about 27.5 organic tons/day/acre. If 5,000 gallons of water/steam were injected it would convert about 44 tons/day/acre.

INTERNAL CONDUITS

Although Internal Conduits were not used during the Pilot Study they will most likely be used in future projects. As the figure below indicates, vacuum and gas pressure layers are often indicated in the same sounding. It is often believed that vacuum is equal the full radius around a collector, when actually it is more like fingers. When this condition is found it is not necessary to install another collector in this area since there is vacuum already located at this location. The PPT is used to install an Internal Conduit much the same way a push-in collector is installed except the casing is removed. Once a 2" diameter flush joint casing is pushed to the desired depth, a ¾" diameter PVC slotted pipe is lowered to the depth required to connect the vacuum layer to the pressure layer. The casing is then removed and the top of the hole is sealed. This allows the pressure to be conveyed to the nearby collector internally increasing its influence and production at a fraction of the cost of installing another collector and connecting it to the header. This will also be used to improve the distribution of steam through the waste prism.

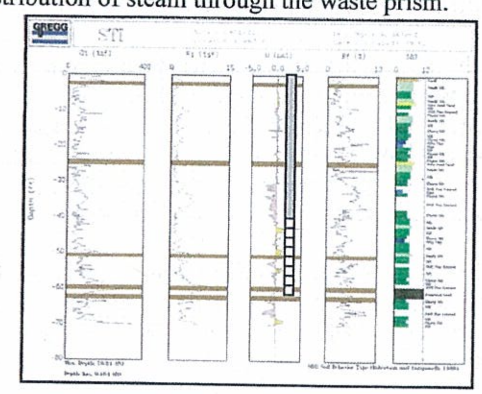

FIGURE 11
INTERNAL CONDUIT

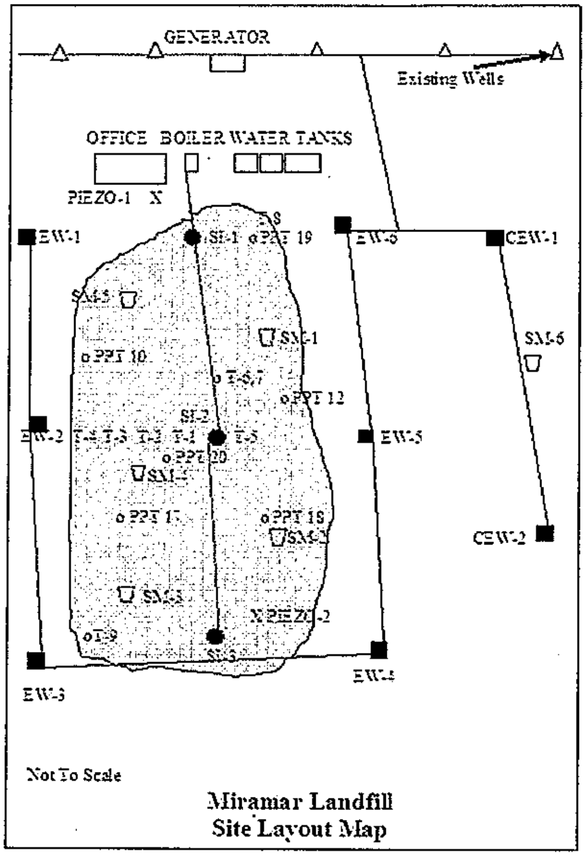

FIGURE 12
SITE LAYOUT MAP

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Landfill CO_2 Conversion to Methane

