September 25, 2014

To: Interested Parties

Re: Request for Proposals (RFP)
Biogas Energy Recovery System
Job No. 14600-04

Dear Sirs:

Las Gallinas Valley Sanitary District is soliciting proposals from qualified consultants to provide design engineering services for the Biogas Energy Recovery System project. The proposal shall be prepared as per the guidelines set forth in the attached RFP.

If you would like your firm to be considered, five (5) hard copies and a CD version of a PDF file of your proposal must be received at the LGVSD Administration Building, 300 Smith Ranch Road, San Rafael, CA 94903; Attention: Mark R. Williams, General Manager, no later than 12:00 PM on October 31, 2014. An interview process for the selection of a consultant, if deemed necessary by the District, is tentatively scheduled for November 5, 2014. Award of a contract for this RFP is scheduled for November 13, 2014.

Please call me at (415) 472-1033, extension 18 if you have any questions.

Sincerely,

Michael P. Cortez, PE
District Engineer

Attachment:
R:\PROJECTS\14000 Projects\14600-04 Cogeneration & Biogas Upgrades\Design RFP\MPC Work Folder\RFP LGVSD Combined Microturbine and CNG Vehicle Fill Station Project.docx
1.0 PROJECT

The project will comprise the following options for recovering energy from the biogas generated as a byproduct of LGVSD’s wastewater treatment process:

1. Microturbine Cogeneration Facility: Provide design services for generating energy from biogas through microturbines. The goal is to replace the existing Waukesha internal combustion engine by January 1, 2016 to meet new air quality standards. See Exhibit A: Biogas Utilization Technologies Evaluation by CH2M Hill, June 10, 2014. The study recommended that a Microturbine Combined Heat and Power (CHP) system be further considered for implementation. The proposed microturbine facility will utilize two (2) 30 kW and two (2) 65 kW generators.

2. CNG Vehicle Fill Station: Provide design services for processing biogas into compressed natural gas (CNG), including an onsite vehicle fill station. See Exhibit C: Biogas Utilization Technologies Evaluation, Combined Microturbines and CNG Vehicle Fill Station by CH2M Hill, June 5, 2014. The study looked at the two most viable technology options that maximize renewable use of biogas and concluded that a combined microturbine and CNG vehicle fill station could take advantage of a single gas conditioning system. However, LGVSD would like a combined system with the exception of carbon dioxide removal.

3. Biogas Conditioning Systems: Provide design services for conditioning biogas for Microturbine CHP System and CNG Vehicle Fill Station purposes, including but not limited to, treatment of hydrogen sulfide, siloxanes, nitrogen, and oxygen, and removal of moisture and other particulate matters. The CNG Vehicle Fill Station will have a separate smaller carbon dioxide removal system.

4. Offsite Natural Gas Filling Station: Provide design services for a utility natural gas fueling station at LGVSD’s Smith Ranch Pump Station to provide a backup fueling location for LGVSD vehicles.

5. Related Project Components:
   a. Sludge Heat Exchanger Replacement: Replacement of the existing spiral heat exchanger with a more efficient unit, including piping modifications.
   b. Hot Water, Heat Recovery, and Ancillary Equipment Upgrades: Modifications and upgrades to the existing hot water and heat recovery systems, including but
not limited to, digester gas flow monitoring, waste heat rejection to ambient air, and integration to the existing boiler and waste gas burner systems.

c. Existing Building Modifications: Structural upgrades to meet current standards, including but not limited to, modifications to eliminate ventilation requirements to the existing engine room.

2.0 MINIMUM REQUIREMENTS

The proposal needs to present your firm's ability to complete the above tasks. It is anticipated that the entire process will include, but not be limited to, detailed design report, equipment selection, preparation of plans and specifications, obtaining required permits, inspection during construction, tie-in to the existing electrical or natural gas system, and preparation of an operation and maintenance plan.

1. Microturbine Cogeneration Facility

a. Consultant shall design an energy cogeneration system that will use biogas (digester gas) as the primary fuel source. LGVSD staff has obtained miscellaneous information related to Capstone microturbines and should be available upon request.

b. The design of the energy recovery system shall include equipment for an immediate, automatic and "seamless" transfer to PG&E power in the event that the cogeneration facility becomes non-operational (planned or unplanned).

c. The design shall include SCADA integration to current LGVSD system. Consultant shall coordinate all work with LGVSD’s current SCADA consultant.

d. Consultant shall prepare detailed equipment specifications for the pre-purchase of microturbines for timely installation and project commissioning by January 1, 2016.

e. Consultant shall design for all necessary piping systems to allow waste heat from the proposed system to meet District’s thermal energy requirements (to be supplemented by natural gas as necessary).

f. Consultant is responsible for acquiring all necessary permits and ensuring the cogeneration plant complies with all regulatory standards.

g. Consultant is responsible for coordinating necessary testing and analysis of biogas for design and other purposes. LGVSD will pay for the cost of the analysis.

h. Proposals should identify grants and funding opportunities that the project could receive.

2. CNG Vehicle Fill Station
a. Consultant shall design a CNG Vehicle Fill Station that will use biogas (digester gas) as the primary fuel source. LGVSD staff has obtained miscellaneous information from the following firms for consideration:

   i. ESC Energy Systems, tel. no. (541) 752-4271
   ii. Southland Industries (design-build firm)
   iii. ACCO Engineered Systems (design-build firm)
   iv. Unison Solutions, tel. no. (563) 585-0967
   v. BioCNG, tel. no. (603) 633-5829

b. Consultant shall prepare selection criteria for a third party vendor (Vendor) of a gas separation system suitable for CNG Vehicle Fill Station in anticipation of a future Service Agreement between LGVSD and Vendor.

c. Minimum mandatory qualifications of Vendor shall include, but not limited to the following:

   i. Vendor shall be the owner of the compression equipment, banked storage, filtration and control system and dispensing and card reader equipment.
   ii. Vendor shall be responsible for all maintenance, repair and support to this equipment 24/7/365.
   iii. Vendor will have factory trained certified technicians on-call 24 hours available to respond within 2 hours of notification of an emergency and within one business day for non-emergency repairs.

Consultant shall perform fleet assessment and prepare a report identifying potential future sewer maintenance equipment for LGVSD that may utilize CNG.

d. The design shall include SCADA integration to current LGVSD system.

e. Proposals should identify grants and funding opportunities that the project could receive.

3.0 SCOPE OF WORK

The scope of work shall consist incorporate the following basic elements:

Task 1 – Document and As-Built Review

- Review of existing technical memorandums prepared by CH2M Hill (See attached).
- Field verification of existing structures and equipment.

Task 2 – Special Funding

- Provide assistance in grant application.
- Identify potential grant funding sources and application requirements.
• Prepare application for grant funding and coordinate processing of the application with awarding agencies.

**Task 3 – Equipment Selection, Pre-Purchase, and Site Layout**

- Prepare detailed equipment specifications for the pre-purchase of Microturbine CHP System for timely installation and project commissioning by January 1, 2016.
- Develop vendor selection criteria and service agreement for CNG Vehicle Fill Station.
- Prepare a site plan based on the proposed equipment.
- This task includes a presentation to LGVSD Board. See project schedule below.

**Task 4 – Environmental Compliance and Permitting**

- The Consultant shall be responsible for preparing, submitting, and obtaining all required permits and environmental review documentation required by all State and local regulatory and jurisdictional agencies needed to ensure this project is cleared for construction on the anticipated dates outlined in the attached technical memorandum, and that it can be successfully completed.

**Task 5 – Preparation of Plans and Specifications**

- Prepare final plans and technical specifications sufficient for bidding. Plans shall include all necessary general, site, demolition, civil, structural, mechanical, electrical and process drawings. Included in this task shall be the preparation of estimates of the probable construction cost at the 65%, and 90% design submittals.

- LGVSD will provide “front end” boiler plate contract language; however, Consultant shall review and update the boiler plate languages for consistency with the plans and specifications.

- Provide for progress meetings during the various tasks as may be required by the permitting agencies.

**Task 6 – Bidding Services**

- Provide services during bidding including attendance at the pre-bid meeting and job walk, answering contractor’s questions and preparation of addenda.

- Coordinate with District the distribution of bidding documents to builder’s exchanges and potential bidders.

- Coordinate bid opening, prepare bid summary, and evaluate bids for District review and approval.

**Task 7 – Design Engineering Services During Construction**
• Provide design engineering services during construction including review of all submittals and shop drawings, attendance at job meetings and responding to RFIs.

• It is anticipated that LGVSD will hire a Construction Manager to coordinate with the construction contractor and provide the inspection services.

Task 8 – Project Closeout

• Coordinate with Contractor (TBD) and Construction Manager the preparation of final as-built drawings, operations and maintenance manuals, final reports, additional permitting requirements, etc.

• Prepare final project O & M Manual (in addition to specific instruction or O & M manuals submitted by vendors and equipment manufacturers.)

4.0 DELIVERABLES

The following deliverables are required:

• Microturbine pre-purchase specifications

• CNG Vehicle Fill Station Selection Criteria and Service Agreement

• 50%, 90% design submittals with cost estimates.

• Biddable plans and specifications with final cost estimate.

• Environmental review documentation.

• Permit applications.

• Addenda, bid summary, and bid evaluation during the bid period.

• RFI, submittal reviews, and design revisions if any, during construction.

• As-built drawings in PDF and AutoCAD formats, and product or equipment manuals.

• Overall project O & M after project completion.

• Technical memorandums, design calculations, studies, and miscellaneous documents prepared by the Consultant during various stages of design and construction.

5.0 PROPOSAL CONTENT REQUIREMENTS

LGVSD welcomes a response to this RFP in any format that best expresses the qualifications of the Consultant. Proposals submitted in response to this RFP must include the following items:

• Qualifications
1. Submit a description and qualifications of the firm and proposed subconsultants, including:
   a. Similar project experience, no more than 2 pages.
   b. References: provide name and telephone number of at least two references for similar projects that can attest to the quality and effectiveness of the Consultant’s work.

2. Submit qualifications on the individuals responsible for the design, if different than the entity’s principals.

- Project Approach

  1. Describe the approach to the project which will expedite its implementation.
  2. Describe the organizational approach and methodologies the Consultant will use to implement a sustainable, high quality design.
  3. Identify any particular problems or design issues and options that the Consultant may need to investigate.

- Project Schedule

  1. Provide a schedule of tasks to be performed including project milestones.
  2. See anticipated schedule for design and construction below.

6.0 SELECTION CRITERIA AND PROCESS

- Selection Criteria

  1. LGVSD will evaluate the written proposal based on the following criteria:
     a. Responsiveness to the RFP.
     b. Firm’s experience with design and construction review of similar projects.
     c. Evidence that the Consultant understands the aspects of the project, including the easement acquisition, permits and construction bidding process as well as BAAQMD requirements and relevant portions of the LGVSD’s NPDES permit conditions.
     d. Evidence of the Consultant’s ability to prepare well-written documents and accompanying technical drawings.
     e. Evidence that the Consultant has the resources and capacity to commit to a schedule.
     f. Firm’s ability to identify and obtain grant funding.

  2. Consultants selected for an interview will be further evaluated based upon their oral presentation and understanding of the project.
7.0 GENERAL CONDITIONS

- LGVSD reserves the right to:

  1. Waive minor irregularities.
  2. Modify or cancel the selection process or schedule at any time.
  3. Negotiate with the second choice Consultant if it is unable to negotiate an acceptable contract with the first choice Consultant within a reasonable period of time.
  4. Reject any and all proposals and to issue a new request for proposals when it is in the best interest of LGVSD to do so.
  5. Seek any clarification or additional information from Consultants as is deemed necessary to the evaluation of a response.
  6. Judge the veracity, substance and relevance of the Consultants’ written or oral representations; including seeking and evaluating independent information on any of the Consultants’ works cited as relevant experience.
  7. Contract with separate entities for various components of the services.

- All expenses related to any Consultant’s response to the RFP, or other expenses incurred during the period of time the selection process is underway, are the sole obligation and responsibility of that Consultant. LGVSD will not directly or indirectly assume responsibility for such costs except as otherwise provided by written agreement.

8.0 CONTRACT AND OTHER REQUIRED DOCUMENTS

- Within ten (10) calendar days of the date of issuance by LGVSD of the Notice of Award, the Consultant shall submit the following documents to LGVSD:

  1. A Consultant Services Agreement executed in duplicate by the successful firm (See Attachment 1).
  2. Evidence of the required insurance coverage.
  3. A completed Internal Revenue Form W-9.

- Failure of the Consultant to make a timely submission to LGVSD may result in a rescission of acceptance of the proposal by LGVSD and in award of contract to another firm.

9.0 DISCLAIMERS

- This RFP does not commit LGVSD to award a contract or to pay any costs incurred in the preparation of a proposal in response to this RFP.

- LGVSD reserves the right to accept or reject any or all proposals received, to negotiate with the qualified firm, or to cancel the RFP.

- LGVSD may require the firm to submit additional data or information LGVSD deems necessary to substantiate the costs presented by the proposer. LGVSD may also require
the proposer to revise one or more elements of its proposal in accordance with contract negotiations.

- LGVSD reserves the right to evaluate proposals for a period of thirty (30) days.

10.0 DEADLINE FOR SUBMISSION OF PROPOSALS

- The Consultant shall submit five (5) hard copies and a CD version of a PDF file, and one (1) copy of its cost proposal in a separately marked (clearly identifying the proposer) and sealed envelope to:

  Mark R. Williams  
  General Manager  
  Las Gallinas Valley Sanitary District  
  300 Smith Ranch Rd., San Rafael, CA 94903

- To be considered, proposals must be received at the address in the above paragraph and by the proposal due date shown below. Proposals received after this date and time will not be accepted and will be returned to the proposer unopened unless necessary for identification purposes.

- The following is the anticipated schedule for Consultant selection and contracting:

  Proposals Due: 12:00 PM, October 31, 2014  
  Interviews (if required): November 5, 2014  
  Negotiations and Final Scope: November 7, 2014  
  Award of Contract: November 13, 2014  
  Notice to Proceed: November 26, 2014

- The following is the anticipated schedule for design and construction:

  Document Review, Equipment Selection,  
  Site Layout, CEQA, Permit Application: + 1 month after Notice to Proceed  
  Board Presentation: January 8, 2015  
  Equipment Pre-Purchase: + 1 month  
  50% Design Package: + 1 month  
  Design Package Final: + 1 months + 2 weeks staff review  
  Contract Documents Bid: + 2 weeks  
  Phase: + 2 months  
  Construction Phase: + 5 months  
  Project Closeout & Testing: + 1 month, ending December 31, 2015

11.0 CONTACT PERSON

- Inquiries relating to this Request for Proposals and/or the required services should be directed to:
12.0 EXHIBITS

Exhibit A: Biogas Utilization Technologies Evaluation by CH2M Hill, June 10, 2014
Exhibit B: Biogas Utilization Technologies Evaluation by CH2M Hill, May 7, 2014
Exhibit C: Biogas Utilization Technologies Evaluation, Combined Microturbines and CNG Vehicle Fill Station by CH2M Hill, June 5, 2014

13.0 ATTACHMENTS

ATTACHMENT A – Agreement For Consultation and Engineering Services. The Consultant selected to provide the scope of services shall use LGVSD’s standard consultant services agreement. A copy of the template of this agreement is attached to this RFP. By submitting a proposal for the work, the Consultant agrees to utilize the LGVSD standard agreement form for the contract. Contractually required insurance coverage and endorsement information is shown in the body of the document.
Las Gallinas Valley Sanitation District - Biogas Utilization Technologies Evaluation

Section 1 - Introduction

Project Vision

The Las Gallinas Valley Sanitary District (LGVSD or District) wastewater treatment plant (WWTP) needs to upgrade its aged cogeneration system by 2016 to meet new air quality standards. Accordingly, the LGVSD wants to evaluate biogas utilization alternatives to understand the long range option that best addresses economic, environmental, technical and social drivers.

Project Description

In 2012 LGVSD contracted CH2M HILL to visit the WWTP, identify the air emissions regulations and permitting issues that impact LGVSD’s equipment, and recommend a path forward for further analyses, including an evaluation of whether LGVSD should replace or upgrade its internal combustion engine and a recommended approach to track air quality and climate change regulatory and permitting issues that may impact the WWTP. The findings, recommendations and proposed second tier follow-on work items are summarized in a September 21, 2012 Technical Memorandum by CH2M HILL.

After considering the recommendations of the Technical Memorandum, LGVSD requested that CH2M HILL implement an updated version of the proposed second tier scope of services, including 1) evaluation of biogas utilization alternatives, 2) assessment of the digester heating and biogas handling systems, 3) development and operations options for a new cogeneration system, and 4) an annual update that summarizes air quality and climate change regulations that may impact LGVSD operations and developments. This technical memorandum will present the results of Tasks 1 – 3. Task 4 was delivered to LGVSD staff on January 30, 2014, as a separate technical memorandum.

Executive Summary

Four alternatives for biogas utilization were analyzed for both economic and non-cost factors: microturbines, compressed natural gas (CNG) vehicle fill station, pipeline injection, and just removing the existing engine. The economic evaluation estimated the construction costs, the annual operations and maintenance costs, and calculated a present worth assuming a 20 year lifespan. A present worth analysis is an estimate of the value that an investment of money has over a fixed lifespan. The analysis uses a discount rate for the devaluation of equipment and an interest rate of the investment. If a present worth has a positive value, the annual operations and maintenance cost are less than the expenditures. If it is negative, the annual operations and maintenance cost are more than the expenditures.

A non-cost decision analysis methodology was also used to make subjective comparisons among the alternatives, rating them among several factors that are generally not directly affected by costs. The non-cost factors are the result of 1) the issues comparison chart that staff from LGVSD and its board filled out to determine a ranking and
weighted score for each criteria, and 2) an engineering evaluation of each alternative to rate how well each technology meets those criteria. Multiplying the criteria weight by the engineer’s rating for each criterion and adding them all up results in the total non-cost factor score.

The analysis shows that the lowest cost alternative is removing the existing engine, followed by a microturbine system. For non-cost factors, the microturbine alternative scored highest overall and somewhat higher than removing the existing engine, but the difference is small. As demonstrated by the annual operations and maintenance (O&M) present worth values, the microturbines alternative produces savings from energy generation that are higher than the costs to operate. Two values are listed under the CNG vehicle fill station for O&M present worth in Table 1-1 below. The first value of $400,000 assumes that all the biogas available is actually used in a vehicle. Since this scenario is not realistically possible, an assumption using the equivalent of 20 gallons of gasoline per day was evaluated. The result of this calculation is the second value listed—($1,020,000).

A summary of the cost and non-cost factor results is shown in Table 1-1. An estimate of the O&M staff time per year for each alternative is also listed in the table. The cost for this time is factored into the O&M present worth estimate.

Table 1-1
Summary of Alternatives Analysis

<table>
<thead>
<tr>
<th></th>
<th>Remove Existing IC Engine (Add Boiler/Flare)</th>
<th>Microturbines</th>
<th>CNG Vehicle Fill Station</th>
<th>Pipeline Injection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction Cost</td>
<td>($1,580,000)</td>
<td>($2,200,000)</td>
<td>($2,900,000)</td>
<td>($8,400,000)</td>
</tr>
<tr>
<td>Estimated Staff O&amp;M</td>
<td>144</td>
<td>260</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>(hours/yr)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual O&amp;M Present</td>
<td>($380,000)</td>
<td>$100,000</td>
<td>$400,000 / ($1,020,000)</td>
<td>($500,000)</td>
</tr>
<tr>
<td>Worth</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Present Worth</td>
<td>($1,960,000)</td>
<td>($2,100,000)</td>
<td>($2,500,000) / ($3,920,000)</td>
<td>($8,900,000)</td>
</tr>
<tr>
<td>Non-Cost Factor</td>
<td>678</td>
<td>706</td>
<td>584</td>
<td>650</td>
</tr>
<tr>
<td>Score</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If the non-cost factor score is then divided by total present worth (in millions of dollars) for each alternative, the result is a benefit to cost ratio, which is shown in Figure 1-1 below.

![Figure 1-1 Benefit to Cost Ratio of Biogas Utilization Alternatives](image-url)
With the lowest cost and relatively high non-cost factor score, the remove IC engine and flaring the excess biogas has the highest benefit to cost ratio.

Operational Parameters

Table 1-2 below summarizes the biogas parameters that were used in the evaluation. Copies of biogas testing reports that formed the basis of these parameters are included in Appendix A. It should be noted that a new biogas flow meter was recently installed so there is no long term trending data on flow rates. *The value used in this evaluation should be confirmed or adjusted before proceeding with any further development of biogas utilization options.*

**TABLE 1-2**

**Biogas Parameters**

*Summary of Biogas measurements and testing results*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Information Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biogas Production Rate</td>
<td>50,000 standard cubic feet per day (scfd)</td>
<td>Plant staff estimate; trending data not available</td>
</tr>
<tr>
<td>Methane Content</td>
<td>63%</td>
<td>From waste gas burner compliance report, Dec 16, 2013.</td>
</tr>
<tr>
<td>Energy Value</td>
<td>638 British Thermal Units per cubic foot (Btu/ft³)</td>
<td>From waste gas burner compliance report, Dec 16, 2013.</td>
</tr>
<tr>
<td>Siloxanes Content</td>
<td>1,500 parts per million (ppm)</td>
<td>Estimated from typical values at other WWTP facilities</td>
</tr>
</tbody>
</table>

**Section 2 - Biogas Utilization Alternatives**

LGVSD’s existing internal combustion (IC) engine must meet the emission standards of Bay Area Air Quality Management District (BAAQMD) Rule 9-8-302 by January 1, 2016, and include the best available control technology applicable at the time the new unit is permitted. Assuming the rich-burn, internal combustion engine continues to operate solely on digester gas, the pertinent emission standards are as follows: 70 ppm nitrogen oxides (NOx) at 15 percent oxygen, dry basis, and 2,000 ppm carbon monoxide (CO) at 15 percent oxygen, dry basis. An evaluation to determine if the engine can be brought into compliance with air emission standards and, if so, what equipment would be required to do so has been performed.

The existing digester operation utilizes biogas as a fuel for a hot water boiler. The boiler supplies hot water to maintain proper temperature within the anaerobic digesters via a sludge heat exchanger. Detailed calculations for the amount of heat required are included in Appendix A.

Since the existing digested sludge heat exchanger is nearing the end of its expected life, all alternatives assumed that the sludge heat exchanger, sludge recirculation pump, and hot water recirculation pump would be replaced.

**Existing IC Engine Retrofit**

Waukesha, the existing engine manufacturer, was contacted and was unwilling to guarantee they could provide equipment allowing the engine to meet the 70 ppm NOx requirement in the permit. Because the existing engine is a rich burn design, it is unlikely that exhaust cleaning through a catalytic converter would be sufficient enough to meet the permit. Additionally, if a catalytic converter was installed, the catalytic material would be spent quickly and need frequent replacement (several times per year). Furthermore, reinvesting in the engine would place the system at risk since replacement parts will become difficult and expensive to replace. Because this conversion would entail a high chance of failure from either the exhaust gas cleaning system or the engine itself, retrofitting the existing engine is not considered a viable option.
Additional Biogas Utilization Alternatives

The following additional biogas utilization alternatives were considered for suitability at the LGVSD WWTP.

1. New IC engine
2. Microturbines
3. Fuel Cells
4. Gas scrubbing and compression for natural gas fueling station for District fleet vehicles
5. Gas scrubbing for pipeline injection into a local natural gas pipeline

Each alternative was initially screened to determine if they were unsuitable or unfeasible for further evaluation. A brief technology overview and subsequent initial screening of the above five alternatives is provided in Section 3. An economic analysis was conducted on the remaining viable alternatives with the results described in the Section 4 and Section 5 is a non-cost factor evaluation.

Section 3 - Technology Overview and Alternatives Screening

This section provides an overview of combined heat and power (CHP) technologies (IC engines and microturbines) and emerging technologies (fuel cells) under consideration for the LGVSD WWTP. Renewable natural gas (RNG) (also known as biomethane) options for natural gas pipeline injection and compressed RNG for vehicle fuel are also being considered. This section includes a brief process description of each technology, typical performance characteristics, advantages and disadvantages, along with recent advancements, operational insights, and future trends. It includes an overview of biogas treatment technologies for the removal of hydrogen sulfide, siloxanes, moisture, and particulate matter, essential to CHP alternatives, and carbon dioxide scrubbing technologies for the biomethane options.

Biogas Treatment Technologies

Several trace compounds in raw biogas produced by anaerobic digestion are proven to have corrosive effects on a CHP system causing service interruptions and need for maintenance and repair. For optimum performance, biogas-fueled CHP systems require pretreatment of the raw biogas. The most significant components that are targeted in biogas treatment are hydrogen sulfide (H₂S) and siloxanes, along with removal of moisture and particulate matter (PM). Carbon dioxide is typically not removed during biogas pretreatment for CHP systems and is discharged along with the combustion products. Selection of biogas pretreatment technologies is critical to CHP performance since different prime movers have different sensitivities to biogas quality. The following section summarizes proven and emerging technologies employed for biogas pretreatment in CHP systems.

Hydrogen Sulfide

The main method of preventing H₂S formation in biogas is liquid phase treatment. The most common method of limiting H₂S concentrations is the addition of iron salts, typically ferrous chloride (FeCl₂), ferric chloride (FeCl₃) or ferrous sulfate (FeSO₄) fed directly to the digester slurry or to the feed to anaerobic digesters. Currently, ferric chloride is being used at the treatment facility to reduce H₂S concentration, however, the amount of H₂S currently measured in LGVSD’s biogas is above the amount recommended by CHP equipment manufacturers. Therefore, it is necessary to treat biogas to further reduce H₂S levels prior to combustion. Gas phase treatments can include adsorption, chemical scrubbing or biological scrubbing (bio-trickling filter).

Iron Sponge Adsorption

Iron sponge adsorption is the most commonly used H₂S removal system. In this process, saturated biogas flows through process vessels (typically two in series) containing wood chips or granular activated carbon impregnated with hydrated ferric oxide (Fe₂O₃·H₂O, also referred to as iron oxide) which is a low cost product. The H₂S reacts with the ferric oxide to form iron sulfide (Fe₂S₃, also referred to as iron pyrite). This process is capable of reducing H₂S to about 35 ppmv. Biogas needs to be saturated with water vapor to prevent drying of the media which subsequently reduces its reactive capacity. Therefore, it is necessary that H₂S removal be the first step in a biogas
pretreatment system. The Fe$_2$S$_3$ can be regenerated by using air to oxidize the Fe$_2$S$_3$ to Fe$_2$O$_3$ and elemental sulfur until the accumulation of sulfur and other reactions render the media ineffective. This process is estimated to regenerate the iron sponge media to about 50-60% of its original capacity, and may be performed two to three times during its lifetime of about three years. Media removal and replacement has proven to be maintenance intensive due to spontaneous combustibility of iron sponge, demanding rigorous safety measures for its O&M staff. Historically, spent iron sponge was disposed of at most municipal landfills and the practice is still vastly predominant; however, it is now characterized as a hazardous chemical by the OSHA Hazard Communication Standard (29 CFR 1910.1200) and is also a listed substance in the California Hazardous Substances. Pursuant to this, local/state regulations are gearing towards mandating the disposal of spent iron sponge as hazardous waste, thus making disposal more expensive and less convenient. For example, Central Marin Sanitation Agency in San Rafael, reported that they need to dispose of their spent iron sponge media as hazardous waste. On account of this, alternative iron oxide adsorbents that overcome these disadvantages of safety and disposal are gaining popularity. SULFATREAT®, Sulfur-Rite®, and SULFA-BIND® are some examples of such proprietary iron oxide adsorbents.

**Moisture**

Mechanical gas dryers or heat exchangers coupled with water chillers are commonly used for moisture removal. These systems typically achieve a gas dew point of 40 °F, which is adequate in most applications. However, the dried gas is reheated to a relative humidity of about 60% to ensure that the biogas does not condense downstream of the dryer. Desiccant dryers with coalescing filters can also be used. Desiccant dryers have high water vapor removal efficiencies (suitable for microturbines) while the coalescing filters remove any water droplets, as well as any particulate that may be discharged from the desiccant dryers.

**Siloxanes**

**Carbon Adsorption**

Carbon adsorption is currently the best available technology for siloxanes removal. Adsorption vessels containing activated carbon typically connected in series adsorb siloxanes and other volatile organic compounds (VOCs). The series configuration allows the first vessel to remove most of the siloxanes while a second vessel acts as a polishing step, and also allows for continuous operation during media regeneration or replacement. Upstream removal of H$_2$S and moisture are important for optimum performance of carbon adsorption. Carbon adsorption is also more effective with cool biogas and therefore it is placed downstream of moisture removal during which the gas is chilled. However, after moisture removal, the biogas should be moderately reheated to ensure an acceptable relative humidity and temperature for optimal adsorption. After its useful life, the spent nonhazardous activated carbon media can be safely disposed off at most municipal landfills. Silica gels are an alternative to activated carbon that are rapidly gaining acceptance for siloxanes removal. They are reportedly capable of achieving siloxanes removal at rates of up to 3 times greater than activated carbon systems.

**Particulate Matter**

Dust and small particles should be removed to improve the performance of downstream CHP equipment, including combustion components. To achieve this, particulate filters are often installed downstream of activated carbon treatment system and immediately upstream of the prime mover.

**Combined Heat and Power Technologies**

In treatment plants with wastewater flows of 10MGD or less, fueling boilers is the most common approach for biogas utilization. Adequate biogas production is critical to the implementation of an economically feasible CHP system. However, a waste gas flaring system and boiler system are often necessary even when a facility is equipped with CHP to manage excess biogas during CHP system outage or maintenance and meet process heat requirements.
Internal Combustion Engines

Internal combustion engines are the most prevalent technology used in combined heat and power applications in WWTPs. The two basic designs of internal combustion engines are compression-ignition (diesel engines) and spark-ignition (Otto-cycle). The essential mechanical components of both types of engines are the same; both use a cylindrical combustion chamber in which a close fitting piston reciprocates the length of the cylinder. The piston connects to a crankshaft that transforms linear motion of the piston into rotary motion. Most engines have multiple cylinders that power a single crankshaft. The primary difference between the two engines is the method of fuel ignition. Spark ignition engines use a spark plug to ignite a pre-mixed air-fuel mixture introduced into the cylinder while compression ignition engines compress the air introduced into the cylinder to a high pressure, raising its temperature to the auto-ignition temperature of the fuel that is injected at high pressure. Spark-ignition engines are almost exclusively used for CHP applications fueled solely by biogas.

Recoverable heat from internal combustion engines typically represents about 60-70 percent of the inlet fuel energy. Jacket coolant and engine exhaust are the primary sources for this recoverable heat, each of which accounts for up to 30 percent of recoverable fuel energy. A small amount of heat is sometimes recoverable from engine turbochargers and lube oil systems. Jacket water cooling systems can produce hot water reaching up to 200 °F while engine exhaust temperatures range from 850-1200 °F. In order to prevent corrosion of exhaust system components, engine exhaust outlet temperatures are maintained above the dew point (typically 250-350 °F) to prevent condensation. Engine exhaust heat available for recovery is capable of generating hot water up to approximately 180 °F.

FIGURE 3-1
Heat Recovery from an Internal Combustion Engine
Design Characteristics

**Size range:** IC engines are available in sizes from 300 kW to over 5 MW.

**Thermal output:** IC engines can produce hot water and low pressure steam (<30 psig).

**Fast start-up:** The fast start-up capability of IC engines allows timely resumption of the system following a maintenance procedure. In peaking or emergency power applications, IC engines can quickly supply electricity on demand.

**Black-start capability:** In the event of an electric utility outage, IC engines require minimal auxiliary power requirements. Generally only batteries are required.

**Availability:** IC engines have typically demonstrated availability greater than 95 percent in stationary power generation applications.

**Part-load operation:** The high part-load efficiency of IC engines ensures economical operation in electric load following applications.

**Reliability and life:** IC engines have proven to be reliable power generators given proper maintenance.

**Emissions:** Typically, exhaust emissions from IC engines are higher than those produced by other prime movers. The most significant pollutants found in IC engine exhaust emissions are carbon monoxide (CO), oxides of nitrogen (NOx) and volatile organic compounds (VOCs). When biogas is used as fuel, oxides of sulfur (SOx) and particulate matter (PM) are also present. However, the emissions profile of IC engines has improved significantly in the last decade through better design and control of the combustion process, and through the use of exhaust catalysts.

Performance Characteristics

Currently, the best available control technology for biogas-fueled internal combustion engines is lean-burn combustion. Lean-burn refers to the use of lower fuel-to-air ratios, i.e. the fuel-air mixture has considerably less fuel in comparison to its stoichiometric combustion ratio. By operating at fuel-to-air ratios up to 100 percent in excess of the stoichiometric ratio, lean-burn engines operate with lower temperatures in the combustion chamber, which results in lower CO, NOx, and VOC emissions. In addition to lower exhaust emissions, lean-burn
engines also achieve higher fuel efficiency due to more complete fuel combustion. For CHP operation, overall energy recovery efficiencies of 70-85% are reported.

TABLE 3-1
Internal Combustion Engine Performance Characteristics

<table>
<thead>
<tr>
<th>Performance Characteristics</th>
<th>Lean Burn Engine</th>
<th>Advanced Generation Lean Burn Engine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (kW)</td>
<td>300 – 2,700</td>
<td>400 – 3370</td>
</tr>
<tr>
<td>Electrical Efficiency (%)*</td>
<td>30 – 38</td>
<td>37 – 42</td>
</tr>
<tr>
<td>Thermal Efficiency (%)*</td>
<td>41 – 49</td>
<td>35 – 43</td>
</tr>
<tr>
<td>Equipment Cost ($/kW)</td>
<td>465 – 1,600</td>
<td>465 – 1,200</td>
</tr>
<tr>
<td>Maintenance Cost ($/kWh)</td>
<td>0.01 – 0.05</td>
<td>0.01 – 0.025</td>
</tr>
<tr>
<td>Availability (%)</td>
<td>90 – 96</td>
<td>90 – 96</td>
</tr>
<tr>
<td>Overhaul Frequency (hours)</td>
<td>28,000 – 90,000</td>
<td>30,000 – 90,000</td>
</tr>
<tr>
<td>NOx Emissions (lb/million Btu)</td>
<td>0.15 – 0.870</td>
<td>0.17 – 0.44</td>
</tr>
<tr>
<td>CO Emissions (lb/million Btu)</td>
<td>0.163 – 2.160</td>
<td>0.34 – 0.92</td>
</tr>
</tbody>
</table>

1. Performance at full continuous duty rated load.
2. Performance characteristics provided by Caterpillar, Jenbacher, MAN, and MWM.
*Electrical and thermal efficiencies are based on the lower heating value (LHV) of biogas; approximately 560 Btu/ft³.

Advantages and Disadvantages Summary

TABLE 3-2
Internal Combustion Engine Advantages and Disadvantages

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Fast start-up.</td>
<td>• Requires fuel pretreatment to remove H₂S, siloxanes, moisture, and particulate matter, to avoid potential engine damage or efficiency loss.</td>
</tr>
<tr>
<td>• Relatively low investment cost.</td>
<td>• Requires continual cooling (plant water or cooling radiator may be utilized).</td>
</tr>
<tr>
<td>• Suitable for most WWTPs due to availability in wide range of fuel input requirements.</td>
<td>• High levels of low frequency noise.</td>
</tr>
<tr>
<td>• Reliable, well-proven technology available from several reputable manufacturers.</td>
<td>• Higher maintenance costs relative to micro-turbines.</td>
</tr>
<tr>
<td>• Greatest combined electrical and thermal efficiency of all CHP technologies.</td>
<td>• Limited to lower temperature (maximum of 170°F) cogeneration applications.</td>
</tr>
<tr>
<td>• Capable of being operated and maintained by plant staff.</td>
<td>• High air emissions.</td>
</tr>
<tr>
<td>• Operates on low pressure gas (3 to 5 psig).</td>
<td>• Supplemental natural gas required if biogas supply is insufficient.</td>
</tr>
<tr>
<td>• Can be used in island mode and have good load following capability.</td>
<td></td>
</tr>
<tr>
<td>• Can be used in conjunction with other gas strategies as peak power generation, during other biogas equipment upgrade routine maintenance.</td>
<td></td>
</tr>
<tr>
<td>• Can be sized at nearly any load capacity.</td>
<td></td>
</tr>
<tr>
<td>• Can be operated at various load levels to ensure minimal flare use.</td>
<td></td>
</tr>
</tbody>
</table>
Over the past decade, engine manufacturers have made significant developments with IC engines to operate primarily on biogas. These types of engines are becoming more common at WWTPs. However, the engine manufacturers only offer these engines as small as approximately 300 kW and require at least 120,000 scf/day. This is more than twice the amount of gas the plant is capable of producing. Some users of IC engines choose to supplement their biogas with natural gas to fulfill the minimum fuel required, but typically the amount of natural gas imported is less than 15% of the total energy required. Since LGVSD currently does not have natural gas service to the plant, this option is not viable at this time.

Another consideration of supplementing with natural gas is that it would increase the carbon footprint of the facility because combusted natural gas is considered an anthropogenic greenhouse gas (GHG) emission; unlike combusted biogas emissions, which the state of California considers biogenic and without any regulatory obligation to reduce. There would be a number of possible regulatory issues and extensive coordination and potential installation cost issues with Pacific Gas and Electric Company (PG&E) to determine if supplementing this amount of natural gas was possible. If it were possible, a pipeline would need to be installed along Smith Ranch Road towards an interconnect point on PG&E’s gas main near the soccer field or Main Drive. For these reasons, IC engines were not considered for further analysis.

Microturbines

Microturbines are a newer energy recovery technology suitable for small to mid-size plants. They are small high-speed combustion gas turbines most of which feature an internal heat exchanger called a recuperator. In a microturbine, a centrifugal compressor compresses the inlet air that is then preheated in the recuperator using heat from the turbine exhaust. The heated air from the recuperator mixes with fuel in the combustor and hot combustion gas expands through the expansion and power turbines. The expansion turbine turns the compressor and, in single-shaft models, turns the generator as well. Two-shaft models use the compressor drive turbine’s exhaust to power a second turbine that drives the generator. Finally, the recuperator uses the exhaust of the power turbine to preheat the air from the compressor.

For heat recovery, a second heat exchanger, the exhaust gas heat exchanger, transfers heat from the microturbine exhaust to a hot water system. Recuperator effectiveness strongly influences the microturbine exhaust temperature. Figure 3-2 shows a schematic of a single shaft microturbine without the recuperator and with heat recovery.

**FIGURE 3-2 - Single Shaft Microturbine with Heat Recovery**
Design Characteristics

Thermal Output: Microturbines produce thermal output in the range of 400 to 600°F.
Reliability and life: Design life is estimated to be in the 40,000 to 80,000 hours range. While units have demonstrated reliability, they have not been in commercial service long enough to provide definitive life data.
Size range: 30 to 250 kW.
Emissions: Low inlet temperatures and high fuel-to-air ratios result in NOx emissions.
Modularity: Units may be connected in parallel to serve larger loads and provide power reliability.
Part-load operation: Because microturbines reduce power output by reducing mass flow and combustion temperature, efficiency at part load can be below that of full-power efficiency.

Performance Characteristics

Microturbines are more complex than the conventional gas turbines because of the recuperator, which introduces several additional internal pressure losses moderately reducing the system efficiency and power. The recuperator has four major internal connections which pose a significant challenge to the engine designer to lower associated pressure losses while keeping manufacturing cost low and not compromising system reliability. Microturbines don’t necessarily have high prime mover O&M costs, but they do have high fuel treatment costs. Hence, their overall CHP O&M costs can be proportionally higher due to their relatively small output. The electrical efficiency of microturbines is approximately 26-27% at 30 kW operations. With combined heat and power recovery, the overall efficiency is between 70-90%. Microturbines are gaining popularity in regions with stringent air quality regulations because of its low NOx emissions during combustion.

TABLE 3-3

Microturbine Performance Characteristics

<table>
<thead>
<tr>
<th>Performance Characteristics(^1,2)</th>
<th>Microturbine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (kW)</td>
<td>30 – 250</td>
</tr>
<tr>
<td>Electrical Efficiency (%)</td>
<td>26 – 30</td>
</tr>
<tr>
<td>Thermal Efficiency (%)</td>
<td>30 – 37</td>
</tr>
<tr>
<td>Equipment Cost ($/kW)</td>
<td>800 – 1,650</td>
</tr>
<tr>
<td>Maintenance Cost ($/kWh)</td>
<td>0.012 – 0.025</td>
</tr>
<tr>
<td>Availability (%)</td>
<td>85 – 90</td>
</tr>
<tr>
<td>Overhaul Frequency (hours)</td>
<td>30,000 – 50,000</td>
</tr>
<tr>
<td>NOx Emissions (lb/million Btu)</td>
<td>0.120 – 0.190</td>
</tr>
<tr>
<td>CO Emissions (lb/million Btu)</td>
<td>0.520 – 1.760</td>
</tr>
</tbody>
</table>

1. Performance at full continuous rated duty load.
2. Performance characteristics provided by Capstone.

Advantages and Disadvantages Summary
TABLE 3-4
Microturbine Advantages and Disadvantages

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Are available in size ranges (30-250 kW) for small gas flows or small capacity plants.</td>
<td>• Low electrical and thermal efficiencies compared to other CHP technologies.</td>
</tr>
<tr>
<td>• Can be used in conjunction with other biogas usage strategies and/or several turbines for various gas flow strategy or maintenance redundancy.</td>
<td>• Require significant fuel gas cleanup including H₂S, siloxanes, and moisture.</td>
</tr>
<tr>
<td>• Compact size and light weight.</td>
<td>• Require high pressure fuel (75-100 psig) which requires fuel compression.</td>
</tr>
<tr>
<td>• Lower maintenance costs compared to internal combustion engines due to small number of moving parts.</td>
<td>• Warm weather (above 59°F) reduces power generation and fuel efficiency.</td>
</tr>
<tr>
<td>• No cooling required.</td>
<td>• Due to issues with fuel treatment, thus far have not demonstrated a long service life.</td>
</tr>
<tr>
<td>• Produce moderate levels of NOx and CO exhaust emissions.</td>
<td>• Currently, only one viable manufacturer of microturbines – Capstone Turbine Corporation.</td>
</tr>
<tr>
<td>• Are relatively quiet and suitable for outdoor installation without adding a separate building.</td>
<td></td>
</tr>
</tbody>
</table>

Applicability to LGVSD WWTP

Microturbines were evaluated to be suitable for implementation at the LGVSD WWTP and therefore considered for further analysis, primarily for the following reasons.

- Currently available microturbine sizes start at 30 kW which match the projected biogas quantity at the plant.
- Microturbines can operate below the BAAQMD required emissions standards
- Sufficient space is available at the site to install a system
- Microturbines provide a source of heat for the digester, existing boiler provides redundancy

Fuel Cells

Fuel cells are an emerging technology, and involve a physical-chemical process for the production of electricity. Fuel cells produce energy without direct combustion of the fuel; the technology uses an electrochemical process which converts chemical energy to electrical energy. A fuel cell consists of an anode, cathode and electrolyte. Hydrogen extracted from the biogas diffuses to the anode and dissociates into positively charged ions and negatively charged electrons. The ions diffuse through the electrolyte to the cathode while the electrons flow to the cathode via an external circuit creating an electric current. At the cathode, the electrons and ions react with oxygen to form water.

The main process modules of a fuel cell unit, shown in Figure 3-3, are as follows:
1. **Gas cleanup unit** – This module purifies the biogas and removes nearly all potential contaminants. Fuel cell stacks are extremely sensitive to impurities and only exceptionally pure, clean and pressurized methane gas leaves this module to the fuel cell reformer. Minute quantities of sulfur compounds, including H₂S, will quickly damage the fuel cell’s nickel catalyst within the cell stack if not removed.
2. **Reformer** – This device combusts a very small amount of the fuel to vaporize water to produce steam. The reformer then mixes this pressurized high temperature steam together with the pure CH₄ gas from the gas cleanup module to produce the hydrogen gas essential to the fuel cell operation.
3. **Cell stack** – The cell stack is the device that produces electricity from the hydrogen gas and consists of an anode, cathode, and electrolyte. The distinguishing feature among the various types of fuel cells is the electrolyte employed in their respective cell stacks. Regardless of the type employed, the electrolyte allows the transfer of
ions from the anode to the cathode while the electrons flow through an external circuit and generate a power output.

4. **Inverter** – The inverter consists of electrical devices that convert the direct current (DC) electric power into alternating current (AC) and transforms this AC power into the required system voltage.

**FIGURE 3-3**
**Fuel Cell Operation with Heat Recovery**

Electrochemical reactions in fuel cells are exothermic and this heat is sufficient to vaporize the water formed during the reaction as well. This can be used for digester heating but rarely sufficient to meet the demand and therefore the shortage needs to be supplemented by a boiler. Phosphoric acid fuel cells (PAFCs) operate at about 350 °F and produce low grade heat suitable for anaerobic digester heating with hot water. Molten carbonate fuel cells (MCFCs) operate at much higher temperatures, reaching about 1,250 °F. In addition to anaerobic digester heating, the recoverable heat from MCFCs is also capable of producing sufficient high pressure steam.

**Design Characteristics**

There are five types of fuel cells in use or under development. These are: (1) phosphoric acid (PAFC), (2) proton exchange membrane (PEMFC), (3) molten carbonate (MCFC), (4) solid oxide (SOFC), and (5) alkaline (AFC). Of these, PAFCs and MCFCs are two types of fuel cells that are known to be suitable for use with biogas.

1. **Phosphoric Acid Fuel Cells** – The first commercial fuel cells used in POTW applications were the phosphoric acid type. Several POTWs throughout the US operate PAFCs with biogas. Some of those installations have over 7 years of operational experience with PAFCs which suggests this is an established and proven technology; however, currently PAFCs are not commercially available for use with biogas.

2. **Molten Carbonate Fuel Cells** – Many of the more recent fuel cell installations since 2003 have used the molten carbonate type. Portions of the MCFCs, such as the reformer and the inverter are similar to those in PAFCs. One important difference is the lithium and potassium carbonate electrolyte solution that allows the transfer of electrons within the unit.
3. Solid Oxide Fuel Cells – Besides PAFCs and MCFCs, SOFCs are also being developed for CHP applications. In SOFCs, the anode, cathode and electrolyte are all made from ceramic substances, because of which the cells can operate at temperatures as high as 1,800°F (1,000 degrees C), significantly hotter than any other fuel cell. This produces exhaust gases at temperatures ideal for use in combined heat and power applications. Third, the cells can be configured either as rolled tubes (tubular) or as flat plates (planar) manufactured using many of the proven techniques employed by the electronics industry. The electricity efficiency of SOFCs is expected to be around 50 percent. If the hot exhaust of the cells is used in a hybrid combination with gas turbines, the electrical generating efficiency may exceed 70 percent. In CHP applications, overall system efficiency is expected to approach 80-85 percent. Siemens has tested the world’s first solid oxide fuel cell/gas turbine hybrid system. The system had a total output of 220 kW, with 200 kW from the fuel cell and 20 kW from the microturbine generator. This proof-of-concept system demonstrated an electrical efficiency of 53 percent.

Performance Characteristics

Fuel cells have demanding gas treatment requirements and specialized operation and maintenance needs. Brief experience with biogas-fueled fuel cells indicates that cell stacks become depleted and must be replaced after about 3 years of service. Cell stack replacement should be characterized as a major overhaul and be included in the fuel cell O&M costs.