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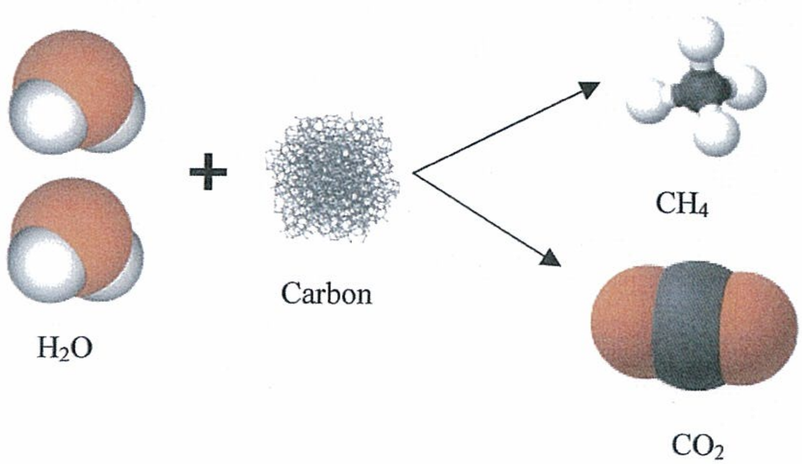
Methane is a chemical compound with the molecular formula CH_4. It is the simplest alkane, and the principal component of natural gas. Methane's bond angles are 109.5 degrees. Burning methane in the presence of oxygen produces carbon dioxide and water. The relative abundance of methane and its clean burning process makes it a very attractive fuel. However, because it is a gas at normal temperature and pressure, methane is difficult to transport from its source. In its natural gas form, it is generally transported in bulk by pipeline or LNG carriers; few countries still transport it by truck. (Wikipedia)

Methanogens are archaea that produce methane as a metabolic byproduct in anoxic conditions. They are common in wetlands, where they are responsible for marsh gas, and in the guts of animals such as ruminants and humans, where they are responsible for the methane content of flatulence. In marine sediments biomethanation is generally confined to where sulfates are depleted, below the top layers. Others are extremophiles, found in environments such as hot springs and submarine hydrothermal vents as well as in the "solid" rock of the earth's crust, kilometers below the surface. Methanogens are usually coccoid or rod shaped. There are over 50 described species of methanogens, which do not form a monophyletic group, although all methanogens belong to Euryarchaeota. (Wikipedia)

Methanogens are anaerobic. Although methanogens cannot function under aerobic conditions they can sustain oxygen stresses for prolonged times. An exception is *Methanosarcina barkeri*, which contains a superoxide dismutase (SOD) enzyme and may survive longer. Some, called hydrogenotrophic, use carbon dioxide (CO_2) as a source of carbon, and hydrogen as a reducing agent. Some of the CO_2 is reacted with the hydrogen to produce methane, which produces an electrochemical gradient across a membrane, used to generate ATP through chemiosmosis. In contrast, plants and algae use water as their reducing agent. (Wikipedia)



CO_2 Conversion To Methane

If we believe that the above conversion occurs only with organic carbon material and not from CO_2 then the landfill gas (LFG) coming out of a gas collector would always be 50% methane and 50% CO_2. However, higher levels of methane over CO_2 levels are often indicated at LFG collectors. The readings will usually indicate a mass balance such as 60% CH_4 and 40% CO_2 totaling 100% unless air has intruded into the gas stream changing the ratios. The only way this change in ratios can occur is that the carbon in the CO_2 was converted into methane by the methanogens.

It has been observed at landfills that if the extraction process is slowed the level of methane increases and the level of CO_2 decreases over time. Conversely if the gas is extracted too fast, the concentration of methane will decrease to 50% and if the well is overdrawn then the methane will drop below 50% and oxygen and nitrogen will be measured.

Therefore, it can be assumed that if the landfill gas is allowed to stay inside the landfill longer and if there is excess moisture, the methanogens will take the carbon from the CO_2 and convert it to methane. This whole process is water/moisture driven.

The CO_2 Sequester Process

Keeping the above natural process in mind it should be possible to enhance this process by using steam injected into the waste prism. Enriching the steam stream with CO_2, CO and NOx by sequestration will also enhance the process further.

From field tests it is known that standard steam injection can produce 66% methane levels with a flow rate average of about 269 scfm. If we had extracted the gas faster the methane levels would have probably decreased. Additional field tests with enriched steam are required to determine how much of an improvement the CO_2 Sequester will make. If we inject enriched steam into the landfill at the same rate as we did in our pilot study and extract the gas at 269 scfm the methane levels should be 66% or higher.

By using the CO_2 Sequester we can have zero-emissions at our landfills and produce additional methane for alternative fuels.

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