### TABLE 3-6
Fuel Cell Performance Characteristics

<table>
<thead>
<tr>
<th>Performance Characteristics</th>
<th>Phosphoric Acid Fuel Cell</th>
<th>Molten Carbonate Fuel Cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (kW)</td>
<td>200</td>
<td>300 – 1,200</td>
</tr>
<tr>
<td>Electrical Efficiency (%)</td>
<td>36 – 40</td>
<td>40 – 45</td>
</tr>
<tr>
<td>Thermal Efficiency (%)</td>
<td>NA⁴</td>
<td>30 – 40</td>
</tr>
<tr>
<td>Equipment Cost ($/kW)</td>
<td>3,800 – 5,280</td>
<td>4,390 – 4,660</td>
</tr>
<tr>
<td>Maintenance Cost ($/kWh)</td>
<td>0.004 – 0.019</td>
<td>0.004 – 0.019</td>
</tr>
<tr>
<td>Availability (%)</td>
<td>90 – 95</td>
<td>90 – 95</td>
</tr>
<tr>
<td>Overhaul Frequency (hours)</td>
<td>10,000 – 40,000</td>
<td>10,000 – 40,000</td>
</tr>
<tr>
<td>NOx Emissions (lb/million Btu)</td>
<td>0.003 – 0.006</td>
<td>0.003 – 0.006</td>
</tr>
<tr>
<td>CO Emissions (lb/million Btu)</td>
<td>0.006 – 0.016</td>
<td>0.006 – 0.016</td>
</tr>
</tbody>
</table>

1. Performance at full continuous duty rated load.
2. Based on historical data. PAFCs are not currently available for use with biogas.
3. Performance characteristics provided by FuelCell Energy.
4. Not aware of any biogas-fueled PAFCs that recovered heat.
Cost Summary
The purchase price for fuel cells on a per kW basis varies depending on the size of the unit. Larger fuel cells (1 MW and larger) cost approximately $4,000 per kW, while smaller units (300 kW) cost approximately $7,000 per kW. A single 300 kW fuel cell, which would be the smallest size available to install at LGVSD, would cost $2,100,000. Additional equipment to clean and compress the gas could cost an additional $400,000-$500,000. Maintenance cost for a fuel cell is approximately $0.06/kW-hr. Since LGVSD only produces approximately one-third of the required methane for the smallest unit, a natural gas pipeline would be required to be installed and natural gas purchased on an on-going basis.

Advantages and Disadvantages Summary

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Produce exceptionally low levels of NOx, SOx, and CO</td>
<td>• High construction and maintenance costs.</td>
</tr>
<tr>
<td>exhaust emissions.</td>
<td>• Require high levels of system redundancy for fuel</td>
</tr>
<tr>
<td>• Are frequently exempt from air permitting.</td>
<td>conditioning to remove all contaminants.</td>
</tr>
<tr>
<td>• Have very high electrical power efficiency.</td>
<td>• Require highly specialized contract maintenance and servicing.</td>
</tr>
<tr>
<td>• Are extremely quiet.</td>
<td>• Cell stacks have short lives; typically 5 years or less, with</td>
</tr>
<tr>
<td>• Are suitable for unattended operation.</td>
<td>high replacement costs.</td>
</tr>
<tr>
<td></td>
<td>• Produce less recoverable heat than internal combustion engines.</td>
</tr>
<tr>
<td></td>
<td>• Have a long start-up time.</td>
</tr>
<tr>
<td></td>
<td>• Supplemental natural gas would need to be purchased to</td>
</tr>
<tr>
<td></td>
<td>operate a single unit.</td>
</tr>
<tr>
<td></td>
<td>• Susceptible to periodic shut-downs during warm weather,</td>
</tr>
<tr>
<td></td>
<td>unless equipped with a load bank.</td>
</tr>
<tr>
<td></td>
<td>• Continuously consume fresh water.</td>
</tr>
<tr>
<td></td>
<td>• Emerging technology.</td>
</tr>
</tbody>
</table>

Applicability to LGVSD WWTP
Fuel cells were evaluated to be unsuitable for implementation at the LGVSD WWTP and therefore not considered for further analysis, primarily for the following reasons.

• LGVSD WWTP biogas production is insufficient for utilization in a fuel cell. The smallest currently available fuel cell is rated for 300 kW, followed by a 1500 kW unit.

• Very high construction and O&M costs for fuel cells, including requirement for a high level of biogas conditioning.

Biomethane Technologies
Biogas cleaned to natural gas quality (95 to 98 percent methane by volume) is referred to as “biomethane” or renewable natural gas (RNG). Biomethane typically has about 6 percent lower caloric value than natural gas. The energy from biomethane is entirely from methane whereas natural gas comprises of some heavy, combustible hydrocarbons giving it a higher heating value than biomethane. The higher heating value (HHV) of biomethane may be as high as 990 Btu/ft³, whereas the HHV of natural gas may be as high as 1050 Btu/ft³.

Biogas Upgrading
Carbon dioxide (CO₂) removal systems are implemented when biogas purification for production of biomethane is desired for either injection into a natural gas pipeline or for use as vehicle fuel. Four different methods that are
presently commercially used for removal of carbon dioxide from biogas to achieve biomethane quality are presented below. Vendors who supply carbon dioxide removal systems typically supply separate systems for H₂S, siloxanes and moisture removal upstream of the CO₂ treatment.

**Water Scrubbing**

Water scrubbing is the simplest and the most commonly used process for CO₂ and H₂S removal since both gases are more soluble in water than methane. In the absorption column (or scrubbing vessel), water is discharged downward over trays or packed media while compressed biogas is fed at the bottom of the vessel in a counter-current configuration, where CO₂ and H₂S are absorbed. After a drying step of pressure swing adsorption/temperature swing adsorption, the methane purity in the product gas can reach up to 98%. Water discharged from the bottom of the column flows into a flashing vessel which operates at an intermediate pressure, where absorbed CH₄ and CO₂ is released and transferred back to the raw gas inlet to minimize methane loss. Water discharged from the flashing vessel flows to the top of the desorption column (or stripping vessel) which operates at approximately atmospheric pressure. Air flows counter-current to the water stripping CO₂ and H₂S from it; regenerated water from the column is pumped to the top of the absorption column. Exhaust air will comprise of <2% CH₄, CO₂, H₂S, N₂, O₂, and saturated with water. As an alternative to regeneration, the most cost effective option is to utilize cheaply available water, for example, effluent water from the WWTP. Some of the advantages and disadvantages associated with water scrubbing are summarized in the table below.

**FIGURE 3-4 - Water Scrubbing Flow Diagram**

![Water Scrubbing Flow Diagram](image)

**TABLE 3-8**

**Water Scrubbing Advantages and Disadvantages**

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Good yield with high purity.</td>
<td>• Moderate to high electrical demand.</td>
</tr>
<tr>
<td>• Simple technique, no special chemicals or equipment required.</td>
<td>• Limitation of H₂S absorption due to changing pH, unless separate H₂S treatment is provided.</td>
</tr>
<tr>
<td>• Neutralization of corrosive gases.</td>
<td>• H₂S damages equipment.</td>
</tr>
<tr>
<td>• Low media replacement costs.</td>
<td>• Requires a lot of water, even with the regenerative process.</td>
</tr>
<tr>
<td>• Highest value product ready for pipeline or CNG vehicles.</td>
<td>• Requires compression of raw biogas.</td>
</tr>
<tr>
<td>• Generally safe to operate since there are few pieces of equipment.</td>
<td></td>
</tr>
</tbody>
</table>
Organic physical scrubbing is an absorption process very similar to water scrubbing, with the important difference that the CO₂ is absorbed in an organic solvent such as polyethylene glycol. CO₂ and H₂S are more soluble in polyethylene glycol than in water and for the same upgrading capacity the flow of the liquid phase can be lower leading to a smaller footprint. The polyethylene glycol solution is regenerated by heating and/or depressurizing. H₂S, water, oxygen and nitrogen may be removed together with CO₂. However, more often H₂S is removed prior to upgrading. Selexol® and Genosorb® are examples of trade names for solvents used in organic physical scrubbing.

Chemical Scrubbing

Chemical scrubbing (also known as amine scrubbing) involves the use of amine solutions. CO₂ is not only absorbed in the liquid, but also reacts chemically with the amine in the liquid. Since the chemical reaction is strongly selective, the methane loss might be as low as <0.1%. Part of the liquid is lost due to evaporation, and has to be replaced. The liquid in which CO₂ is chemically bound is regenerated by heating. Monoethanol amine (MEA) and dimethyl ethanol amine (DMEA) are two commonly used compounds. If H₂S is present in the raw gas, it will be absorbed in the amine scrubber solution and higher temperatures will be needed for the regeneration. Therefore H₂S pretreatment is necessary prior to amine scrubbing.

**TABLE 3-9**  
**Chemical Scrubbing Advantages and Disadvantages**

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Low pressure operation; therefore electrical demand is low.</td>
<td>▪ H₂S pretreatment necessary prior to chemical scrubbing.</td>
</tr>
<tr>
<td>▪ Annual operational requirements for makeup water, oil and other chemicals are low.</td>
<td>▪ Moderate energy cost associated with media replacement and regeneration of the amine solution.</td>
</tr>
<tr>
<td>▪ &gt;99% methane recovery.</td>
<td>▪ Spent amine solution is hazardous waste making disposal expensive and less convenient.</td>
</tr>
<tr>
<td>▪ Well used technology in the oil and gas industry.</td>
<td></td>
</tr>
<tr>
<td>▪ Generally safe to operate since there are few pieces of equipment.</td>
<td></td>
</tr>
</tbody>
</table>

Pressure Swing Adsorption

Pressure swing adsorption (PSA) is a process where different species are separated from a gas mixture under pressure based on their molecular characteristics and affinity for an adsorbent. Preferential adsorption occurs at high pressure and near-ambient temperatures and desorption occurs when the pressure is swung to low.

Molecular sieves made up of adsorptive materials, for example, activated carbon or zeolites, of a precise, uniform pore size are typical in this process. The biogas upgrading system typically consists of four vessels filled with the adsorbent connected in series. During normal operation, each column operates in an alternating cycle of adsorption, regeneration and pressure build-up. During the adsorption phase, biogas enters from the bottom into one of the columns and CO₂, O₂ and N₂ are adsorbed on the media. The exiting enriched gas contains more than 97% CH₄ and is substantially free of siloxanes, VOCs, and water. In addition, water present in the raw gas can destroy the structure of the material. Therefore H₂S and water need to be removed before the PSA-column. Before the media is completely saturated with the adsorbed species, the adsorption phase is stopped and another vessel that has been regenerated is switched into adsorption mode to achieve continuous operation. Regeneration of the saturated media is performed by a stepwise depressurization of the spent column to atmospheric pressure and finally to near vacuum conditions. Initially, the pressure is reduced by a pressure balance with an already regenerated column. This is followed by a second depressurization step to atmospheric pressure. The gas exiting the column during regeneration contains significant amounts of CH₄ and is recycled to the gas inlet. Before the adsorption phase starts again, the column is repressurized stepwise to the final adsorption pressure. After a pressure balance with a column that has been in adsorption mode before, the final pressure build-up is achieved with feed gas. The advantages and disadvantages associated with PSA are summarized in the table below.
### TABLE 3-10
Pressure Swing Adsorption Advantages and Disadvantages

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• &gt;97% methane recovery.</td>
<td>• H₂S and moisture pretreatment necessary prior to PSA.</td>
</tr>
<tr>
<td>• Annual operational requirements for oil and other chemicals are low.</td>
<td>• High electrical demand.</td>
</tr>
<tr>
<td>• Low level of emissions.</td>
<td>• Moderate media replacement costs.</td>
</tr>
<tr>
<td>• Adds flexibility on how the gas is used.</td>
<td></td>
</tr>
<tr>
<td>• Small unit size.</td>
<td></td>
</tr>
<tr>
<td>• Generally safe to operate since there are few pieces of equipment.</td>
<td></td>
</tr>
</tbody>
</table>

### Membrane Separation

Membrane separation is a proven technology in the natural gas industry. It involves high pressure gas separation in membrane modules which operate on the basis of selective permeation. The rate of permeation is determined by the product of a solubility coefficient and a diffusion coefficient. Very small and highly soluble molecules (such as CO₂ and H₂S) permeate faster than large molecules (such as N₂, CH₄). When pressurized biogas is passed through the membrane modules, it gets separated into a CO₂-rich, low pressure permeate stream and a CH₄-rich, high pressure biomethane stream.

Membranes made of polymers and copolymers, for example, cellulose acetate, in the form of a flat film or a hollow fiber have been used for gas separation. The utilization of hollow fiber membranes allows the construction of very compact modules working in cross flow. Biogas may be pretreated to remove H₂S and PM, followed by the cellulose acetate membranes which separate CO₂, moisture and the remaining H₂S. These membranes are not effective in separating nitrogen from methane. Biogas is typically upgraded in three stages to an enriched gas with 96% methane or more. The waste gas from the first two stages is recycled to recover methane. The waste gas from stage 3 (and in part of stage 2) is flared or used in a steam boiler as it contains about 10 to 20% methane. Application of polyimide membranes has also been found, in which, a single stage unit is capable of achieving 94% enrichment of the gas. Some of the advantages and disadvantages associated with membrane separation are summarized in Table 3-11 below.

### TABLE 3-11
Membrane Separation Advantages and Disadvantages

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Compact and lightweight.</td>
<td>• Membranes are expensive.</td>
</tr>
<tr>
<td>• Low labor intensity.</td>
<td>• Certain solvents can quickly and permanently destroy the membrane.</td>
</tr>
<tr>
<td>• Modular design permitting easy expansion or operation at partial capacity.</td>
<td>• Certain colloidal solids, especially graphite and residues from vibratory operations, can permanently foul the membrane surface.</td>
</tr>
<tr>
<td>• Low maintenance (no moving parts).</td>
<td>• The energy costs are higher than chemical treatment, although less than evaporation.</td>
</tr>
<tr>
<td>• Low energy requirements and low cost especially for small sizes.</td>
<td></td>
</tr>
<tr>
<td>• No specialized chemical knowledge required.</td>
<td></td>
</tr>
<tr>
<td>• Generally safe to operate since there are few pieces of equipment.</td>
<td></td>
</tr>
<tr>
<td>• Complex instrumentation is not required.</td>
<td></td>
</tr>
</tbody>
</table>

### Biomethane Alternatives

In a biogas upgrading system, it is important to minimize the loss of methane (methane slip) in order to achieve an economical viable biogas upgrading plant and also because methane is a potent GHG. Thus the release of
methane to the atmosphere should be minimized by treating the off-gas, air or water streams leaving the plant even though the methane cannot be beneficially utilized. Methane may be present in the exit-gas from a PSA-column, in air from a water scrubber with water recirculation or in water in a water scrubber without water recirculation. The exit-gas from an upgrading plant rarely contains a high enough methane concentration to maintain a flame without addition of natural gas or biogas. One way of limiting the methane slip is to mix the exit-gas with air that is used for combustion. Alternatively the methane can be oxidized by thermal or catalytic (platinum, palladium or cobalt) oxidation.

**Biomethane for Pipeline Injection**

This option requires treating the biogas to an extent that the gas is essentially pure methane. Biomethane suitable for injection into a natural gas pipeline is typically at least 95 percent CH₄ and less than 3 percent CO₂. To achieve pipeline quality gas, H₂S must also be removed from the biogas. Typically, after the odorous organics are removed, a mercaptan odorant (same as that added to natural gas) is added back in as a safety feature. However, since the amount of gas produced is very small compared to the amount of gas in the pipeline, Ken Brennen at PG&E indicated during a phone call on March 10, 2014, that an odorant system would not likely be required. Prior to pipeline injection, the biomethane stream must be compressed to approximately 450 pounds per square inch (psi) to match the pipeline pressure.

Biomethane transported via the natural gas pipeline is required to meet PG&E gas quality standards. Key natural gas pipeline quality requirements are summarized below.

**TABLE 3-12**

**PG&E Natural Gas Pipeline Quality Standards**

<table>
<thead>
<tr>
<th>Gas Quality</th>
<th>PG&amp;E</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>≤1%</td>
</tr>
<tr>
<td>O₂</td>
<td>≤0.1%</td>
</tr>
<tr>
<td>H₂S</td>
<td>≤0.25 grains/100 scf</td>
</tr>
<tr>
<td>Mercaptan sulfur</td>
<td>≤0.5 grains/100 scf</td>
</tr>
<tr>
<td>Total sulfur</td>
<td>≤1 grain/100 scf</td>
</tr>
<tr>
<td>H₂O</td>
<td>≤7 lbs/million scf</td>
</tr>
<tr>
<td>Total inert</td>
<td>No requirement</td>
</tr>
<tr>
<td>Heating value</td>
<td>Specific to receipt point</td>
</tr>
<tr>
<td>Landfill gas</td>
<td>Not allowed</td>
</tr>
<tr>
<td>Temperature</td>
<td>60 - 100°F</td>
</tr>
<tr>
<td>Gas Interchangeability</td>
<td>Per AGA Bulletin 36*</td>
</tr>
<tr>
<td>Wobbe Number</td>
<td>Specific to receipt point</td>
</tr>
<tr>
<td>Lifting Index</td>
<td>Specific to receipt point</td>
</tr>
<tr>
<td>Flashback Index</td>
<td>Specific to receipt point</td>
</tr>
</tbody>
</table>
Table 3-13
Summary of Natural Gas Pipeline Injection

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Eligible for Renewable Energy Credits (RECs) per the Energy Policy Act of 2005 and the CA Renewables Portfolio Standard.</td>
<td>• Requires extremely clean gas.</td>
</tr>
<tr>
<td>• Enables users to participate in Self Generation Incentive Program.</td>
<td>• Not economically viable when the cost of natural gas is lower than the cost of electricity for the total demand of each at the facility.</td>
</tr>
<tr>
<td>• PG&amp;E Gas Rule 21 has been revised to include a new subsection that describes the requirements for biomethane injection into PG&amp;E’s pipeline system as directed by the California Public Utilities Commission.</td>
<td>• Up to about 12 percent of the biogas methane is lost depending on the purification process selected.</td>
</tr>
<tr>
<td>• Generally safe to operate since there are few pieces of equipment.</td>
<td>• Energy cost savings are significantly reduced due to the energy required to compress the gas, often to several hundred psi.</td>
</tr>
</tbody>
</table>

Applicability to LGVSD WWTP

Biomethane for pipeline injection is technically possible and was further evaluated for implementation at the LGVSD WWTP.

Biomethane for Vehicle Fuel

Another biomethane utilization approach is to use as fleet vehicle fuel. Compressed biomethane in compliance with the California Air Resources Board (CARB) Alternative Fuel Specification for Compressed Natural Gas (CNG) can be used in any natural gas vehicle with exhaust emissions comparable to retail CNG (Specifications for Compressed Natural Gas, CARB, California Code of Regulations, Title 13, Article 2292.5).

The key requirements from the CARB CNG fuel specification are:

- Methane: 88% Min.
- Ethane: 6% Max.
- Propane: 3% Min.
- Oxygen: 1% Max.
- Inert Gases (CO₂ + N₂): 1.5 – 4.5%
- Total Sulfur: 16 ppm
- Dew point: ≥10°F below 99% applicable local winter design temperature

This option may be attractive to municipalities that have natural-gas-fired bus or industrial vehicle fleets. Among conventional fuels and fuel substitutes, upgraded biogas is proven to be the cleanest vehicle fuel with respect to environment, climate and human health. The primary disadvantages with this alternative are the costs associated with converting fleet vehicles for operation with biomethane, installing fueling stations, and installing biogas purification and compression equipment. The cost of converting heavy duty vehicles, such as trucks and buses, from traditional fuel to biomethane is estimated at about $40,000 to $55,000 per vehicle. Smaller fleet vehicles can be converted to operate on biomethane for significantly less cost than the larger vehicles (approximately $7,000 to $17,000). There is currently only one CNG vehicle available directly from a manufacturer: a Honda Civic, all other vehicles are retrofitted with CNG systems after they are manufactured. In some cases, conversion of biogas to vehicle fuel is not practical due to the difficulty in identifying sufficient local fleet users to use all of the
biomethane produced and making the necessary arrangements for fuel delivery. Some of the advantages and disadvantages associated with implementation of biomethane as vehicle fuel are summarized in the table below.

Reports indicate that the compressors are the most expensive part of producing CNG both in terms of construction and operating costs. Compressor reliability and vendor support are very important in selecting machinery for a CNG system. It is noted that most compressor problems were not related to the gas feed. Compressor oil carryover is a common problem causing the CNG fuel injection system to foul; some CNG fuel systems are more subject to fouling than others. The industry has conducted substantial research on the complex interactions between lubrication oil and compressed methane. A new finding that novices to the CNG industry should be aware of is the interaction between conventional lubricants and methane. High pressure methane acts like a solvent for heavy hydrocarbons, and the fraction of hydrocarbons that dissolve is a function of pressure. This dissolving of heavy hydrocarbons in compressed methane severely limits filters in stopping oil carryover. A filter can be placed at the high pressure dispenser to remove liquefied oil in the stream, but it is far less effective in removing oil that has solubilized into the gas. To minimize oil carryover, many CNG stations have switched to alternative lubricants, such as polyalkaline glycols (PAG), which are not soluble in high pressure methane. If membrane separation is used for biogas upgrading, the use of PAG may be limited as it suspected to be deleterious to the membranes. For future membrane purification projects, non-lubricated compressors are recommended upstream of the membranes to prevent oil contamination.

**TABLE 3-14**
Biomethane for Vehicle Fuel Advantages and Disadvantages

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Fuel self-generation would hedge against rising and uncontrollable fossil fuel costs.</td>
<td>• Requires a natural-gas fueled fleet preferably nearby.</td>
</tr>
<tr>
<td>• Cleanest vehicle fuel compared to conventional and other substitute fuels.</td>
<td>• Requires special infrastructure for fueling vehicles and/or accommodating increased traffic to the treatment plant for fleet fueling.</td>
</tr>
<tr>
<td>• Use of biomethane is very visible to the public.</td>
<td>• Requires a long term commitment to the converted fleet vehicles.</td>
</tr>
<tr>
<td>• Use of biomethane is potentially politically advantageous.</td>
<td>• Requires significant high pressure onsite fuel storage.</td>
</tr>
<tr>
<td>• Potential for construction project funding under various State and Federal programs (AB 118, AB 32, and Renewable Fuel Standard 2).</td>
<td>• Quantities of methane produced at WWTPs may be low to justify vehicle fueling.</td>
</tr>
<tr>
<td>• Eligible for Federal fuel credits (RINs).</td>
<td>• Potential for increased traffic on site.</td>
</tr>
<tr>
<td>• Biomethane as transportation fuel should command a premium tied to carbon credit trading under the Low Carbon Fuel Standard.</td>
<td>• No heat or power for plant use is recovered.</td>
</tr>
<tr>
<td>• Removed CO&lt;sub&gt;2&lt;/sub&gt; can be of economic value to some industrial users.</td>
<td></td>
</tr>
<tr>
<td>• Biogas used in vehicle fueling can have as low as 88% methane (relatively lower than that required for injection into gas grid).</td>
<td></td>
</tr>
</tbody>
</table>

**Applicability to LGVSD WWTP**

Biomethane for vehicle fuel was evaluated to be suitable for implementation at the LGVSD WWTP and therefore considered for further analysis.
Section 4 - Biogas Utilization Alternatives Economic Evaluation

The following alternatives were considered for further economic and non-cost factors evaluation.

- Microturbines
- Compressed Natural Gas Vehicle Fueling Station
- Natural Gas Pipeline Injection
- Remove Existing IC Engine

Low Pressure Gas Storage

It was requested by LGVSD to consider the need or benefit of installing low pressure biogas storage. Low pressure storage is typically considered to be in the range of 8 to 15 inches of water column pressure, corresponding to the pressure range that the digester cover is rated for. Low pressure storage is useful if the biogas utilization equipment can operate near those pressures, or up to approximately 5 psig. Equipment that can run at this pressure are IC engines and boilers. Storage is useful if the equipment utilizing the biogas requires a gas flow rate that could be higher than the amount of gas produced. The currently installed boiler has a larger capacity than is required, causing it to cycle on and off more frequently and causing the existing low pressure gas storage, which is limited to the head space inside the digesters, to fluctuate quickly. It is recommended that any future boiler be sized smaller, closer to the average heat required, and low pressure gas storage added. A low pressure gas storage unit could be installed where the existing medium pressure gas storage unit is located. All the remaining alternatives require high gas pressure to operate or come with storage included in their systems.

Remove Existing IC Engine (Add Boiler and Waste Gas Burner)

This option represents the “do nothing” alternative, however, by simply demolishing the existing engine, the primary source of heat and biogas disposal are also being removed. To alleviate this vulnerability, a second boiler and waste gas burner must be installed to provide the required redundancy. As mentioned above, the existing boiler has a capacity that is larger than the anticipated peak heat demand, so it was assumed for this evaluation that any new boiler would be smaller than the existing equipment. The current boiler operates on essentially untreated biofuel, but this is not recommended for long term use, as the moisture, H2S, and siloxanes will greatly diminish the lifespan of the equipment. It is recommended that a gas treatment system, similar to the equipment listed above be installed.

If a third boiler was added to the system (two duty, one standby), additional hot water could be produced for possible beneficial use. Currently, there is little use for additional heat, but a possible future use could be to convert more building heating systems to operate on hot water. If in the future LGVSD is required to produce class A biosolids, additional heat would be required. There are many options for producing class A biosolids, including thermal drying of sludge, composting, thermal hydrolysis process digestion, and temperature phase anaerobic digestion. All of these options will result in significant cost and/or major solids treatment process changes. Additional information could be prepared as a separate task to evaluate these options. It is not recommended to consider producing class A biosolids unless the LGVSD is required to do so because of the significant process and cost impacts.

The construction cost to add a gas cleaning system, an additional boiler, and waste gas burner equipment is summarized in Table 4-1 below.
TABLE 4-1
Boiler/Waste Gas Burner Cost
Summary of adding second boiler and flare

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Equipment Cost</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boiler</td>
<td>$82,000</td>
<td>Based on quote from CTI Controltech (Burnham Boiler)</td>
</tr>
<tr>
<td>Waste Gas Burner</td>
<td>$90,000</td>
<td>Based on installation cost of previous burner in 2012</td>
</tr>
<tr>
<td>Gas Conditioning System</td>
<td>$250,000</td>
<td>Based on quote from Regatta Solutions (Unison Solutions)</td>
</tr>
<tr>
<td>Low Pressure Gas Storage</td>
<td>$150,000</td>
<td></td>
</tr>
<tr>
<td>Pump and piping connecting to existing hot water system</td>
<td>$15,000</td>
<td>Allowance</td>
</tr>
<tr>
<td><strong>Existing Facility Improvements</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demolition</td>
<td>$10,000</td>
<td>Allowance</td>
</tr>
<tr>
<td>Equipment Installation</td>
<td>$58,700</td>
<td>10% of equipment cost</td>
</tr>
<tr>
<td>Piping and valves</td>
<td>$58,700</td>
<td>10% of mechanical equipment cost</td>
</tr>
<tr>
<td>Electrical</td>
<td>$29,400</td>
<td>5% of equipment cost</td>
</tr>
<tr>
<td>Instrumentation</td>
<td>$29,400</td>
<td>5% of equipment cost</td>
</tr>
<tr>
<td><strong>SUBTOTAL of New Equipment and Facility Improvements</strong></td>
<td>$773,000</td>
<td></td>
</tr>
<tr>
<td><strong>Contractor Markups and Contingency</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mob/Bonds/Permits/Insurance</td>
<td>$40,000</td>
<td>5% of above subtotal</td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong></td>
<td>$813,000</td>
<td></td>
</tr>
<tr>
<td>Contractors Overheads</td>
<td>$80,000</td>
<td>10% of above subtotal</td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong></td>
<td>$893,000</td>
<td></td>
</tr>
<tr>
<td>Contractors Profits</td>
<td>$40,000</td>
<td>5% of above subtotal</td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong></td>
<td>$933,000</td>
<td></td>
</tr>
<tr>
<td>Contingency</td>
<td>$280,000</td>
<td>30% of above subtotal</td>
</tr>
<tr>
<td><strong>SUBTOTAL with Contractor's Markups and Contingency</strong></td>
<td>$1,213,000</td>
<td></td>
</tr>
<tr>
<td><strong>Non-construction Costs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering, Legal, Admin</td>
<td>$364,000</td>
<td>30% of above subtotal</td>
</tr>
<tr>
<td><strong>TOTAL CONSTRUCTION COSTS</strong></td>
<td>$1,580,000</td>
<td></td>
</tr>
</tbody>
</table>

**Operations and Maintenance**

The biogas cleaning and compression equipment generally requires more maintenance than the boilers and flares. The SulfaTreat media for H2S removal requires replacement approximately every 24 months, the moisture and particulate filters must be cleaned regularly, the gas pressure boosting blower must have its oil changed, and the
siloxane removal media must be replaced every 3 to 6 months. For the purposes of this evaluation, it was assumed that LGVSD would contract out the maintenance of the gas cleaning system, which is very commonly done. The supplier of the gas cleaning equipment, Unison, would supply a maintenance contract through a local vendor. It is projected that the annual number of operations staff hours required to operate and maintain the equipment for this alternative is 520, or 0.25 full time equivalent (FTE). Table 4-2 below is a summary of the O&M costs for this alternative.

**TABLE 4-2**

**Boiler and Waste Gas Burner O&M**

*Summary of boiler and waste gas burner system O&M (including gas cleaning)*

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Task</th>
<th>Frequency</th>
<th>Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂S Removal System</td>
<td>Clean Filters</td>
<td>Monthly</td>
<td>($3000)¹</td>
</tr>
<tr>
<td></td>
<td>Replace Media</td>
<td>Every 19 months</td>
<td></td>
</tr>
<tr>
<td>Gas Compression/Chiller System</td>
<td>3rd party maintenance contract</td>
<td>Annually</td>
<td>($5,000)</td>
</tr>
<tr>
<td>Siloxane Removal System</td>
<td>Replace Media</td>
<td>Every 2-3 months</td>
<td>($5,000)²</td>
</tr>
<tr>
<td>Boiler / Waste Gas Burner</td>
<td>General O&amp;M by plant staff</td>
<td>Annual</td>
<td>($6,000)³</td>
</tr>
<tr>
<td></td>
<td>Electrical cost of ancillary equipment</td>
<td>Annual</td>
<td>($5,000)⁴</td>
</tr>
</tbody>
</table>

**Total Annual O&M Cost** ($24,000)

Table Notes
1. Cost amortized annually; media replacement cost is $7915. Cost does not include labor or disposal.
2. Assumed 2.5 media changes per year, $2145 per replacement.
3. Based on an estimated 144 hours/year at $40/hour.
4. Based on average of summer and winter electrical rates from PG&E; $0.09/kW-hr.

**Microturbines**

One distinct advantage installing microturbines has over natural gas filling stations or pipeline injection is that useful heat in the form of hot water (up to 180 °F) can be recovered from them, allowing the currently installed boiler to remain as the backup source of heat. It also allows the continued use of a single waste gas burner (flare) as backup to both the microturbine and boiler to safely dispose of biogas from the digester. As mentioned above, there is currently only one viable microturbine manufacturer, Capstone Turbine Corporation, located in Chatsworth, CA. Fortunately, there are several appropriate size options for microturbines at LGVSD based on the amount of biogas available; Table 4-3 below summarizes these options.
### TABLE 4-3

**Appropriate Microturbine Sizes**

*Summary of microturbine capacity and quantities*

<table>
<thead>
<tr>
<th>Model Number</th>
<th>Quantity</th>
<th>Total Biogas Flow Required</th>
<th>Maximum Electrical Output</th>
<th>Peak Electrical Efficiency</th>
<th>Maximum Heat Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>C30</td>
<td>3</td>
<td>31 scfm</td>
<td>90 kW (30 kW each)</td>
<td>26%</td>
<td>0.57 MMBTUH (0.19 MMBTUH each)</td>
</tr>
<tr>
<td>C65</td>
<td>2</td>
<td>35 scfm¹</td>
<td>104 kW (52 kW each)²</td>
<td>29%</td>
<td>0.40 MMBTUH (0.20 MMBTUH each)²</td>
</tr>
</tbody>
</table>

Table Notes
1. This is the average amount of gas available. Full output of C65 model requires 22 scfm each; units must run at reduced output.
2. Output based on running units at reduced capacity; limited to run at estimated average daily gas available.

Since the estimated average biogas production is 35 scfm, operating three C30 units would not use all of the available biogas resulting in some gas being burned in the waste gas burner. As mentioned in the Table 4-1 above, on average, the C65 units would run at reduced capacity, but could possibly run at full output (65 kW each) on peak gas production days. The C65 units would be provided with an integral heat recovery system mounted on top of the cabinet, while the C30 units would require a custom built heat recovery system because they are not available with integral heat recovery. The C65 units have an electrical efficiency that is approximately 10% higher than the C30 units. Since a system using two C65 units has several key advantages over three C30 units, this configuration was used as the basis for evaluating the microturbine option.

### Gas Storage

The existing gas storage tank has a volume of 1000 cubic feet (cf). If it is continued to operate at up to 20 psig, it would provide approximately one hour of gas storage for a microturbine system running at the output described above. A positive displacement gas compressor for the microturbine system would be able to handle large variations in gas storage pressure. This capacity is adequate to generally provide consistent biogas flows to the microturbines, taking out much of the variation in biogas production throughout the day.

A storage volume of four hours or more would provide additional capacity to account for higher levels of biogas production variations of short disruptions in gas production. This would require a storage unit with either four times the currently installed volume, or a tank of the same size running at 80 psig. There is not adequate space on the site for additional gas storage at the current operating pressure. The current tank has a rating to operate at up to 200 psig, but since the tank is over 15 years old, it is not recommended to operate it at that pressure unless it was recertified to operate at a higher pressure. It is possible to install a new 1000 cf tank at the existing tank location operated at approximately 100 psig; the compressor included with the microturbine system could be used to pressurize it. Since a new tank would be an optional enhancement, it was not included in the economic evaluation. A new storage tank would cost approximately $200,000.

### Required Ancillary Equipment

Several additional pieces of equipment are required in a microturbine system, which are summarized in Table 4-4 below. This equipment is needed to clean and compress the biogas so it can be used by the microturbines. Since none of these systems would be considered critical for plant operations, it was assumed that no redundant equipment would be provided and none of the equipment would be provided with emergency backup power.
TABLE 4-4
Ancillary Equipment

Summary of biogas cleaning and compression equipment

<table>
<thead>
<tr>
<th>Equipment System</th>
<th>Subsystem Equipment</th>
<th>Approximate Size</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂S Removal System</td>
<td>Moisture/Particulate Filter</td>
<td>4 ft by 8 ft</td>
<td>99% removal of 3 micron particles and droplets</td>
</tr>
<tr>
<td></td>
<td>H₂S Removal Media Vessel</td>
<td>5 ft dia., 12 ft H</td>
<td>SulfaTreat media vessel</td>
</tr>
<tr>
<td>Gas Compression/</td>
<td>8 ft by 15 ft by 10 ft H</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moisture/ Siloxane Removal System</td>
<td>Gas Compressor</td>
<td>25 HP, variable speed, twin screw compressor, 100 psi output</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heat Exchanger</td>
<td>40 deg F dew point moisture removal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Siloxane Removal Vessels</td>
<td>(3) 14-inch dia. by 8’ H, activated carbon media</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Glycol Chiller</td>
<td>5 ft by 10 ft</td>
<td>14 kW compressor and fans</td>
</tr>
</tbody>
</table>

Site Layout

All the gas cleaning equipment and the microturbines could be located on the west side of the digesters or the microturbines could be located on the east side of the digesters. Figure 4-1 illustrates the approximate size and location of the microturbine equipment shown on the west side of the digesters.

![Figure 4-1 Microturbine Equipment Layout](image)
Construction Costs

The preliminary cost estimates for the equipment, installation, contractor’s mark ups, and engineering fees are summarized in Table 4-5 below. Since this alternative does not require an additional boiler or waste gas burner for redundancy, these costs were subtracted from the costs included for the microturbines.

<table>
<thead>
<tr>
<th>TABLE 4-5</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Microturbine System Construction Costs</strong></td>
<td><strong>Cost</strong></td>
</tr>
<tr>
<td><strong>Description</strong></td>
<td><strong>Assumptions</strong></td>
</tr>
<tr>
<td><strong>Equipment Cost</strong></td>
<td></td>
</tr>
<tr>
<td>Microturbine (two C65 units, including heat recovery system)</td>
<td>$250,000</td>
</tr>
<tr>
<td>Based on quote from Regatta Solutions (Capstone Turbine)</td>
<td></td>
</tr>
<tr>
<td>Gas Conditioning System</td>
<td>$440,000</td>
</tr>
<tr>
<td>Based on quote from Regatta Solutions (Unison Solutions)</td>
<td></td>
</tr>
<tr>
<td>Sludge Heat Exchanger</td>
<td>$35,000</td>
</tr>
<tr>
<td>Based on recent project quotes</td>
<td></td>
</tr>
<tr>
<td>Pump and piping connecting to existing hot water system</td>
<td>$15,000</td>
</tr>
<tr>
<td>Allowance</td>
<td></td>
</tr>
<tr>
<td>Electrical switchgear</td>
<td>$60,000</td>
</tr>
<tr>
<td>Allowance</td>
<td></td>
</tr>
<tr>
<td><strong>Existing Facility Improvements</strong></td>
<td></td>
</tr>
<tr>
<td>Demolition</td>
<td>$10,000</td>
</tr>
<tr>
<td>Allowance</td>
<td></td>
</tr>
<tr>
<td>Lighting</td>
<td>$5,000</td>
</tr>
<tr>
<td>Allowance</td>
<td></td>
</tr>
<tr>
<td>Equipment Installation</td>
<td>$80,000</td>
</tr>
<tr>
<td>10% of equipment cost</td>
<td></td>
</tr>
<tr>
<td>Piping and valves</td>
<td>$74,000</td>
</tr>
<tr>
<td>10% of mechanical equipment cost</td>
<td></td>
</tr>
<tr>
<td>Electrical</td>
<td>$40,000</td>
</tr>
<tr>
<td>5% of equipment cost</td>
<td></td>
</tr>
<tr>
<td>Instrumentation</td>
<td>$40,000</td>
</tr>
<tr>
<td>5% of equipment cost</td>
<td></td>
</tr>
<tr>
<td><strong>SUBTOTAL of New Equipment and Facility Improvements</strong></td>
<td>$1,050,000</td>
</tr>
<tr>
<td><strong>Contractor Markups and Contingency</strong></td>
<td></td>
</tr>
<tr>
<td>Mob/Bonds/Permits/Insurance</td>
<td>$50,000</td>
</tr>
<tr>
<td>5% of above subtotal</td>
<td></td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong></td>
<td>$1,100,000</td>
</tr>
<tr>
<td>Contractors Overheads</td>
<td>$110,000</td>
</tr>
<tr>
<td>10% of above subtotal</td>
<td></td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong></td>
<td>$1,210,000</td>
</tr>
<tr>
<td>Contractors Profits</td>
<td>$60,000</td>
</tr>
<tr>
<td>5% of above subtotal</td>
<td></td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong></td>
<td>$1,270,000</td>
</tr>
<tr>
<td>Contingency</td>
<td>$380,000</td>
</tr>
<tr>
<td>30% of above subtotal</td>
<td></td>
</tr>
<tr>
<td><strong>SUBTOTAL with Contractor’s Markups and Contingency</strong></td>
<td>$1,650,000</td>
</tr>
<tr>
<td><strong>Non-construction Costs</strong></td>
<td></td>
</tr>
<tr>
<td>Engineering, Legal, Admin</td>
<td>$500,000</td>
</tr>
<tr>
<td>30% of above subtotal</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL CONSTRUCTION COSTS</strong></td>
<td>$2,200,000</td>
</tr>
</tbody>
</table>
Operations and Maintenance (O&M)

The biogas cleaning and compression equipment generally requires more maintenance than the microturbines themselves. The SulfaTreat media for \( \text{H}_2\text{S} \) removal requires replacement approximately every 19 months, the moisture and particulate filters must be cleaned regularly, the gas compressor oil must be changed, and the siloxane removal media must be replaced every 2 to 3 months. For the purposes of this evaluation, it was assumed that LGVSD would contract out the maintenance of the microturbine and heat recovery system, which is very commonly done. The local supplier of Capstone Turbine (Regatta Solutions) is based in southern California and would supply a maintenance contract. In addition to subcontracting maintenance of the microturbine and some of the gas cleaning system maintenance, it is projected that the annual number of LGVSD operations staff hours required to operate and maintain the equipment for this alternative is 400, or 0.2 FTE. A summary of O&M activities and annual costs are summarized in Table 4-6 below.

**TABLE 4-6**

**Microturbine System O&M**

*Summary of microturbine O&M*

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Task</th>
<th>Frequency</th>
<th>Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>H(_2)S Removal System</td>
<td>Clean Filters</td>
<td>Monthly</td>
<td>($5,000)(^1)</td>
</tr>
<tr>
<td></td>
<td>Replace Media</td>
<td>Every 19 months</td>
<td>($4,000)</td>
</tr>
<tr>
<td>Gas Compression/Chiller System</td>
<td>3(^{rd}) party maintenance contract</td>
<td>Annually</td>
<td>($11,000)(^2)</td>
</tr>
<tr>
<td>Siloxane Removal System</td>
<td>Replace Media</td>
<td>Every 2-3 months</td>
<td>($10,000)(^3)</td>
</tr>
<tr>
<td>Microturbine</td>
<td>3(^{rd}) party maintenance contract</td>
<td>On-going</td>
<td>($30,000)</td>
</tr>
<tr>
<td></td>
<td>General O&amp;M by plant staff</td>
<td>Annual</td>
<td>($87,000)(^4)</td>
</tr>
<tr>
<td></td>
<td>Electrical cost of ancillary equipment</td>
<td>Annual</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Value of electricity generated</td>
<td>Annual</td>
<td></td>
</tr>
</tbody>
</table>

**Total Annual O&M Cost** $8,000

**Table Notes**
1. Cost amortized annually; media replacement cost is $7915. Cost does not include labor or disposal.
2. Assumed 5 media changes per year, $2145 per replacement.
3. Based on an estimated 260 hours/year at $40/hour.
4. Based on average of summer and winter electrical rates from PG&E; $0.09/kW-hr.

Compressed Natural Gas (CNG) Vehicle Fueling Station

In evaluating a CNG vehicle fueling system, several options were considered with regard to equipment packaging, storage capacity, fill time, and final gas product quality. Ultimately, a system built around the Environmental Systems & Composites (ESC) Corporation’s modular biogas recovery system was used as the base of financial analysis. Other suppliers of vehicle fill stations were contacted but were unwilling to release quotes due to the high system production unit cost that would result from the poor economy of scale caused by the relatively small amount of biogas produced at the LGVSD facility. Since a CNG vehicle fueling system, including the ancillary equipment to run it, are critical for plant operations, it was assumed that no redundant equipment would be provided and none of the equipment would be provided with emergency backup power.
The ESC system is built around modular skids, which decrease fabrication cost and increase system quality. They are very similar to the system described above for the microturbine gas cleaning system. For LGVSD, the system would consist of the following skids:

- **Gas Treatment Skid** - This skid contains iron sponge H₂S removal vessels, a booster blower, particulate filters, carbon absorption siloxane removal, a catalytic oxidizer for removal of VOCs, followed by H₂O and CO₂ removal through a membrane system. A thorough gas analysis is required for optimizing and predicting system performance; however, the quoted arrangement is expected to produce at least 90% methane content with a 90% capture rate. Increasing content and capture will add to the construction cost.

- **Chiller Skid** - This skid contains the chiller unit which allows for H₂O removal upstream of the membranes. The dew point of gas coming into the treatment membranes needs to be controlled to optimize membrane performance.

- **Compression and Storage Skid** - This skid receives purified gas and compresses it to 3600 psi and stores it in high pressure storage tanks. The storage tanks are sized to store approximately two days of CNG production. The skid is designed for allowing fast fill of vehicles.

- **Filling Station** - The filling station is designed to have 4 hoses which can be used to fill fleet vehicles. Vehicles can be connected to the station over a long weekend to utilize the vehicles' tanks as extra storage for the system, preventing flaring of biogas when the system reaches capacity.

**Site Layout**

Figure 4-2 represents how the ESC system could be installed on site, west of the primary digester.

![Figure 4-2 CNG Vehicle Fill Station Equipment Layout](image-url)
The fill station with the hose connections was placed at the north end of the parking area adjacent to the primary clarifier, which has space for up to three vehicles or possibly one larger truck.

A disadvantage of this option is that heat for digester operations must still be generated. This option assumes that since the existing IC engine will be removed, however, by simply demolishing the existing engine, the primary source of heat and biogas disposal is also being removed. To alleviate this vulnerability, a second boiler and waste gas burner must be installed to provide the required redundancy. The equipment would be the same size as the existing equipment and it would be recommended to match the make and model number of the existing units for maintenance commonality. Although the current boiler operates on essentially untreated biogas, this is not recommended for long term use, as the moisture, H2S, and siloxanes will greatly diminish the lifespan of the equipment. It is recommended that a gas treatment system, similar to the equipment listed above be installed.

The biogas produced must primarily be used by the boiler since this is critical to operation of the treatment plant, so any remaining biogas can be converted to vehicle fuel. Table 4-7 below summarizes the amount of gas required for the boiler and the amount that can be converted to CNG.

### TABLE 4-7
**CNG Vehicle Fill Station Operating Capacity**

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Quantity</th>
<th>Units</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Biogas Available</td>
<td>35</td>
<td>scfm</td>
<td>Based on 50,000 scf/day</td>
</tr>
<tr>
<td>Boiler Gas Consumption</td>
<td>14</td>
<td>scfm</td>
<td>Average usage based on annual average heat required</td>
</tr>
<tr>
<td>Amount of CNG produced</td>
<td>13</td>
<td>scfm</td>
<td>Includes losses from gas cleaning process</td>
</tr>
<tr>
<td>Gallons of Gasoline Equivalent (GGE)</td>
<td>117</td>
<td>Gallons/day</td>
<td>Equivalent gallons of gasoline produced each day that can be used in a vehicle</td>
</tr>
</tbody>
</table>

A considerable amount of gas can be produced by this system, however the amount of equivalent gasoline that can be used may be much less. It is unlikely that LGVSD will be able to use this amount on a daily basis. Any unused biogas once the storage tanks are full would be flared.

**Construction Costs**

As mentioned in the general CNG fill station description above, there are significant costs to convert a vehicle to run on CNG. It is unknown whether LGVSD would convert existing vehicles or purchase new CNG vehicles. Those costs were not included in the analysis below, but should factor into any decision LGVSD makes regarding implementing this system. Table 4-8 below summarizes the construction costs.
## TABLE 4-8
CNG Vehicle Fill Station Construction Costs

### Summary of Construction Costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Equipment Cost</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boiler</td>
<td>$85,000</td>
<td>Based on quote from CTI Controltech (Burnham Boiler)</td>
</tr>
<tr>
<td>Sludge Heat Exchanger</td>
<td>$35,000</td>
<td>Based on recent project quotes</td>
</tr>
<tr>
<td>Waste Gas Burner</td>
<td>$90,000</td>
<td>Based on installation cost of previous burner in 2012</td>
</tr>
<tr>
<td>Gas Conditioning System</td>
<td>$440,000</td>
<td>Based on quote from ESC</td>
</tr>
<tr>
<td>Gas Compression and Preparation Equipment</td>
<td>$200,000</td>
<td>Based on quote from ESC</td>
</tr>
<tr>
<td>High-Pressure Gas Storage/Fill Station</td>
<td>$225,000</td>
<td>Based on quote from ESC</td>
</tr>
<tr>
<td><strong>Existing Facility Improvements</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demolition</td>
<td>$10,000</td>
<td>Allowance</td>
</tr>
<tr>
<td>Lighting</td>
<td>$5,000</td>
<td>Allowance</td>
</tr>
<tr>
<td>Site Work</td>
<td>$15,000</td>
<td>Allowance</td>
</tr>
<tr>
<td>Equipment Installation</td>
<td>$107,500</td>
<td>10% of equipment cost</td>
</tr>
<tr>
<td>Piping and valves</td>
<td>$107,500</td>
<td>10% of equipment cost</td>
</tr>
<tr>
<td>Electrical</td>
<td>$53,750</td>
<td>5% of equipment cost</td>
</tr>
<tr>
<td>Instrumentation</td>
<td>$53,750</td>
<td>5% of equipment cost</td>
</tr>
<tr>
<td><strong>SUBTOTAL of New Equipment and Facility Improvements</strong></td>
<td><strong>$1,430,000</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Contractor Markups and Contingency</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mob/Bonds/Permits/Insurance</td>
<td>$70,000</td>
<td>5% of above subtotal</td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong></td>
<td>$1,500,000</td>
<td></td>
</tr>
<tr>
<td>Contractors Overheads</td>
<td>$150,000</td>
<td>10% of above subtotal</td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong></td>
<td>$1,650,000</td>
<td></td>
</tr>
<tr>
<td>Contractors Profits</td>
<td>$80,000</td>
<td>5% of above subtotal</td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong></td>
<td>$1,730,000</td>
<td></td>
</tr>
<tr>
<td>Contingency</td>
<td>$520,000</td>
<td>30% of above subtotal</td>
</tr>
<tr>
<td><strong>SUBTOTAL with Contractor's Markups and Contingency</strong></td>
<td><strong>$2,250,000</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Non-construction Costs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering, Legal, Admin</td>
<td>$680,000</td>
<td>30% of above subtotal</td>
</tr>
</tbody>
</table>

**TOTAL CONSTRUCTION COSTS**: $2,900,000
Operations and Maintenance (O&M)

The CNG vehicle fill station contains much of the same equipment as the microturbine system, but adds in the carbon dioxide scrubbing equipment, the redundant boiler, and waste gas burner. Typically, the maintenance for the filling station equipment is contracted through the manufacturer, so the amount of time required by LGVSD staff for operations is anticipated to be 260 hours per year, or approximately 0.1 FTE. There are several suppliers of these systems with multiple systems installed in northern California. Currently, service is provided by out-of-state staff, but with the increasing number of local installations, there may be local based maintenance staff in the near future. Table 4-9 provides a summary of O&M activities and costs.

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Task</th>
<th>Frequency</th>
<th>Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂S Removal System</td>
<td>Clean Filters</td>
<td>Monthly</td>
<td>($5000)¹</td>
</tr>
<tr>
<td></td>
<td>Replace Media</td>
<td>Every 19 months</td>
<td></td>
</tr>
<tr>
<td>Gas Compression/Chiller System</td>
<td>3rd party maintenance contract</td>
<td>Annually</td>
<td>($4,000)</td>
</tr>
<tr>
<td>Siloxane Removal System</td>
<td>Replace Media</td>
<td>Every 2-3 months</td>
<td>($11,000)²</td>
</tr>
<tr>
<td></td>
<td>3rd party maintenance contract</td>
<td>On-going</td>
<td>($15,000)</td>
</tr>
<tr>
<td></td>
<td>General O&amp;M by plant staff</td>
<td>Annual</td>
<td>($10,000)³</td>
</tr>
<tr>
<td></td>
<td>Electrical cost of ancillary equipment</td>
<td>Annual</td>
<td>($38,000)</td>
</tr>
<tr>
<td></td>
<td>Value of CNG generated (savings if all fuel used by LGVSD CNG fleet and/or sold to external customers)</td>
<td>Annual</td>
<td>$107,000</td>
</tr>
<tr>
<td></td>
<td>Value of CNG generated (savings of 20 GGE per day used by LGVSD CNG fleet; remainder of biogas flared)</td>
<td>Annual</td>
<td>$18,250</td>
</tr>
<tr>
<td><strong>Total Annual O&amp;M Cost (all CNG used)</strong></td>
<td></td>
<td></td>
<td><strong>$24,000</strong></td>
</tr>
<tr>
<td><strong>Total Annual O&amp;M Cost (20 GGE used)</strong></td>
<td></td>
<td></td>
<td><strong>($65,000)</strong></td>
</tr>
</tbody>
</table>

Table Notes
1. Cost amortized annually; media replacement cost is $7915. Cost does not include labor or disposal.
2. Assumed 5 media changes per year, $2145 per replacement.
3. Based on an estimated 250 hours/year at $40/hour.

Natural Gas Pipeline Injection

The alternative to construct a pipeline from the LGVSD WWTF to a nearby PG&E gas main is evaluated below. As with the CNG vehicle fill station alternative, the biogas will need to be cleaned and carbon dioxide removed so to produce a gas that is at least 97% methane using a similar gas cleaning system that is described above for the CNG vehicle fill station (details of system would be developed later). The PG&E gas main runs at 450 psig average pressure, with the nearest connection point located approximately 3000 feet away from the facility. PG&E requires that an interconnect station be constructed. PG&E would complete the construction and be responsible for the O&M of the interconnect station, but would charge LGVSD for the construction and maintenance of it.
California state and federal taxes that would be collected from PG&E for the construction would be passed along to LGVSD. A 60 ft by 100 ft tract of land where the interconnect station is located would also have to be purchased by LGVSD. Similar to the CNG vehicle fill station alternative, a redundant boiler and waste gas burner would also be required to be installed, but since the pipeline injection system would be considered critical for plant operations, it was assumed that no redundant equipment would be provided and none of the equipment would be provided with emergency backup power.

**Site Layout**
The gas conditioning equipment layout would be nearly identical to what is shown in Figure 4-2 above. Figure 4-3 below shows an approximate alignment of the PG&E gas main and a possible location for the interconnect station.

![Figure 4-3 Location of Interconnect Station and PG&E’s Gas Main Alignment](image)

**Construction Costs**
Table 4-10 below summarizes the construction costs required for the natural gas pipeline injection alternative.
### TABLE 4-10
**Pipeline Injection Construction Costs**

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Equipment Cost</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boiler</td>
<td>$85,000</td>
<td>Based on quote from CTI Controltech (Burnham Boiler)</td>
</tr>
<tr>
<td>Sludge Heat Exchanger</td>
<td>$35,000</td>
<td>Based on recent project quotes</td>
</tr>
<tr>
<td>Waste Gas Burner</td>
<td>$90,000</td>
<td>Based on installation cost of previous burner in 2012</td>
</tr>
<tr>
<td>Gas Conditioning System</td>
<td>$440,000</td>
<td>Based on quote from ESC</td>
</tr>
<tr>
<td>Gas Compression and Preparation Equipment</td>
<td>$200,000</td>
<td>Based on quote from ESC</td>
</tr>
<tr>
<td>Gas Pipeline</td>
<td>$360,000</td>
<td>3000 ft at $120 per ft</td>
</tr>
<tr>
<td>Property Acquisition for Interconnect Station</td>
<td>$30,000</td>
<td>6000 sq. ft. at $5/sq. ft.</td>
</tr>
<tr>
<td>Pipeline Interconnect Station</td>
<td>$2,500,000</td>
<td>Estimate from PG&amp;E</td>
</tr>
<tr>
<td>Interconnect Station Maintenance Fee</td>
<td>$1,950,000</td>
<td>78% of interconnect station cost, paid to PG&amp;E</td>
</tr>
<tr>
<td>State and Federal Taxes for Interconnect Station</td>
<td>$875,000</td>
<td>35% total tax rate</td>
</tr>
<tr>
<td><strong>Existing Facility Improvements</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demolition</td>
<td>$10,000</td>
<td>Allowance</td>
</tr>
<tr>
<td>Lighting</td>
<td>$5,000</td>
<td>Allowance</td>
</tr>
<tr>
<td>Site Work</td>
<td>$15,000</td>
<td>Allowance</td>
</tr>
<tr>
<td>Equipment Installation</td>
<td>$81,500</td>
<td>10% of contractor installed equipment cost</td>
</tr>
<tr>
<td>Piping and valves</td>
<td>$81,500</td>
<td>10% of contractor installed equipment cost</td>
</tr>
<tr>
<td>Electrical</td>
<td>$40,750</td>
<td>5% of contractor installed equipment cost</td>
</tr>
<tr>
<td>Instrumentation</td>
<td>$40,750</td>
<td>5% of contractor installed equipment cost</td>
</tr>
<tr>
<td><strong>SUBTOTAL of Interconnect Station Costs</strong></td>
<td>$5,360,000</td>
<td>Costs not paid to the construction contractor</td>
</tr>
<tr>
<td><strong>SUBTOTAL of New Equipment and Facility Improvements</strong></td>
<td>$1,450,000</td>
<td>Costs paid to the construction contractor</td>
</tr>
<tr>
<td><strong>Contractor Markups and Contingency</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mob/Bonds/Permits/Insurance</td>
<td>$70,000</td>
<td>5% of above subtotal</td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong></td>
<td>$1,519,500</td>
<td>10% of above subtotal</td>
</tr>
<tr>
<td>Contractors Overheads</td>
<td>$150,000</td>
<td>10% of above subtotal</td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong></td>
<td>$1,669,500</td>
<td>5% of above subtotal</td>
</tr>
<tr>
<td>Contractors Profits</td>
<td>$80,000</td>
<td>5% of above subtotal</td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong></td>
<td>$1,749,500</td>
<td>30% of above subtotal</td>
</tr>
<tr>
<td>Contingency</td>
<td>$520,000</td>
<td>30% of above subtotal</td>
</tr>
</tbody>
</table>
TABLE 4-10
Pipeline Injection Construction Costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUBTOTAL with Contractor’s Markups and Contingency</td>
<td>$2,270,000</td>
<td></td>
</tr>
</tbody>
</table>

Non-construction Costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering, Legal, Admin</td>
<td>$680,000</td>
<td>30% of above subtotal</td>
</tr>
</tbody>
</table>

TOTAL CONSTRUCTION COSTS $8,300,000

Operations and Maintenance

The O&M of this alternative would be nearly identical to the CNG vehicle fill station requirements, with the addition of the gas interconnect station. While PG&E will maintain all equipment at the station, they will charge a fee to LGVSD. The maintenance fee can be handled in two ways: monthly payments or initial lump sum. The monthly payment option would be 0.5% of the construction cost of the interconnect station, while the lump sum option would be a one-time payment of 78% of the construction cost paid up front. The monthly option would cost approximately $12,500 per month over the lifetime of the interconnection; over a 20 year period it would cost $3,000,000. Over the 20 year period, and certainly over the lifetime of the interconnection, it would be less costly to opt for the lump sum fee and will be used as the assumption for this evaluation. As with the CNG vehicle fill station equipment, the maintenance is typically contracted through the gas cleaning system manufacturer. The amount of time required by LGVSD staff for operations is anticipated to be 260 hours per year, or approximately 0.1 FTE. The O&M costs are summarized in Table 4-11 below.

TABLE 4-11
Pipeline Injection O&M
Summary of Pipeline Injection O&M

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Task</th>
<th>Frequency</th>
<th>Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂S Removal System</td>
<td>Clean Filters</td>
<td>Monthly</td>
<td>($5000)¹</td>
</tr>
<tr>
<td></td>
<td>Replace Media</td>
<td>Every 2 months</td>
<td></td>
</tr>
<tr>
<td>Gas Compression/Chiller System</td>
<td>Change oil, clean filters, clean chiller condenser, test glycol</td>
<td>Annually</td>
<td>($4,000)</td>
</tr>
<tr>
<td>Siloxane Removal System</td>
<td>Replace Media</td>
<td>Every 2-3 months</td>
<td>($11,000)²</td>
</tr>
<tr>
<td></td>
<td>3rd party maintenance contract</td>
<td>On-going</td>
<td>($15,000)</td>
</tr>
<tr>
<td></td>
<td>General O&amp;M by plant staff</td>
<td>Annual</td>
<td>($10,000)³</td>
</tr>
<tr>
<td></td>
<td>Electrical cost of ancillary equipment</td>
<td>Annual</td>
<td>($30,000)</td>
</tr>
<tr>
<td></td>
<td>Value of CNG generated (all fuel purchased by PG&amp;E)</td>
<td>Annual</td>
<td>$44,000⁴</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Annual O&amp;M Cost</td>
<td></td>
<td></td>
<td>($31,000)</td>
</tr>
</tbody>
</table>

Table Notes
1. Cost amortized annually; media replacement cost is $7915. Cost does not include labor or disposal.
2. Assumed 5 media changes per year, $2145 per replacement.
3. Based on an estimated 250 hours/year at $40/hour.
4. Based on $6.00 per million Btu’s.
Grant / Alternative Funding Opportunities

Projects involving renewable energy utilization have potential for obtaining funding from outside resources. These funds may be in the form of grants or low cost loans. At this stage of project development it is not possible to pinpoint any specific program where funding could potentially be obtained, but if the selected alternative is qualified and is approved, outside funding may be possible. While, there are not many funding opportunities for LGVSD due to the small scale of the biogas utilization alternatives, grant and loan opportunities should continue to be monitored, including opportunities for disadvantaged or rural communities that LGVSD may be eligible for based on the relatively small population it serves. Also given LGVSD’s small size, multi-jurisdictional “teaming” opportunities in the region should be considered since many awards are given to applicants that provide economies of scale in offsetting carbon intensive fuel production, reducing GHGs, increasing renewable energy, etcetera. Table 4-12 below summarizes some of the current opportunities for outside funding.
### Outside Funding Opportunities

#### Summary of Currently Available Grants and Loans

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Grant/Loan</th>
<th>Description</th>
<th>Website</th>
<th>Application Deadline</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shovel-ready infrastructure projects.</td>
<td>State Water Board’s Clean Water State Revolving Fund (CWSRF) Program</td>
<td>Accepts applications on a continuous basis. Offers low interest financing for water quality projects. Disburses $200 - $300 million annually. Any city, town, district, or other public body created under State law is eligible for funding.</td>
<td><a href="http://www.waterboard.s.ca.gov/water_issues/programs/grants_loans/srf/srf_forms.shtml">www.waterboard.s.ca.gov/water_issues/programs/grants_loans/srf/srf_forms.shtml</a></td>
<td>Continuous</td>
<td>Eligible projects include, but not limited to, construction of wastewater treatment facilities.</td>
<td>Current focus is water recycling.</td>
</tr>
<tr>
<td>CNG Vehicle Fill Station</td>
<td>Carl Moyer Memorial Air Quality Standards Attainment Program</td>
<td>Provides funding to encourage the voluntary purchase of cleaner-than-required engines, equipment, and emission reduction technologies for vehicles. Plays a complementary role to California’s regulatory program by funding emission reductions that are surplus, i.e., early and/or in excess of what is required by regulation.</td>
<td><a href="http://www.arb.ca.gov/msprog/moyer/guidelines/current.htm">http://www.arb.ca.gov/msprog/moyer/guidelines/current.htm</a></td>
<td>Continuous; first come first serve</td>
<td>Program funds engine replacements &amp; retrofits, new vehicle purchases, fleet modernization, equipment replacements, and vehicle retirements.</td>
<td>Focus is on vehicles. Funding for stationary sources only applies to the agricultural industry. Funding only awarded to projects without regulatory drivers.</td>
</tr>
<tr>
<td>CNG Vehicle Fill Station</td>
<td>California Energy Commission Alternative and Renewable Fuel and Vehicle Technology Program</td>
<td>Provides up to $100 million per year toward the development and deployment of low-carbon alternative fuels, fueling infrastructure, and advanced vehicle technologies.</td>
<td><a href="http://www.energy.ca.gov/2013publications/CEC-600-2013-003/CEC-600-2013-003-LCF.pdf">http://www.energy.ca.gov/2013publications/CEC-600-2013-003/CEC-600-2013-003-LCF.pdf</a></td>
<td>TBD for F.Y. 2014/15 F.Y. 2013/14 applications were due 3/11/14</td>
<td>Potential funding for the production of low carbon biofuels, such as CNG from biogas. $39 million awarded to 12 biomethane production projects to date. $17.5 million awarded to 48 natural gas fueling infrastructure projects to date. $33.5 million awarded to 3 natural gas vehicle deployment projects to date.</td>
<td>Scoring criteria focuses on a project’s ability to compete in the commercial California marketplace, increase the in-state production of low carbon biofuels, and advance the state-of-the-art in biofuels production technology. Only $1.5 million will be awarded in CA in F.Y. 2014/15 for natural gas fueling infrastructure.</td>
</tr>
</tbody>
</table>
Present Worth Analysis

Combining the construction costs and a present worth calculation of the O&M costs provides an overall analysis of the total present worth of each alternative. The interest rate was assumed to be 3%, discount rate was assumed to be 5%, and the time period evaluated was 20 years. Table 4-13 below summarizes the results for each alternative.

Table 4-13
Present Worth of Alternatives
Summary of present worth analysis

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Construction Cost</th>
<th>Annual O&amp;M Present Worth</th>
<th>Total Present Worth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remove Existing IC Engine</td>
<td>($1,580,000)</td>
<td>($380,000)</td>
<td>($1,960,000)</td>
</tr>
<tr>
<td>Microturbines</td>
<td>($2,200,000)</td>
<td>$100,000</td>
<td>($2,100,000)</td>
</tr>
<tr>
<td>CNG Vehicle Fill Station</td>
<td>($2,900,000)</td>
<td>$400,000 / ($1,360,000)</td>
<td>($2,500,000) / ($4,260,000)</td>
</tr>
<tr>
<td>Pipeline Injection</td>
<td>($8,400,000)</td>
<td>($500,000)</td>
<td>($8,900,000)</td>
</tr>
</tbody>
</table>

Figure 4-4 below is a chart of the present worth analysis.

![Chart showing present worth analysis](chart.png)

Legend:
- **Red**: Annual O&M Present Worth
- **Blue**: Construction Cost
Section 5 - Non-Cost Evaluation

It is desirable to balance the economic quantitative factors on biogas utilization options with several qualitative non-cost factors. To provide a method of weighing these options and determining priorities, a decision matrix of non-cost factors was provided to LGVSD. Each factor was compared to the other factors to decide which factor was more important. The factors included in the decision matrix are listed below.

- Odor emissions
- Safety & Health
- Consistent with community values
- Green House Gas (GHG) offsets
- Criteria air pollutant emissions
- Net renewable energy generation
- Proven technology
- Long term permitability
- Site impacts
- O&M expertise
- System longevity

Once the district staff and board members filled in the matrix, a ranking of factor importance and a scoring weight could be determined based on the responses. The results of this exercise are summarized in Table 5-1 below.

### TABLE 5-1
Non-cost Factor Ranking
Summary of non-cost factor scoring

<table>
<thead>
<tr>
<th>Factor</th>
<th>Avg. Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety &amp; Health</td>
<td>14.5</td>
</tr>
<tr>
<td>Long Term Permitability</td>
<td>12.4</td>
</tr>
<tr>
<td>O&amp;M Expertise</td>
<td>11.8</td>
</tr>
<tr>
<td>Site impacts</td>
<td>10.9</td>
</tr>
<tr>
<td>Proven technology</td>
<td>10.0</td>
</tr>
<tr>
<td>System Longevity</td>
<td>10.0</td>
</tr>
<tr>
<td>Net renewable energy generation</td>
<td>8.2</td>
</tr>
<tr>
<td>Criteria air pollutant emissions</td>
<td>7.9</td>
</tr>
<tr>
<td>GHG offsets</td>
<td>7.6</td>
</tr>
<tr>
<td>Consistent with community values</td>
<td>4.2</td>
</tr>
<tr>
<td>Odor emissions</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Independent of this effort by LGVSD, the engineer determined a 1 through 10 score of each biogas technology alternative for each of the non-cost factors listed above. The engineering’s score for each factor was then multiplied by the scoring weight determined by LGVSD. The values for each alternative were then summed for a final score. The results of the non-cost evaluation are presented in Table 5-2 below.
<table>
<thead>
<tr>
<th>Non-Cost Factor</th>
<th>Microturbines Score</th>
<th>NG Vehicle Fill Station Score</th>
<th>Pipeline Injection Score</th>
<th>Remove IC Engine Score</th>
<th>Notes</th>
<th>Notes</th>
<th>Notes</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety &amp; Health</td>
<td>8</td>
<td>5</td>
<td>9</td>
<td>9</td>
<td>Low amount of equipment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long Term Permitability</td>
<td>6</td>
<td>Strict air standards for stationary fuel burning equipment</td>
<td>6 Generally unregulated now, so future regulations are unknown</td>
<td>8</td>
<td>Backup equipment only</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O&amp;M Expertise</td>
<td>8 3rd party maintenance</td>
<td>8 3rd party maintenance</td>
<td>8 3rd party maintenance</td>
<td>8</td>
<td>Same as existing equipment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site impacts</td>
<td>6 Similar to current cogeneration, but less noise and greater footprint</td>
<td>4 Location for vehicles to park while filling will disrupt site</td>
<td>6 No combustion emissions and less noise</td>
<td>7</td>
<td>Same as existing equipment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proven technology</td>
<td>7</td>
<td>7</td>
<td>3 New concept; only one example in CA</td>
<td>8</td>
<td>Same as existing equipment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System Longevity</td>
<td>6 Turbines will wear faster than other alternatives</td>
<td>7</td>
<td>8</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net renewable energy generation</td>
<td>7 Good efficiency</td>
<td>4 Inherent losses decrease efficiency</td>
<td>4 Inherent losses decrease efficiency</td>
<td>3</td>
<td>Only generates heat with biogas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Criteria air pollutant emissions</td>
<td>8 Low emissions meet permit requirements</td>
<td>5 Methane slip from CO2 scrubber must be either vented or flared</td>
<td>5 Methane slip from CO2 scrubber must be either vented or flared</td>
<td>3</td>
<td>Most gas burned in flare; higher emissions than engine burned gas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GHG offsets</td>
<td>8 Utilizes all gas generated to make either electricity or heat</td>
<td>6 Does not fully utilize gas available</td>
<td>5 Does not fully utilize gas available</td>
<td>3</td>
<td>Most gas burned in flare</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consistent with community values</td>
<td>6</td>
<td>5 Does not fully utilize gas available</td>
<td>5</td>
<td>1</td>
<td>Decrease in goals for biogas usage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Odor emissions</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Weighted Points</td>
<td>707</td>
<td>584</td>
<td>651</td>
<td>678</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 5-1 is a chart of the above results.

The microturbine alternative had the highest score of the non-cost factor analysis, with the IC engine removal alternative fairly close in second place. The remove IC engine alternative scored very high in the top rated factors as selected by LGVSD, and very low in the factors that were not considered as important. The microturbine alternative had a more balanced set of scores.

Section 6 – Project Delivery and Operations Options

As part of CH2M HILL overall investigation into the development of solutions for the Biogas Utilization Technologies Evaluation, CH2M HILL also investigated management options to develop and operate a new biogas utilization system. The following three options will be assessed:

- Public development and/or operation
- Third party private development and/or operation
- Public/Private Partnership development and/or operation

The overview of each option will touch upon key aspects of each method of delivery such as management of each option by LGVSD, engineering, implementation, operation and maintenance.

Public Development and/or Operations

For a traditional public development approach, LGVSD has the familiarity and procedures in place for what is normally defined as design/bid/build (DBB) procurement. The needed oversight of engineering, the support of the procurements, the staff review, including operations and involvement during construction, and the ultimate transition from final acceptance to full operation can normally be handled by the current staff of LGVSD.
Typically, LGVSD, working with its conceptual design engineer, decides which biogas utilization alternative is most advantageous. Then, LGVSD can initiate the necessary design activity to complete the design with the help of the same conceptual design engineer or other design firm. While the design is ongoing, LGVSD will work to develop the permitting requirements and determine the need to integrate the proposed system with the current permit requirements and determine any necessary revision/additions to permits.

Once the design is complete, a request for quotation is issued (similar to the Waste Gas Burner System Replacement (Job No. 10600-08)) and responses received. LGVSD will evaluate the responses and select the lowest cost proposer. Once the contract is awarded, LGVSD will monitor the performance of the construction to assure itself that the installation meets the requirements of the contract documents and that the schedule and budget are in compliance.

Upon completion of the construction, LGVSD will have the performance/acceptance test completed and the operation responsibility of the chosen system will now be LGVSD’s.

Depending on the options selected, LGVSD might have the contractor provide some type of additional training of LGVSD staff for any specialized requirements. Other than normal warranty and guarantee from the contractor and or the equipment supplier, LGVSD is responsible for the on-going performance and warranty obligation requirements and other operations and maintenance (O&M) obligations. Table 6-1 below summarizes the advantages and disadvantages of the DBB option.

<table>
<thead>
<tr>
<th>Table 6-1</th>
<th>DBB Advantages and Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Summary of Design-Bid-Build Advantages and Disadvantages</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Advantages</strong></td>
<td><strong>Disadvantages</strong></td>
</tr>
<tr>
<td>• Project requirements are defined by owner and engineer</td>
<td>• Linear process takes time with less opportunity for schedule acceleration</td>
</tr>
<tr>
<td>• Can work toward preferred equipment</td>
<td>• Reduced collaboration between designer, contractor and operator</td>
</tr>
<tr>
<td>• Independent contracts for engineering and construction</td>
<td>• Relies on engineer’s estimate to fund program</td>
</tr>
<tr>
<td>• Legal and widely used in all states and municipalities</td>
<td>• Owner warrants design document</td>
</tr>
<tr>
<td>• Well understood and time-tested process</td>
<td>• Less opportunity for cost savings</td>
</tr>
<tr>
<td>• Owners, regulatory agencies, and the public usually accept the results</td>
<td>• Owner deals with disputes, change orders and may delay project completion.</td>
</tr>
</tbody>
</table>

**Third Party Private Development and/or Operation**

Under a third party private development project delivery approach, LGVSD can consider two types of variation depending on the level of involvement it would prefer. The first approach—prescriptive Design/Build (DB) would be to select the preferred biogas utilization alternative which meets LGVSD’s criteria and through working with the design engineer, develop the concept design to a 10-20% design level. With this level of design, LGVSD could structure a two-step procurement RFQ/RFP process to solicit firms, Design/Builders (DB) interested in completing the design and providing schedule, cost and operating performance guarantees. In this approach, LGVSD would need to hire engineering support, commercial support and legal support in moving the procurement through its normal process. Also, LGVSD would have to clearly define the input for the project and the expected output which would be used to determine compliance with its requirements.

Once the firm is selected to perform the work based on the agreed to contract, LGVSD will, with its support staff, monitor the progress of the DB entity in an oversight role much different than the traditional DBB procurement. Structured correctly, LGVSD will not be dealing with the change orders typical with the DBB approach since the normal conflicts between designer and contractor is eliminated. LGVSD will have to be able to deal with the
overall management of the project and not the normal details of the design. However, during the prequalification stage it will be critical for LGVSD to select DB entities with demonstrated capability to perform the intended work and have the resource of both personnel and financial strength to warrant the work for on time performance and for the agreed to contract value. Again, LGVSD will monitor the acceptance test and once the system has complied with LGVSD’s performance requirements, it will take control of the facility and begin to operate it. In this approach LGVSD passes to the DB entity many of the risks such as permitting, pricing, and scheduling that would normally under the DB approach LGVSD’s sole responsibility or at a minimum shares the risks with the DBB designer.

A variation of the prescriptive Design/Build (DB) approach would be a more performance based approach, performance DB. Here LGVSD would determine the preferred outcome. This could include such detail as generating the most recovered energy from the available digester gas. This would include the value to LGVSD of any recovered energy and the capital expenditure.

As part of the performance DB approach, LGVSD could indicate to the proposers what type of option(s) LGVSD is not interested in, if any, from the evaluated alternatives listed above. This is important since at the completion of the contract, LGVSD will need to operate the selected system. LGVSD would need engineering, commercial and legal support to move through the procurement process, especially in evaluating the option(s) selected by each proposer and developing a life-cycle cost comparison of the various option(s).

Performance DB approach will require more intense involvement of LGVSD and its advisors in a shorter period of time. However the outcome is similar to what would have transpired in the longer traditional DBB approach. One advantage of the performance DB approach is a warranty of performance is established by the DB entity. Besides cost, schedule and equipment warranties, LGVSD could expect guarantees such as the amount of energy recovered for a certain amount of digester gas handled.

In both of the prescriptive DB and the performance DB approaches, LGVSD may determine that the O&M of the proposed system be operated and maintained for a period of time after completion of the acceptance test. LGVSD could obtain performance guarantees for O&M consumables such as electricity, chemicals, etc. This would provide LGVSD with further assurance that the system will work as intended and the DB entity is responsible. Clearly this O&M involvement creates further detail for LGVSD to review and monitor during the procurement and ongoing operations.

One area LGVSD needs to understand and monitor in any of these third-party approaches would be any side streams created by the selected process and its impact on the operation of the WWTP. Such items as nutrients or returned water (pH and or temperature) could have significant impact on the WWTP if it is not properly defined and managed.

Table 6-2 below summarizes the Design-Build approach advantages and disadvantages.

**Table 6-2**  
*DB Advantages and Disadvantages*  
*Summary of Design-Build Advantages and Disadvantages*

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Single point of responsibility</td>
<td>• Limited input from Owner after 30% design</td>
</tr>
<tr>
<td>• Provides early fixed price with reduced design cost</td>
<td>• Less Owner control over final construction details</td>
</tr>
<tr>
<td>• Performance warranty for design/builder</td>
<td>• Limited oversight by Independent Owner's agent</td>
</tr>
<tr>
<td>• Risk transfer to design/builder</td>
<td>• Design drawings are not as detailed</td>
</tr>
<tr>
<td>• Collaboration between designer and builder</td>
<td>• Costs beyond lump sum unknown to owner</td>
</tr>
<tr>
<td>• Time savings, shorter schedule due to reduced design and early start construction</td>
<td></td>
</tr>
</tbody>
</table>
Public/private partnership development and/or operation

The National Council for Public Private Partnerships defines this type of development as “A Public-Private Partnership (PPP) is a contractual arrangement between a public agency (federal, state or local) and a private sector entity. Through this agreement, the skills and assets of each sector (public and private) are shared in delivering a service or facility for the use of the general public. In addition to the sharing of resources, each party shares in the risks and rewards potential in the delivery of the service and/or facility.”

As can be seen from our discussion concerning third party private development, the above definition seems to apply to that case. For purpose of this discussion we will assume the added difference of the PPP approach is in the ownership and management of the underlying asset being shared between the public and private firm.

Once this dimension is added, we open the area of financing the assets, revenue to support the ownership structure of the assets and the various commercial and legal requirements this approach will necessitate. In order to consider this approach, there needs to be an economic motivation for both the public and private entity to participate in the partnership.

Typically the assets in question, in this case the system used to generate valuable methane gas from the digestion of wastewater sludge in the treatment process by LGVSD, can possibly be monetized by the private company and the value proposition created. The private company could use this digested gas to create hot water, combust the gas in an engine to generate power, use with photovoltaic cells to create power or sell the gas for natural gas distribution or any combination that is sound financially.

In all these potential uses for the digester gas, both the owner and the private company would have to consider how the proposed system compares with the available replacement items, purchased natural gas cost ($/Million Btu) or electricity cost ($/kWh for distribution cost and generation cost). Along with this there are many issues that must also be considered: reliability of the digester gas generation, both quality and quantity, handling of any side stream generated by the resulting system, and whether the gas utilization system is integrated into the facility or is a stand-alone system.

There are many commercial issues also to be considered: permitting, asset ownership, site lease, reliability, performance obligations, payment obligations and many others. All of these can be addressed and resolved in a workable manner but the motive to resolve all these issues is driven by the potential savings gained by the public owner and the ability of the private company to earn a reasonable return on its investment.

Additionally, there may be incentives available to both the owner and the private company such as loan/grants or tax incentive for renewable energy production. Together the owner and private entity can work to determine the lowest cost structure and determine the best way to achieve this structure.

But ultimately the conceptual design must demonstrate the ability to satisfy the financial interest of both the owner and the private entity while permitting both to meet their objects of servicing their customer’s needs in the case of the owner and for the private entity providing value to their shareholders.

Table 6-3 below summarizes the advantages and disadvantages of a public-private partnership approach.
### Table 6-3
PPP Advantages and Disadvantages

**Summary of Design-Build Advantages and Disadvantages**

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Single point of responsibility</td>
<td>• Limited input from Owner after initial concept design</td>
</tr>
<tr>
<td>• Provides early service fee price</td>
<td>• Complex negotiations</td>
</tr>
<tr>
<td>• Service performance warranty</td>
<td>• Limited oversight by Independent Owner's agent</td>
</tr>
<tr>
<td>• Risk transfer to PPP provider</td>
<td>• State laws vary on whether this can be done</td>
</tr>
<tr>
<td></td>
<td>• Owner is “hands-off” of the long term performance and operations, other than service requirements</td>
</tr>
<tr>
<td></td>
<td>• Limited input from Owner after initial concept design</td>
</tr>
<tr>
<td></td>
<td>• Requires performance guaranties by Owner for the minimum amount of gas produced with penalties if they are not met</td>
</tr>
<tr>
<td></td>
<td>• Could be conflicts over the amount of heat required by the plant and who would supply the heat</td>
</tr>
</tbody>
</table>

Figure 6-1 illustrates the interrelationships between the separate parties for each project delivery approach described above.

![Figure 6-1 Project Delivery Approach Relationships](image)

### Recommendations

As LGVSD assesses how to implement this project the following are recommendations of the various options being considered.
Microturbines

Key with this option is the interconnection of the microturbine(s) with the source digester gas and adaptation with the existing electrical supply system of the WWTP. Because of these two reasons the DBB and the DB approach would be preferred. Since the microturbine(s) is the critical component LGVSD, working with either team DBB team or the prescriptive DB team, could identify the preferred microturbine(s) supplier and develop the project around this design. All interconnections could be managed and the transition to LGVSD O&M could be accommodated.

For the P3 approach the total quantity of digester gas is small and the ability to attract private investment could be difficult. If LGVSD would consider a capital or operating lease for the microturbines, the commercial requirements to establish the necessary obligations between LGVSD and the proposer might require extensive legal support and for this size project might not be warranted.

CNG Vehicle Fill Station

For this option it is assumed that LGVSD would be fueling their own or other City vehicles outfitted to operate with CNG. In this case the necessary coordination with the type of vehicle being supplied might make the DBB a more logical choice to execute this project. The functionality would seem more in line with LGVSD coordinating this effort and then living with the desired outcome. Either DB option would possibly work but the functionality with the vehicles would remain with LGVSD.

For the P3 option it might work if the use of the CNG fueling was for a larger user base but again the amount of digester gas may not warrant this approach.

Pipeline Injection

Working with PG&E would not allow the use of either DBB or DB other than the production and cleaning of the digester gas stream to meet their quality requirements. Furthermore the tie-in to their higher pressure gas line with the necessary safety precautions would be conducted by PG&E.

Again for the amount of digester gas involved it is hard to contemplate that a P3 would be worth the effort to use the P3 approach.

ICE Removal with Boiler/Flare installation

This option is relatively similar in scope and operation as the current ICE unit being replaced. This familiarity and simplicity would seem to be best implemented with using the DBB approach. Also if schedule was a concern using the DB approach either prescriptive or performance would work.

From the P3 approach the size and the simplicity would make the P3 approach not desirable.

Table 6-4 below summarizes the recommended project implementation options.

<table>
<thead>
<tr>
<th>Option Recommendations</th>
<th>Design/Bid Build</th>
<th>Design/Build</th>
<th>Public Private Partnership</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microturbines</td>
<td>Yes (1st Choice)</td>
<td>Yes (2nd Choice)</td>
<td>No</td>
</tr>
<tr>
<td>CNG Fueling</td>
<td>Yes (1st Choice)</td>
<td>Yes (2nd Choice)</td>
<td>No</td>
</tr>
<tr>
<td>PG&amp;E Pipeline injection</td>
<td>Yes (1st Choice)</td>
<td>Yes (2nd Choice)</td>
<td>PG&amp;E</td>
</tr>
<tr>
<td>ICE Removal with Boiler/Flare installation</td>
<td>Yes (1st Choice)</td>
<td>Yes (2nd Choice)</td>
<td>No</td>
</tr>
</tbody>
</table>
Section 7 – Recommendations

Before any final decisions are made regarding further development of any alternative described above, the following actions are recommended:

- Confirm the biogas production values with longer term trending data
- Test the biogas for siloxane levels and confirm the methane and hydrogen sulfide content
- Confirm the acceptability of the proposed equipment locations
- Decide if a new gas storage tank is desired

A summary of major advantages and disadvantages for each evaluated alternative is included in Table 7-1 below.

Table 7-1
Alternative Advantages and Disadvantages

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
</table>
| Microturbines       | • Produces approximately same amount of electricity as current IC engine system  
<p>|                     | • Clean burning technology                                                  | • Additional equipment to maintain that LGVSD staff is unfamiliar with        |
|                     | • Lower cost than CNG vehicle fill station and pipeline injection           | • Significant capital cost                                                    |
|                     | • All biogas would be utilized when system is not down for equipment maintenance | • Would cost more to operate than electrical energy savings gained             |
|                     | • Majority of biogas would still be utilized even if one turbine was down for maintenance |                                                                              |
| CNG Vehicle Fill Station | • LGVSD could self support its own CNG vehicle fleet fueling needs        | • Cost to convert or purchase fleet of CNG vehicles is high                   |
|                     | • Minor impacts to the facility site and operations                         | • Unlikely that biogas would be fully utilized, resulting in increased flaring of biogas |
|                     | • All biogas would be utilized when system is not down for equipment maintenance | • Possible significant impacts to site and safety due to increased vehicle traffic |
| Pipeline Injection   | • Minor impacts to the facility site and operations                         | • Access for non-LGVSD may be undesirable due to increased safety and security risk |
|                     | • All biogas would be utilized when system is not down for equipment maintenance | • LGVSD would be responsible for ensuring gas quality and be responsible for damages if quality was not met |
|                     |                                                                              | • Cost of CNG produced is higher than cost at commercial fill station         |</p>
<table>
<thead>
<tr>
<th>Remove IC Engine</th>
<th>Would be the first biogas injection system with PG&amp;E</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Lowest cost</td>
<td>• Reduces the amount of beneficial biogas utilization</td>
</tr>
<tr>
<td>• High non-cost factor score</td>
<td>• Additional biogas would be flared</td>
</tr>
<tr>
<td>• Simple to operate</td>
<td></td>
</tr>
<tr>
<td>• Minor impacts to the facility site and operations</td>
<td></td>
</tr>
<tr>
<td>• Could be expanded in the future if additional uses of heat are found</td>
<td></td>
</tr>
<tr>
<td>• Little to no issues obtaining an air emissions permit</td>
<td></td>
</tr>
<tr>
<td>• Least amount of maintenance required</td>
<td></td>
</tr>
</tbody>
</table>

Unfortunately, all the alternatives evaluated resulted in costs that are higher than any possible savings in energy or selling of gas, including the option that removes the existing engine and does not add any additional biogas utilization capability. The economic evaluation indicates that the alternative to remove the existing IC engine and add a standby boiler and waste gas burner would have the least costs and as stated above, this alternative was the second highest scoring for non-cost factors. The microturbine alternative was the second lowest cost, but had the highest non-cost factor score. As shown in the executive summary section above, if a benefit to cost ratio is calculated by dividing the non-cost factor score by the present worth cost, removing the IC engine has the highest ratio. Operationally, however, a microturbine system would be a good substitute to replace the existing engine system, as it would keep operations similar to the existing system. It is recommended that LGVSD review the rankings of the non-cost factors to determine if priorities should altered from the results initially determined. It is possible to remove the existing engine now to comply with the air permit requirements and add one of the systems described above at a later date if additional financial incentives become available. If a natural gas service is added to the plant in the future, the microturbines could be supplemented with natural gas so that they can run at full capacity, providing some additional electricity. Although the cost is higher, installing a microturbine system would allow the district to continue utilizing all of the available biogas, while only using the biogas for heat via the boiler would result in significant flaring of the gas. It is therefore recommended that a microturbine system be further considered for implementation at the LGVSD WWTP.
Appendix – Digested Sludge Heating Calculations
Las Gallinas Digestor Heat Loss Approximation

Summary of Calculations:
Ambient air temperature (annual median) 60 deg. F
Transfer Sludge Temperature (average) 55 deg. F
Desired sludge temperature 105 deg. F

SLUDGE HEATING (FROM DIGESTION TEMP TO DESIRED TEMP) 265,212 Btuh
HEAT LOSS FROM ONE TANK 122,795 Btuh

TOTAL 388,007 Btuh

Daily heat required 9,312,176 Btu
Biogas energy value 638 Btu/scf
digester gas requirement (includes losses) 20272 scf
14.1 scfm
LGVSD Biogas Utilization Evaluation - Heat Required for Digested Sludge

**CALCULATE REQUIRED HEAT TO RAISE TRANSFERRED SLUDGE UP TO DESIRED TEMPERATURE**

<table>
<thead>
<tr>
<th>Flowrate</th>
<th>Mass Flowrate</th>
<th>Delta Temperature</th>
<th>Heat Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPM</td>
<td>Lbs/hr</td>
<td>deg F</td>
<td>BTU/hr</td>
</tr>
<tr>
<td>Heating Rate Required</td>
<td>11</td>
<td>5,304</td>
<td>50</td>
</tr>
</tbody>
</table>

Transfer flow rate (daily avg) 15,264 gal per day
Transfer sludge temperature 55 deg. F
Desired sludge temperature 105 deg. F
LGVS Biogas Utilization Evaluation - Heat Loss from Primary Digester

**CALCULATE SLUDGE HOLDING TANK SURFACE AREA & HEAT LOSS**

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>R Value</th>
<th>R Value/inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 mph air</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>Ambient air (minimum)</td>
<td>60 deg F</td>
<td>annual median temperature</td>
</tr>
<tr>
<td>Heated Sludge</td>
<td>105 deg F</td>
<td>still digester gas 0.6</td>
</tr>
<tr>
<td>Control Building/Adjacent Tank</td>
<td>70 deg F</td>
<td>wet soil 0.5</td>
</tr>
<tr>
<td>Soil Temperature</td>
<td>50 deg F</td>
<td>still air (per inch) 0.4</td>
</tr>
</tbody>
</table>

**TANK ELEMENTS, DIMENSIONS, AND R-VALUES**

**Roof - Flat**
- Diameter: 60 ft.
- Surface Area: 2,827 sf

<table>
<thead>
<tr>
<th>R Values</th>
<th>R Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>outside air film</td>
<td>0.17</td>
</tr>
<tr>
<td>Rigid insulation</td>
<td>9.2</td>
</tr>
<tr>
<td>Concrete thickness</td>
<td>0.75 average between 13.8&quot; at center and 6&quot; at edge</td>
</tr>
<tr>
<td>Still digester gas</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Total = 10.72

**Wall Exposure 1 - Above grade**
- Width: 188.49 ft. (2 wall sections)
- Height: 25.00 ft.
- Surface Area: 4,712 sf

<table>
<thead>
<tr>
<th>R Values</th>
<th>R Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>outside air film</td>
<td>0.17</td>
</tr>
<tr>
<td>precast conc.</td>
<td>1.5 9&quot; minus 2&quot; for insulation</td>
</tr>
<tr>
<td>Insulation thickness</td>
<td>0</td>
</tr>
<tr>
<td>Air gap</td>
<td>0.3</td>
</tr>
<tr>
<td>Concrete thickness</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Total = 3.77

**Tank Bottom - Flat**
- Diameter: 59.00 ft.
- Surface Area: 2734 sf

<table>
<thead>
<tr>
<th>R Values</th>
<th>R Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>wet soil</td>
<td>0.5</td>
</tr>
<tr>
<td>Concrete thickness</td>
<td>2.25</td>
</tr>
</tbody>
</table>

Total = 2.75

**HEAT LOSS FROM SLUDGE INSIDE HOLDING TANK**

<table>
<thead>
<tr>
<th>Tank Surface</th>
<th>Area</th>
<th>R</th>
<th>Temp ° F</th>
<th>Temp ° F</th>
<th>Difference ° F</th>
<th>Heat Loss Btu/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof - Flat</td>
<td>2,827</td>
<td>10.72</td>
<td>105</td>
<td>60</td>
<td>45</td>
<td>11,869</td>
</tr>
<tr>
<td>Wall Exposure 1 - Above grade</td>
<td>4,712</td>
<td>3.77</td>
<td>105</td>
<td>60</td>
<td>45</td>
<td>56,247</td>
</tr>
<tr>
<td>Tank Bottom - Flat</td>
<td>2,734</td>
<td>2.75</td>
<td>105</td>
<td>50</td>
<td>55</td>
<td>54,679</td>
</tr>
<tr>
<td>Total/Digester</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>122,795</td>
</tr>
</tbody>
</table>
Appendix – Equipment Vendor Quotes and Information
Boiler Quote and Catalog Information
Dan,

The budget price for LN4F78-50-GG-W Burnham Firebox boiler with a stainless steel jacket and Webster Low NOx burner firing digest gas and propane (as a stand by fuel) will be $82,000.

Regards,

Michael Gamburg
Combustion Specialist
CTi-Controltech
Cell: (415) 221-6177
e-mail: mg@cti-ct.com
www.cti-ct.com
"Design. Implement. Service"

Please note our new address; 22 Beta Court, San Ramon, CA 94583

---

Michael, I received feedback from LGVSD that the existing boiler is oversized for their needs. Can you give me a price for the LN4F78-50 unit?

---

Dan,

Attached is the budget price for identical Boiler/ Burner package as we supplied for Las Galinas Sanitation District in 2010.

Regards,
Combustion, Emission and Steam Solutions

- Conceptual design
- Low and ultra low NOx burners and burner retrofits
- BMS and CCS system design and hardware
- Custom design SCR Systems
- Burner tune ups
- Pre-emission source testing measurements and evaluation
- Vapor recovery
- Particulate and CO2 control

Services

- Factory trained service personnel
- Commissioning and startup technical support
- Technical seminars and training
- Valve and actuator calibration and startup
- Instrument calibration and startup
- Complete turnkey project capabilities
- Heat rate, efficiency and plant improvement studies
- U.L. 508 custom design
- Project CAD drawings
- PLC Programming
- CFD and modeling

Valve and Automation Solutions

- Severe service valve sizing and selection
- Valve and actuation packages, pneumatic, hydraulic and electric
- Noise and cavitation control
- Total valve management programs
- Damper drives
- Vent to atmosphere and silencers
- Best fit for purpose replacement recommendations
- Ease of operation and life cycle cost considerations

Instrumentation Solutions

- Flow, level, pressure, density and temperature

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www.cti-ct.com
22 Beta Court
San Ramon, CA 94583
Combustion & Burner Management

Controls Expertise

General Engineering California Contractor License #851363

Successful implementation of hundreds of combustion and emission control strategies.

Application: Steam and hot water boilers, industrial furnace, dryer, fluid bed incinerator or other combustion equipment.

A total turn-key solution from initial design, equipment supply, through installation & startup.

Design and supply of single and multiple fuel combustion control and systems integration, using the latest in package control technologies such as Allen Bradley, Siemens, Fireye, Nexus, and Autoflame.

Our Combustion and Controls team is staffed with seasoned specialists who’s work history include companies such as: Rockwell Automation, Koch - John Zink, TOOD Combustion and Coen. CTI service engineers have many years of experience in start-up/tuning/instrument integration/troubleshooting for a wide variety of combustion systems such as those manufactured by: Coen, TOOD, Natcom, Pillard, Powerflame, Webster Engineering, Clever Brooks, Industrial Combustion, and Gordon-Platt.

Custom approach using programmable logic controllers (PLC) often providing a more flexible and economical solution than microprocessor packaged systems.

Supply and installation of professionally assembled and quality tested custom panels that meet UL508 approval.

Survey existing plant fuel-fired equipment to rate your existing control system in compliance with safety codes such as NFPA, UL, FM, IRI, OSHA etc.

Helping customers with obtaining approval of systems with their insurance carrier or local regulatory agencies.

Since its establishment in 1976, Controltech has focused on combustion control and burner management systems. If the application involves a single burner or multiple burners, CTI can help you with your burner, combustion control and burner management needs.

Capabilities

Burner
- Conceptual System Design
- Component Integration
- Start-up & Commissioning

Controls
- Custom Combustion Controls & Burner Management Systems
- Control System Integration
- Instrumentation, Calibration & Start-up

Selective Catalytic Reduction (SCR)
- Custom SCR System Design
- SCR systems for challenging applications
- Installation & Calibration

Emissions Monitoring
- CAM: Continuous Assurance Monitoring Solutions
- PEMS: Predictive Emissions Monitoring Systems
- CEMS: Continuous Emissions Monitoring Systems

Contact:
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**Capabilities**

**Burner**
- Conceptual System Design
- Component Integration
- Start-up & Commissioning

**Controls**
- Custom Combustion Controls & Burner Management Systems
- Control System Integration
- Instrumentation, Calibration & Start-up

**Selective Catalytic Reduction (SCR)**
- Custom SCR System Design
- SCR systems for challenging applications
- Installation & Calibration

**Emissions Monitoring**
- CAM: Continuous Assurance Monitoring Solutions
- PEMS: Predictive Emissions Monitoring Systems
- CEMS: Continuous Emissions Monitoring Systems

(925) 208-4250
www.cti-ct.com
22 Beta Court
San Ramon, CA 94583

RPP - Biogas Energy Recovery (9/29/2014)
Combustion, Emission and Steam Solutions

- Conceptual design
- Low and ultra low NOx burners and burner retrofits
- BMS and CCS system design and hardware
- Custom design SCR Systems
- Burner tune ups
- Pre-emission source testing measurements and evaluation
- Vapor recovery
- Particulate and CO2 control

Services

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- Commissioning and startup technical support
- Technical seminars and training
- Valve and actuator calibration and startup
- Instrument calibration and startup
- Complete turnkey project capabilities
- Heat rate, efficiency and plant improvement studies
- U.L. 508 custom design
- Project CAD drawings
- PLC Programming
- CFD and modeling

Valve and Automation Solutions

- Severe service valve sizing and selection
- Valve and actuation packages, pneumatic, hydraulic and electric
- Noise and cavitation control
- Total valve management programs
- Damper drives
- Vent to atmosphere and silencers
- Best fit for purpose replacement recommendations
- Ease of operation and life cycle cost considerations

Instrumentation Solutions

- Flow, level, pressure, density and temperature
Microturbine Quote and Catalog Information
Dan,

I apologize for the late response due to my travels last week.

Two C65s with heat recovery and configured for digester gas use will cost approximately $253,000

The gas cleanup skid including H2S and siloxane removal for the two C65s will cost approximately $436,700

These prices do not include commissioning costs.

Please let me know if you have any questions.

Thanks,
Alden Rodulfo
General Manager Northern California
Regatta Solutions
arodulfo@regattasp.com
408.836.1158
www.regattasp.com

From: "Dan.Robillard@CH2M.com" <Dan.Robillard@CH2M.com>
Date: Friday, February 14, 2014 at 11:23 AM
To: Alden Rodulfo <arodulfo@regattasp.com>
Subject: RE: Regatta/Capstone Follow Up

Here’s some gas data to work with:
63% methane
HHV 638 Btu/scf
200 mg/L H2S
There is a gas storage tank upstream that operates at 20 psig.
I do not have temperature data, but my guess is with the storage unit gas is about 70 deg F on average (95 deg to 50 deg F range).
For siloxanes, until we have testing data, let’s assume 1,600 ppbv.

Can you get me a quote for two C65 units with heat recovery and gas treatment by the end of next week?
Robust power system achieves ultra-low emissions and reliable electrical/thermal generation from waste gas.

- Years of renewable experience
- Ultra-low emissions
- Operates on landfill or digester gas
- One moving part – minimal maintenance and downtime
- Patented air bearing – no lubricating oil or coolant
- 5 and 9 year Factory Protection Plans available
- Remote monitoring and diagnostic capabilities
- Integrated utility synchronization and protection
- Small, modular design allows for easy, low-cost installation
- Reliable – tens of millions of run hours and counting
- Dual Mode option available for digester gas operation

### Electrical Performance

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Power Output</td>
<td>65kW</td>
</tr>
<tr>
<td>Voltage</td>
<td>400–480 VAC</td>
</tr>
<tr>
<td>Electrical Service</td>
<td>3-Phase, 4 wire</td>
</tr>
<tr>
<td>Frequency</td>
<td>50/60 Hz, grid connect operation</td>
</tr>
<tr>
<td>Maximum Output Current</td>
<td>100A, grid connect operation</td>
</tr>
<tr>
<td></td>
<td>100A, stand alone operation</td>
</tr>
<tr>
<td>Electrical Efficiency LHV</td>
<td>29%</td>
</tr>
</tbody>
</table>

### Fuel/Engine Characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landfill Gas HHV</td>
<td>13.0–22.3 MJ/m³ (350–600 BTU/scf)</td>
</tr>
<tr>
<td>Digester Gas HHV</td>
<td>20.5–32.6 MJ/m³ (550–875 BTU/scf)</td>
</tr>
<tr>
<td>H₂S Content</td>
<td>&lt; 5,000 ppmv</td>
</tr>
<tr>
<td>Inlet Pressure</td>
<td>517–552 kPa gauge (75–80 psig)</td>
</tr>
<tr>
<td>Fuel Flow HHV</td>
<td>888 MJ/hr (842,000 BTU/hr)</td>
</tr>
<tr>
<td>Net Heat Rate LHV</td>
<td>12.4 MJ/KWh (11,800 BTU/kWh)</td>
</tr>
</tbody>
</table>

### Exhaust Characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx Emissions @ 15% O₂</td>
<td>&lt; 9 ppmvd</td>
</tr>
<tr>
<td></td>
<td>(18 mg/m³)</td>
</tr>
<tr>
<td>NOx / Electrical Output</td>
<td>0.16 g/bhp-hr (0.46 lb/MWhe)</td>
</tr>
<tr>
<td>Exhaust Gas Flow</td>
<td>0.49 kg/s (1.08 lbm/s)</td>
</tr>
<tr>
<td>Exhaust Gas Temperature</td>
<td>309°C (588°F)</td>
</tr>
</tbody>
</table>
### C65 ICHP Heat Recovery

<table>
<thead>
<tr>
<th>Integrated Heat Recovery Module Type</th>
<th>Stainless Steel Core</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Water Heat Recovery</td>
<td>70kW (0.24 MMBTU/hr)</td>
</tr>
</tbody>
</table>

### Dimensions & Weight

<table>
<thead>
<tr>
<th></th>
<th>CR65</th>
<th>CR65 ICHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width x Depth (7) x Height (8)</td>
<td>0.76 x 2.0 x 1.9 m (30 x 77 x 75 in)</td>
<td>0.76 x 2.2 x 2.36 m (30 x 87 x 93 in)</td>
</tr>
<tr>
<td>Weight - Grid Connect Model</td>
<td>758 kg (1,671 lb)</td>
<td>1000 kg (2,200 lb)</td>
</tr>
<tr>
<td>Weight - Dual Mode Model (2)</td>
<td>1121 kg (2,471 lb)</td>
<td>1364 kg (3,000 lb)</td>
</tr>
</tbody>
</table>

### Minimum Clearance Requirements

<table>
<thead>
<tr>
<th></th>
<th>CR65</th>
<th>CR65 ICHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal Clearance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left &amp; Right</td>
<td>0.76 m (30 in)</td>
<td>0.76 m (30 in)</td>
</tr>
<tr>
<td>Front</td>
<td>0.76 m (30 in)</td>
<td>0.76 m (30 in)</td>
</tr>
<tr>
<td>Rear</td>
<td>0.91 m (36 in)</td>
<td>0.76 m (30 in)</td>
</tr>
</tbody>
</table>

### Sound Levels

<table>
<thead>
<tr>
<th></th>
<th>CR65</th>
<th>CR65 ICHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acoustic Emissions at Full Load Power (10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal at 10 m (33 ft)</td>
<td>70 dBA</td>
<td>65 dBA</td>
</tr>
</tbody>
</table>

### Certifications

- Classified UL 2200 and UL 1741 for raw natural gas and biogas operation (UL file AU5040)
- Complies with IEEE 1547 and meets statewide utility interconnection requirements for California Rule 21 and the New York State Public Service Commission
- Models available with optional equipment for CE Marking

---

(1) Nominal full power performance at ISO conditions: 59°F, 14.696 psia, 60% RH
(2) Only applies to digester gas (and Capstone “Type-B” fuels) only
(3) With linear load
(4) For surrogate landfill and digester gases. Please contact Capstone for additional details
(5) Heat recovery for water inlet temperature of 60°C (140°F) and flow rate of 2.5 l/s (40 GPM)
(6) Approximate dimensions and weights
(7) Depth includes 10 inch extension for the heat recovery module rain hood on ICHP versions
(8) Height dimensions are to the roof line. Exhaust outlet extends at least 7 inches above the roof line
(9) Clearance requirements may increase due to local code considerations
(10) The optional acoustic inlet hood kit can reduce acoustic emissions at the front of the MicroTurbine by up to 5 dBA

Specifications are not warranted and are subject to change without notice.
CR30 MicroTurbine

Renewable Fuels

Achieve ultra-low emissions and reliable electrical generation from waste gas.

- Years of renewable experience
- Ultra-low emissions
- Operates on landfill or digester gas
- One moving part – minimal maintenance and downtime
- Patented air bearing – no lubricating oil or coolant
- 5 and 9 year Factory Protection Plans available
- Remote monitoring and diagnostic capabilities
- Integrated utility synchronization and protection
- Small, modular design allows for easy, low-cost installation
- Reliable – tens of millions of run hours and counting

Electrical Performance

<table>
<thead>
<tr>
<th>Electrical Power Output</th>
<th>30kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>400–480 VAC</td>
</tr>
<tr>
<td>Electrical Service</td>
<td>3-Phase, 4 wire</td>
</tr>
<tr>
<td>Frequency</td>
<td>50/60 Hz</td>
</tr>
<tr>
<td>Maximum Output Current</td>
<td>36A, grid connect operation</td>
</tr>
<tr>
<td>Electrical Efficiency LHV</td>
<td>26%</td>
</tr>
</tbody>
</table>

Fuel/Engine Characteristics

<table>
<thead>
<tr>
<th>Digester / Landfill Gas HHV</th>
<th>13.0 – 32.6 MJ/m³ (350 – 875 BTU/scf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂S Content</td>
<td>&lt; 70,000 ppmv</td>
</tr>
<tr>
<td>Inlet Pressure – HHV dependent</td>
<td>414–483 kPa gauge (60–70 psig)</td>
</tr>
<tr>
<td>Fuel Flow HHV</td>
<td>457 MJ/hr (433,000 BTU/hr)</td>
</tr>
<tr>
<td>Net Heat Rate LHV</td>
<td>13.8 MJ/kWh (13,100 BTU/kWh)</td>
</tr>
</tbody>
</table>

Exhaust Characteristics

<table>
<thead>
<tr>
<th>NOx Emissions @ 15% O₂</th>
<th>&lt; 9 ppmvd (18 mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx / Electrical Output</td>
<td>0.22 g/bhp-hr (0.64 lb/MWhe)</td>
</tr>
<tr>
<td>Exhaust Gas Flow</td>
<td>0.31 kg/s (0.68 lbm/s)</td>
</tr>
<tr>
<td>Exhaust Gas Temperature</td>
<td>275°C (530°F)</td>
</tr>
</tbody>
</table>
Some utilities may require additional equipment for grid interconnectivity.

Nominal full power performance at ISO conditions: 59˚F, 14.696 psia, 60% RH

For surrogate landfill and digester gases. Please contact Capstone for additional details.

Approximate dimensions and weights:
- Height dimensions are to the roof line. Exhaust outlet extends at least 7 in above the roof line.
- Clearance requirements may increase due to local code considerations.

Specifications are not warranted and are subject to change without notice.

Dimensions & Weight
- Width x Depth x Height: 0.76 x 1.5 x 1.8 m (30 x 60 x 70 in)
- Weight: 405 kg (891 lb)

Minimum Clearance Requirements
- Vertical Clearance: 0.61 m (24 in)
- Horizontal Clearance:
  - Left & Right: 0.76 m (30 in)
  - Front: 0.93 m (37 in)
  - Rear: 0.90 m (35 in)

Sound Levels
- Acoustic Emissions at Full Load Power:
  - Nominal at 10 m (33 ft): 65 dBA

Certifications
- Models available with optional equipment for CE Marking

---

(1) Some utilities may require additional equipment for grid interconnectivity
(2) Nominal full power performance at ISO conditions: 59°F, 14.696 psia, 60% RH
(3) For surrogate landfill and digester gases. Please contact Capstone for additional details
(4) Approximate dimensions and weights
(5) Height dimensions are to the roof line. Exhaust outlet extends at least 7 in above the roof line
(6) Clearance requirements may increase due to local code considerations
Specifications are not warranted and are subject to change without notice.
Biogas Cleaning Equipment Information
Thank you for giving Unison Solutions the opportunity to provide you with the enclosed proposal. If you have questions or require additional information, please contact me at your convenience.

Sincerely,

Unison Solutions, Inc.
EQUIPMENT/SUB-SYSTEMS

HYDROGEN SULFIDE REMOVAL SYSTEM

- Hydrogen Sulfide Inlet Moisture/Particulate Filter
- Hydrogen Sulfide Removal Media Vessel
- Work Platform and Ladder
- Initial Charge of Sulfate Treat Media

GAS COMPRESSION/MOISTURE/SILOXANE REMOVAL SYSTEM

- Gas Compressor Inlet Moisture/Particulate Filter
- Pre-cooler
- Gas Compressor
- Oil/Gas Separator
- Oil Cooler
- Oil Particulate Filter
- Gas to Gas Heat Exchanger
- Gas to Glycol Heat Exchanger
- Moisture Separator
- Gas Recirculation
- Siloxane Removal Vessels
- Work Platform and Ladder
- Initial charge of Siloxane Removal Media
- Siloxane Removal Final Particulate Filter
- Skid Base

GLYCOL CHILLER

- Glycol Chiller
- Initial fill of Propylene Glycol/Water Mixture

CONTROL SYSTEM

- Gas Conditioning System Control Panel
- Transformer

DESIGN CONDITIONS

SITE INFORMATION

- Minimum Ambient Temperature 18°F
- Maximum Ambient Temperature 108°F
- Site Elevation 0' AMSL

SYSTEM REQUIREMENTS

- Nominal Gas Flow 42 scfm
- Maximum Gas Flow: 63 scfm

**INLET GAS CONDITIONS**

- Inlet Gas Pressure: 10" WC
- Minimum Inlet Gas Temperature: 80°F
- Maximum Inlet Gas Temperature: 85°F
- Relative Humidity: 100%
- Methane (CH₄): 64%
- Carbon Dioxide (CO₂): 34%
- Hydrogen Sulfide (H₂S): 190 ppmv
- Siloxanes (L₂, L₃, L₄, L₅, D₃, D₄, D₅, D₆): 260 ppbv

**DISCHARGE GAS CONDITIONS**

- Discharge Gas Pressure: 100 psig
- Discharge Gas Temperature: 80°F
- Dew Point Temperature: 40°F
- Maximum Hydrogen Sulfide: <10 ppmv
- Maximum Siloxane: <100 ppbv
- Particulate Removal: 99% removal of >3 micron

**SITE REQUIREMENTS**

**ELECTRICAL CLASSIFICATION**

- NEC Class I, Division 1 Group D Areas
  - Hydrogen Sulfide Removal System
  - Gas Compression/Moisture/Siloxane Removal System

- Unclassified Electrical Areas
  - Glycol Chiller
  - Gas Conditioning System Control Panel

**EQUIPMENT MOUNTING**

- Skid Mounted
  - Gas Compression/Moisture/Siloxane Removal System

- Standalone
  - Hydrogen Sulfide Removal System
  - Glycol Chiller
  - Gas Conditioning System Control Panel
EQUIPMENT/SUB-SYSTEM DETAILS

HYDROGEN SULFIDE REMOVAL SYSTEM

- Hydrogen Sulfide Inlet Moisture/Particulate Filter
  - Mounted upstream of the Hydrogen Sulfide Removal Media Vessels
  - 99% removal of 3micron and larger particulates and liquid droplets
  - Materials of construction shall be 304L stainless steel
  - 150# ANSI B16.5 side inlet and outlet connections
  - Cleanable polypropylene structured mesh element
  - Differential pressure gauge across the filter element
  - Float operated gauge for liquid level indication
  - Level switch above the condensate drain to warn of failure
  - Bottom drain with strainer, float drain, manual bypass and piping

- Hydrogen Sulfide Removal Media Vessel
  - 5’Ø x 12’ straight side
  - Rated for 5psig pressure and 1psig vacuum
  - Materials of construction shall be 304L stainless steel
  - 150# ANSI B16.5 side inlet and outlet connections
  - Flanged and dished top and bottom heads
  - Vessel shall be free-standing on four 304L stainless steel legs
  - Vessel equipped with a 24” top manway
  - Vessel equipped with a 24” side manway
  - Internal supports and grating for media
  - Pressure relief valves included
  - Two top vents with stainless steel ball valves
  - Bottom manual condensate drain with stainless steel ball valves

- Work Platform and Ladder
  - Work platform shall be welded carbon steel construction with satin black powder coat finish
  - Ladder shall be galvanized steel construction

- Initial Charge of SulfaTreat Media
  - The initial charge of SulfaTreat media for each Hydrogen Sulfide Removal Media Vessel will be provided.
  - SulfaTreat to be loaded into Hydrogen Sulfide Removal Vessel by INSTALLATION CONTRACTOR

GAS COMPRESSION/MOISTURE/SILOXANE REMOVAL SYSTEM

- Gas Compressor Inlet Moisture/Particulate Filter
- Mounted upstream of the Gas Compressor
- 99% removal of 3micron and larger particulates and liquid droplets
- Materials of construction shall be 304L stainless steel
- 150# ANSI B16.5 side inlet and outlet connections
- Cleanable polypropylene structured mesh element
- Differential pressure gauge across the filter element
- Float operated gauge for liquid level indication
- Level switches above the condensate drain to warn of failure
- Bottom drain with strainer, condensate pump, check valve, manual bypass and piping
- Pre-cooler
- Within the heat exchanger the gas will be cooled to 70°F
- Gas to Glycol fin/tube core
- Materials of construction shall be aluminum fins on 304L stainless steel tubes
- 150# ANSI B16.5 inlet and outlet connections

- Gas Compressor

- One Oil Flooded Twin Screw Compressor rated for 63scfm
- Direct drive 25Hp, 480V/3Ph/60Hz electric motor
- Motor speed will controlled by a VFD
- All gas and oil components other than the compressor head shall be constructed of stainless steel and/or aluminum.
- Gas inlet and discharge flex connectors
- Gas inlet check valve
- Discharge pressure safety valve
- Oil handling system will include an oil handling reservoir, coalescing filter, pressure safety valve, oil cooler, three way thermal bypass valve and an oil particulate filter.
- Initial fill of oil for the Gas Compressor system will be provided
- Gas Compressor shall have a hydrogen sulfide tolerance of 40,000 ppmv

- Oil/Gas Separator

- ASME Section VIII, Division 1 code stamped
- Materials of construction shall be 304L stainless steel
- 150# ANSI B16.5 inlet and outlet connections
- Discharge check valve

- Oil Cooler

- Air to oil fin/tube core
- Materials of construction shall be aluminum fins and tubes
- 150# ANSI B16.5 inlet and outlet connections
- 480V/3Ph/60Hz EXP electric motor
- Oil Particulate Filter
  - ASME Section VIII, Division 1 code stamped
  - Materials of construction shall be 304L stainless steel
  - 150# ANSI B16.5 inlet and outlet connections
  - Removable bag style elements for 5 micron

- Gas to Gas Heat Exchanger
  - Brazed plate
  - Materials of construction shall be 304L stainless steel body with nickel/chrome brazing
  - 150# ANSI B16.5 inlet and outlet connections

- Gas to Glycol Heat Exchanger
  - Brazed plate
  - Materials of construction shall be 304L stainless steel body with nickel/chrome brazing
  - 150# ANSI B16.5 inlet and outlet connections

- Moisture Separator
  - Uni-Flow Model
  - ASME Section VIII, Division 1 code stamped
  - Materials of construction shall be 304L stainless steel
  - 150# ANSI B16.5 inlet and outlet connections
  - Centrifugal style with no element to be cleaned or changed
  - Integral level switched for drain control
  - Bottom drain with strainer, solenoid valve, check valve, manual bypass and piping

- Gas Recirculation
  - Backpressure regulator shall be provided to allow excess gas to flow from the discharge of the system back to the inlet of the Gas Compressor.

- (3) Siloxane Removal Media Vessels
  - 14" Ø x 8’ straight side
  - Materials of construction shall be 304L stainless steel
  - 150# ANSI B16.5 inlet and outlet connections
  - Flat bottom with flanged top head
  - Flanged access nozzle on top of each vessel
  - Internal septas for even gas distribution through media
  - Pressure relief valves included
  - Bottom manual condensate drain with stainless steel ball valves
- Test/purge ports with ball valves on the inlet and outlet of each Siloxane Removal Media Vessel
- Series piping and valves between Siloxane Removal Media Vessels will be provided

- Work Platform and Ladder

  - Work Platform shall be welded carbon steel construction with satin black powder coat finish
  - Ladder shall be galvanized steel construction

- Initial charge of Siloxane Removal Media

  - The initial charge of siloxane removal media for each Siloxane Removal Media Vessel will be provided.
  - The media shall be specifically engineered for removal of siloxanes and similar contaminants from landfill and digester gas sources.
  - Siloxane media to be loaded into the Siloxane Removal Media Vessels by the INSTALLATION CONTRACTOR.

- Siloxane Removal Final Particulate Filter

  - Mounted downstream of the Siloxane Removal Vessels
  - 99% removal of .5 micron and larger particulate
  - Materials of construction shall be 304L stainless steel for filter housing and cartridge style element
  - 150# ANSI B16.5 side inlet and outlet connections

- Skid Base

  - Welded carbon steel construction with satin black powder-coat finish
  - All components mounted, piped and wired on skid base
  - 24V and 120V electrical components wired to one of two junction boxes on edge of skid
  - INSTALLATION CONTRACTOR to provide conduit and wiring to 480V components
  - Conduit shall be rigid aluminum
  - Condensate drains piped to edge of the skid base. Drains to be routed to floor drain by INSTALLATION CONTRACTOR.

GLYCOL CHILLER

- Glycol Chiller

  - Sized for the heat load of the Pre-cooler and Gas to Glycol Heat Exchangers
  - Suitable for outdoor installation
  - Refrigeration System
    - One refrigeration circuit
- One compressor sized for 100% capacity
- System has the capability to unload to 25%
- EC motor driven condenser fans
- Aluminum micro-channel air cooled condensers
- 316L stainless steel evaporator
- R410a refrigerant. R-410a is an HFC refrigerant with 0 ODP
- Refrigeration circuit has sealed core filter drier, liquid line solenoid valve, liquid line shut-off valve, sight glass/moisture indicator and unload solenoid valve
- Electronic expansion valve
- Glycol Chiller shall be factory tested and shipped with complete refrigerant charge

- Glycol Circulation
  - One glycol circulation pump sized for 100% capacity
  - Pump is stainless steel end suction centrifugal
  - Pump motor is TEFC
  - Pump isolation valves on inlet and outlet
  - Pump discharge check valve
  - Glycol reservoir is a 304 stainless steel closed tank
  - Glycol piping is copper with anti-corrosion coating
  - Armavlex insulation
  - Glycol Chiller to utilize propylene glycol/water mix
  - Initial fill of Propylene glycol will be provided

- Support Structure
  - G90 galvanized steel member frame
  - Powder-coated aluminum cover panels
  - All components mounted, piped and wired on skid

- Glycol Chiller Control Panel
  - UL Type 4
  - UL 508A Listed Industrial Control Panel
  - Painted carbon steel
  - 480V/3Ph/60Hz feed will be required
  - 480V disconnect
  - Microprocessor based controller with full text LCD display
  - 480VAC to 24VAC transformer

CONTROL SYSTEM

- Gas Conditioning System Control Panel

- Enclosure
  - UL Type 4
  - UL 508A Listed Industrial Control Panel
  - Painted carbon steel
  - Indoor location
  - Outdoor location, out of direct sunlight

- Thermal Management (as necessary)
  - Rated for installation in ambient temperatures from 40°F to 104°F
- Air Conditioner
- Heater
- Power Distribution
  - Fused Disconnect
  - 480V/3Ph/60Hz feed required
  - 35kA Short Circuit Current Rating
  - Over current and branch circuit protection via fuses
  - 480VAC field wiring to terminate at the component or terminal strips inside control panel
- Surge Suppression
  - 480VAC Transient Voltage Surge Suppressor
  - 120VAC Surge Filter
- Motor Control
  - (1) 25Hp rated VFD for Gas Compressor Motor
  - (1) 1Hp rated Motor Starter Overload for Oil Cooler Motor
  - (1) 1Hp rated Motor Starter Overload for Condensate Pump
- Programmable Logic Controller
  - Allen Bradley
  - Compact Logix PLC and I/O
  - Native Allen Bradley Ethernet IP data network
  - Modbus TCP data network
- Human Machine Interface
  - Proface PFXGP4601TAF
  - TFT Color LCD Display
  - 12” diagonal
  - 800 x 600 pixels
- Digital Data Recorder
  - Eurotherm
  - 5.5” Graphic Display
  - 6 input Channels
  - 36 virtual Channels
  - Ethernet I/P data network
- Instrument wiring to terminate at terminal strips inside Control Panel
- Transformer
  - 5kVA
  - 480VAC to 120VAC
  - NEMA 3R; Painted carbon steel

**INSTRUMENTATION**

- All instrumentation provided will be designed for gas service and rated for use in a NEC Class I, Division 1 Group D area.
- Hydrogen Sulfide Removal System Instrumentation
  - Inlet Pressure Transmitter
- Gas Compression/Moisture/Siloxane Removal System Instrumentation
  - Level Switches at each Condensate Drain
  - Level Indicators at each Condensate Drain
  - RTD’s at each Temperature Change Point
- RTD to Monitor Glycol Temperature
- Bi-metal Thermometers at each Temperature Change Point
- Gas Compressor Discharge Pressure Transmitter
- Delivery Pressure Transmitter

PIPING

- Pipe will be SA-312 TP304/304L Weld Pipe, minimum Schedule 10S. Threaded pipe shall be minimum Schedule 40S.
- Flange connections will be ANSI B16.5, SA-182 F304/304L Class 150.
- Pipe welding will follow ASME B31.3 Process Piping. Welded pipe will be visually inspected and pressure tested.

VALVES

- Inlet Electric Actuated Butterfly Valve
  - Butterfly valve will be lug style, iron body with stainless steel disc and stem and FKM seat.
  - Type 7 explosion proof actuator
  - Spring return closed upon power loss
  - 120V weatherproof
- Ball Valves
  - Stainless steel with PTFE or RTFE seat.
  - Valves will be full port.
- Butterfly Valves
  - Lug style iron body with stainless steel disc and stem and FKM seat.
- Check Valves
  - Will be one of 2 styles; ball or dual-door.
  - Ball check valves shall be stainless steel with RTFE ball.
  - Dual-door check valves shall be wafer style body, material shall be aluminum and/or stainless steel with an FKM seat.
- Globe Valves
  - Stainless steel with PTFE packing

FASTENERS

- Fasteners shall be Grade 5 zinc plated

SUBMITTALS

- Quantity: (3) copies of 3 ring binders and (1) electronic CD copy
- Shop Drawings and Product Data will be provided in sufficient detail to confirm compliance with the requirements for the project. Shop Drawings and Product Data will be provided in a complete submittal package.
- Shop Drawings
  - Installation drawings and specifically prepared technical data, including design capacities will be provided.
- Specifically prepared wiring diagrams unless standard wiring diagrams are submitted with product data will be provided.
- Written description of operation will be provided.

**Product Data**
- Catalog cuts and product specifications for each product specified will be provided.
- Standard wiring diagrams unless wiring diagrams are specifically prepared and submitted with Shop Drawings will be provided.

**FACTORY TESTING**
- The System will be tested on ambient air at Unison’s facility prior to shipment.
- The CUSTOMER is allowed to witness the testing and Unison will inform the customer (2) weeks prior to anticipated testing date so customer can make travel arrangements.

**OPERATION & MAINTENANCE MANUALS**
- Quantity: (6) copies of 3 ring binders and (1) electronic CD copy
- After shipment the Gas Conditioning System will be provided with a specifically prepared Operation & Maintenance Manuals. The information provided includes a system overview, operator interface, start-up/shut down procedures, communications, alarms procedures, maintenance overview, mechanical component cut spec sheets and electrical component spec sheets.

**OPERATION & MAINTENANCE**

- **Hydrogen Sulfide Removal System**
  - Clean Hydrogen Sulfide Inlet Moisture/Particulate Filter
  - Replace Hydrogen Sulfide Media
  - Estimated Cost = $7,150.00 every 19 months
  *Labor for change out, disposal and shipping of media not included

- **Gas Compression/Moisture Removal System**
  - Clean Gas Compressor Inlet Moisture/Particulate Filter
  - Change Blower Oil
  - Clean Glycol Chiller Condenser
  - Test Glycol for Freeze Point
  - Estimated Cost = $4,000.00 every 12 months

- **Siloxane Removal System**
  - Replace Siloxane Media
  - Estimated Cost = $2,145.00 every 2-3 months
  *Labor for change out, disposal and shipping of media not included

**ELECTRICAL PARASITIC**

- **Electrical Parasitic**
  - Condensate Pump = 1 kW
  - Gas Compressor Motor = 19 kW
- Glycol Chiller = 14 kW
- Controls & Auxiliary Equipment = 4 kW
Total = 38 kW (Full Load)

DELIVERY SCHEDULE

- Submittals delivered 3 weeks after order acceptance
- Equipment delivery 16 to 18 weeks after submittal approval
- Delivery is subject to confirmation at the time of order placement and/or submittal approval

PRICING SUMMARY

- Price includes all labor and expenses associated with the fabrication of the system.
- Prices do not reflect any taxes that may be applicable and are valid for 30 days.
- Price is FCA; Factory, Dubuque, IA 52002, per Incoterms 2010. Shipping costs not included, see estimate below
- Price does not include Start-up and Commissioning. Costs are shown below

Hydrogen Sulfide Removal System

Gas Compression/Moisture/Siloxane Removal System

Siloxane Removal System

Shipping ESTIMATE
Cost is an estimate and is subject to change without notice. It does not include any special packaging or permitting that may be required and is dependent on the final equipment dimensions and weights.

Start-up and Commissioning Services ESTIMATE.
Price includes Four (4) consecutive, 8 hour days, for one Unison Technician onsite with travel and expenses included. Additional days may be necessary to complete start-up and commissioning, they will be billed to the Buyer/Owner/End User at the cost of $1,200 per day, per technician, plus travel & expenses.

PAYMENT SCHEDULE

- 30% upon order acceptance
- 30% at midpoint of construction
- 30% upon equipment delivery
- 10% upon site acceptance not to exceed 180 days from shipment
- Net 30 days on all payments

PROVIDED BY OTHERS

- VPN connection for remote access to Unison supplied equipment for troubleshooting and remote assistance.
PRICE DOES NOT INCLUDE

- Shipping of equipment to jobsite
- Start-up and commissioning services
- Wind or seismic calculations for all equipment
- Any maintenance work after start-up
- Siloxane or H2S removal media after initial fill
- Performance guarantee or service/maintenance contract
- Any gas testing or analyses
- Permitting for the installation of the equipment or air permits
- Freeze protection; including insulation and/or heat trace and heat trace power
- Pipe stands for field piping

ASSUMPTIONS

MECHANICAL

- Flare is supplied by OTHERS
- If an existing flare is being used, it is assumed this flare is in good working order, with all safety and control equipment.
- Foundations and/or maintenance pads are designed by OTHERS to properly support the equipment.

ELECTRICAL

- 480V/3Ph/60Hz is available
- The following Equipment/Sub-systems will be located in an NEC Class I, Division 1 Group D Area
  - Hydrogen Sulfide Removal System
  - Gas Compression/Moisture/Siloxane Removal System
- The following Equipment/Sub-systems will be located in an Unclassified Area
  - Glycol Chiller
  - Gas Conditioning System Control Panel

INSTALLATION CONTRACTOR RESPONSIBILITIES

- Installation responsibilities are broken out below into three categories to outline the work; these responsibilities by no means fall on any single contractor or individual. It is the responsibility of the Buyer/Owner/End User to ensure all these conditions are adhered to, as necessary. It is responsibility of the Buyer/Owner/End User to install all equipment in compliance with local and national codes applicable to the installation site.

BUYER/OWNER/END USER RESPONSIBILITIES

- All foundations and/or maintenance pads as necessary for equipment
- Provide and seal all roof and building penetrations as necessary
- Provide all anchor bolts, temporary lift equipment, power, labor, and all other
  incidentals required for proper installation of the equipment shown on the drawings
  that will be provided by Unison Solutions, Inc.
- All rigging and setting of equipment at job site
- Proper storage of the equipment and media prior to installation
- Provide installation of Equipment/Sub-systems per the Unison Solutions Installation
  Guide
- Load initial charge of Hydrogen Sulfide Media and Siloxane Media into the vessels

MECHANICAL CONTRACTOR RESPONSIBILITIES

- Provide all field piping between the Equipment/Sub-systems, including but not limited
to:
  - Hydrogen Sulfide Removal System
  - Gas Compression/Moisture/Siloxane Removal System
  - Glycol Chiller
- Provide pipe supports as necessary. Piping shall be self-supporting, and not supported
off of the Unison supplied equipment.
- Install all field located or shipped loose devices
- Provide all Heat Trace and/or Insulation as necessary to provide proper freeze
  protection as defined by Unison Solutions.

ELECTRICAL CONTRACTOR RESPONSIBILITIES

- Provide 480V/3Ph/60Hz feed to the Gas Conditioning System Control Panel.
- Provide all field wiring and conduits between the Equipment/Sub-systems to the Gas
  Conditioning Control Panel and associated equipment. This includes but not limited to:
  - Hydrogen Sulfide Removal System
  - Gas Compression/Moisture/Siloxane Removal System
  - Glycol Chiller
  - Gas Conditioning System Control Panel
- Provide local disconnects as necessary
- Provide all Hazardous location conduits & wiring systems per Article 500 of the NEC
- Provide conduit seals entering and/or leaving the Class I, Division 1 Electrical Area.
  Conduit seals will need to be filled during Start-up and Commissioning after verification
  of field wiring by Unison's Start-up Technician. Conduit seals are to be filled prior to the
  introduction of gas to the equipment.
- Provide heat trace power from local lighting panel, as necessary.

WARRANTY

- Unison Solutions, Inc. will warrant all workmanship and materials in conformance with the
  attached Warranty Statement. Warranty is valid for **18** months from the time the equipment
  is shipped from Unison's factory or **12** months from the date of startup, whichever occurs first.

- Unison Solutions, Inc. will not release the PLC program for this system. This is considered
  proprietary and the intellectual property of Unison Solutions, Inc.
CNG Vehicle Fill Station Equipment Quote and Catalog Information
Biogas Separation System

Scope of Work includes:
ADG Gas Separation System to CNG Grade Methane
From 27 SCFM Municipal Anaerobic Digester Gas

Submitted to:

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Process Mechanical Engineer
CH2M Hill
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Date 04/15/2014

From:
Jeffrey V. Wetzel
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Redmond WA 98052
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Mobile: (425) 614-9293
Fax (425) 881-3378
Table of Contents

1. ESC Scope of Supply
2. Design Conditions
3. ESC Scope of Work
4. Scope of Work by Others
5. Pricing, terms and Schedule
6. ESC Standard Terms and Conditions of Sale
7. Appendix (Warranties and Guarantees – TBA)
**Detailed Table of Contents**  
(NOTE: an “x” represents what is included in the proposal)

1. ESC Scope of Supply  
   Gas Conditioning/Treatment/Purification  
   - Water Knock-out  
     - Pre-cooler  
   - H₂S Removal  
   - Particulate Removal  
   - Blower or Compressor  
     - Spare/Redundant Blower or Compressor  
   - Moisture Removal Package  
     - Chiller Package  
       - Redundant Chiller Package  
     - Economizer or Interchanger (Gas/Gas HX)  
   - Condenser (Gas/Liquid HX)  
     - Secondary HX (optional)  
   - Siloxanes/VOCs Removal (non-Regenerable)  
     - Siloxanes/VOCs Removal (Regenerable)  
   - Final Particulate Removal  
   Gas Management  
   - Secondary Compression  
   - Gas Holder  
   - Programmable Logic Controller (PLC)  
   - Gas Monitoring Module  
     - Gas Separation Module  
   - Gas Separation Module + CNG Module  
   - Complete Power Generation Package

2. Basis for Design

3. ESC Scope of Work

4. Scope of Work by Others

5. ESC Pricing, Payment Terms, and Schedule

6. ESC Standard Terms and Conditions of Sale

7. Appendix
SECTION ONE

ESC Corporation Equipment Scope of Supply
ESC offers a complete gas separation system package for the Las Gallinas Valley Sanitary District in California. This budgetary proposal is based on preliminary data which does not include a detailed gas analysis.

The following Scope of Supply sections define the equipment, services, and warranties as required, per referenced specification sections for this project

**ESC Service Contract Scope of Supply**

ESC Corp as the manufacturer of the SPUR™ gas separation system, will provide an equipment warranty as part of its service contract that offers full coverage of operation and maintenance over (up to) a ten year duration. Service will be provided by an ESC Field Service Engineer (FSE) with supplies from ESC’s inventory of spares and media in its various warehouses in California and Washington. The following categories are covered by this maintenance and service agreement.

1. Up to monthly site visits for inspection, measurement, calibration, replacement and/or repair of gas separation media, analyzer sensors, fluids, drive belts, and filter elements. A “bumper to bumper” equipment warranty is available for other system components.
2. “Bumper to bumper” service agreement and warranty will incorporate all of the above, plus complete equipment maintenance on all motor-driven equipment, motors, gauges, and electronics.
3. Performance evaluation will be by means of gas testing and reporting over the contracted period based on the minimum requirements of the agreement.

**ESC Scope of Supply**

**Biogas pretreatment system**

The gas separation module requires the biogas to have a pressure degree d dew point of < 40 Fahrenheit, and be free of H₂S and siloxanes. The ESC pretreatment system will consist of:

1. an H₂S removal stage, 1 vessel, 4 ft. diameter x 12 ft. straight side elevation;
2. a moisture reduction system, 3 ton, 1 circuit, with an interchanger, condenser and heat exchanger;
3. a siloxane removal stage, 1 vessel, 2 ft. diameter x 12 ft. straight side elevation;
4. a common work platform between the 2 vessels;
5. a final particulate filter.

The entire pretreatment system will be on a skid with dimensions of approximately 9 feet 6 inches by 30 feet. The remote chiller unit will be on a separate skid with dimensions of approximately 4 feet x 6 feet.
Biogas Separation System

ESC Corp as the manufacturer/packager of the SPUR™ gas separation system, will provide the Engineering design, fabrication, and startup (installation supervision by ESC is optional) of a complete biogas process to separate the specified digester gas flow at the Las Gallinas WWTP to remove sufficient carbon dioxide, nitrogen and oxygen to produce a ≥90% methane fuel gas. The SPUR™ System design will be based on the inlet digester gas composition specified in Section 3 of this proposal, and shall treat the gas to quality standards also defined in Section 3 of this proposal. The SPUR™ System provided will include moisture removal, compression to a nominal 160 psig to effect gas separation, filters, heat exchangers, piping, valves, controls, electrical, and all accessories for a complete operable system.

The ESC Corp. supplied SPUR™ System consists of the following equipment for Digester Gas Separation and Compression to CNG:

1. A gas compression package capable of pressuring, drying, and cooling the digester gas, to effect gas separation. Dimensions are approximately 9 feet six inches by 30 feet.
2. A gas separation skid with approximate dimensions of 9 feet 6 inches width by 16 feet length, enclosed in a container to protect it from the weather, producing > 90% methane from the specified digester gas, with a methane recovery rate of > 90%.
(The waste gas stream disposal is by others).

RCNG Storage System (based on gas supply volume, not demand volume)

A pre-packaged gas storage system, consisting of three (3) vessels with a nominal capacity of 13,800 SCF of RCNG (Renewable Compressed Natural Gas) each at 4,600 psig will be provided. This unit has a nominal footprint of approximately 4 feet x 20 feet. The three vessels will contain approximately 3 days’ production of the high BTU methane.

RCNG Dispensing System

In addition to the gas separation and storage, a time-fill or fast-fill post will be provided. This will have a footprint of approximately 2 feet x 6 feet.
SECTION TWO

Design and Performance Conditions
## I. DESIGN CONDITIONS

### Inlet Conditions (Given and Assumed)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity (Air = 1.0)</td>
<td>0.90 to 0.92</td>
</tr>
<tr>
<td>Digester Gas Flow Rate - DGCS</td>
<td>27 SCFM Maximum</td>
</tr>
<tr>
<td>Methane, mole %</td>
<td>60 percent +/- 5 percent</td>
</tr>
<tr>
<td>Carbon Dioxide, mole %</td>
<td>40 percent +/- 5 percent</td>
</tr>
<tr>
<td>Nitrogen, mole % (ESC Estimate)</td>
<td>N/A</td>
</tr>
<tr>
<td>Oxygen, mole % (ESC Estimate)</td>
<td>N/A</td>
</tr>
<tr>
<td>Hydrogen Sulfide, ppmv</td>
<td>165 average, 200 peak</td>
</tr>
<tr>
<td>Siloxanes, ppbv</td>
<td>Unknown - removal required</td>
</tr>
<tr>
<td>VOCs (ESC basis for design and performance)*</td>
<td>Unknown</td>
</tr>
<tr>
<td>Digester Gas Temperature</td>
<td>95 degrees Fahrenheit</td>
</tr>
<tr>
<td>Ambient air Temperature</td>
<td>30-110 degrees Fahrenheit</td>
</tr>
<tr>
<td>Moisture</td>
<td>Dew Point of 40 degrees F</td>
</tr>
<tr>
<td>Gas Pressure at Inlet</td>
<td>0.3 psig</td>
</tr>
<tr>
<td>Elevation</td>
<td>0 to 40 feet above mean sea level estimated</td>
</tr>
<tr>
<td>Relative Humidity Range (Ambient)</td>
<td>20% to 100%</td>
</tr>
<tr>
<td>Exposure</td>
<td>Indoors (Containerized)</td>
</tr>
</tbody>
</table>

### Outlet Conditions (Given and Assumed)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane Content</td>
<td>&gt; 90%</td>
</tr>
<tr>
<td>Methane Recovery percentage</td>
<td>&gt; 90%</td>
</tr>
<tr>
<td>Dew Point Temperature</td>
<td>- 60 Degrees F.</td>
</tr>
<tr>
<td>Discharge Temperature</td>
<td>90°F (maximum)</td>
</tr>
<tr>
<td>Outlet Pressure</td>
<td>160 psig (Separation pressure), nominal</td>
</tr>
</tbody>
</table>
Performance*

SPUR™ (2 stage) System for Production of CNG Grade Methane from Biogas

<table>
<thead>
<tr>
<th>Nominal Feed Gas</th>
<th>Feed</th>
<th>Product Gas (Retentate)</th>
<th>Waste Gas (Permeate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure, BARA</td>
<td>11.0</td>
<td>11.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Nm³/H</td>
<td>15.9</td>
<td>10.78</td>
<td>5.17</td>
</tr>
<tr>
<td>SCFM</td>
<td>27</td>
<td>18.3</td>
<td>8.8</td>
</tr>
<tr>
<td>Methane, Vol. %</td>
<td>62.93%</td>
<td>89.8%</td>
<td>7.46%</td>
</tr>
<tr>
<td>BTU/ft³</td>
<td>637</td>
<td>909</td>
<td>75</td>
</tr>
<tr>
<td>MJ/Nm³</td>
<td>23.7</td>
<td>33.8</td>
<td>2.8</td>
</tr>
<tr>
<td>Carbon Dioxide, Vol. %</td>
<td>35.0%</td>
<td>7.62%</td>
<td>91.3%</td>
</tr>
<tr>
<td>Nitrogen, Vol. %</td>
<td>0.50%</td>
<td>2.09%</td>
<td>0.48%</td>
</tr>
<tr>
<td>Oxygen, Vol. %</td>
<td>0.5%</td>
<td>0.48%</td>
<td>0.51%</td>
</tr>
<tr>
<td>Water Vapor Vol. %</td>
<td>0.07%</td>
<td>0.00%</td>
<td>0.21%</td>
</tr>
<tr>
<td>Dew Point, °C.</td>
<td>&lt; 4</td>
<td>≤ - 60</td>
<td>- 15</td>
</tr>
<tr>
<td>Methane Yield (% Recovery)</td>
<td></td>
<td></td>
<td>96.73%</td>
</tr>
</tbody>
</table>

*There are 15 or more ways to configure the gas separation module, depending on the % by volume methane and % methane recovery required. A higher methane concentration is traded off for a lower overall methane recovery percentage. A detailed gas analysis is required to further refine the separation process.
SECTION THREE

ESC Corporation Scope of Work
ESC CORPORATION SCOPE OF WORK

A. ESC Corporation is responsible for process design and Original Equipment Manufacturing procurement required for the ESC Gas Separation System. The system will be designed and supplied in accordance with the applicable sections of the project Plans and Specifications as described herein. ESC Corporation’s scope of work does not include any engineering, selection, procurement, installation, or operation of any equipment, materials or other services not specifically defined in this proposal.

B. Process and Design Engineering – ESC Corporation will perform engineering in accordance with the project Plans and Specifications and those applicable national codes, standards and / or regulations (except as otherwise noted) in effect at the time of this submittal. Additionally, ESC Corporation will provide all necessary design, installation and operating information for equipment within its stated scope of supply. ESC Corporation is not responsible for the design, selection, installation, operation or maintenance of any materials, equipment or services supplied by others. All specified and applicable Professional Engineering Calculations required for the ESC Corp supplied equipment is included.

C. ESC Corporation will provide process engineering and design support for the system as follows:
   1. Specifications for all equipment supplied by ESC Inc.
   2. Technical instructions for operation and start-up of the system
   3. Equipment location drawings
   4. Equipment installation plans
   5. Seismic and load calculations for all structural members and hold down lugs.
   6. Project Specific O&M manuals

D. The equipment scope of supply of ESC Corporation shall include the equipment as shown in the ESC Corporation Scope of Supply.

E. SHIPPING & FIELD ASSEMBLY REQUIREMENTS:
   1. General
      a. ESC estimates equipment will comprise 3 partial/ full flatbed truck loads.
      b. All equipment will be shipped assembled to the maximum extent possible.
      c. Loose pieces will be banded and palletized to the greatest extent possible.
      d. Field assembly fasteners will be boxed and marked.

   2. Gas Compression Package
      a. Inlet battery limit is the flange on the inlet of the gas compression skid.
      b. Outlet battery limit is the separated methane outlet and the waste gas outlet.
c. All skids are completely pre-piped, pre-wired, and pre-assembled to the battery limits of the skid. The interconnecting piping between skids is not included or connected.
d. Electrical power supply conduit and wiring to and from the gas compression package is by others.
e. Connections to/from SCADA system inside local control panel is by others. Wiring between the control panel and the junction box mounted on the skid is by others.

3. Gas Separation Package
   a. The gas separation package is a completely pre-assembled and pre-wired containerized unit. All intra skid piping between components is provided.
   b. The local electrical control panel and/or the junction box for the chiller skid is supplied mounted and pre-wired.
   c. Electrical power supply conduit and wiring between the junction box and the Gas Separation package control panel is by others. Terminal connections inside local control panel to field wiring shall be by others. Local power to chiller blowers will be pre-wired and tested prior to skid arriving at jobsite.

4. Gas Storage and Dispensing equipment will arrive pre-assembled as much as possible. (Not provided with this proposal).
   a. Storage tanks rack is a pre-manufactured unit that is lifted off truck and installed by others.
   b. CNG Dispensing station is an integrated unit that is installed by others and connected to the storage tanks by others.
   c. The natural gas blending package is incorporated into the gas storage package.

F. Field Services

ESC Corporation will provide the services necessary to start-up, test, and functional test the system as follows:
1. Advice during installation
2. Equipment checkout and initial testing 1 trip with a total of 3 days.
3. Start-up assistance, 1 trip with a total of 2 days.
4. Operators training, 1 trip with a total of 1 day.
SECTION FOUR

Scope of Work by Others
**SCOPE OF WORK BY OTHERS**

The following is a non-inclusive list of material that is not in ESC Corporation’s scope of work or supply and shall be furnished by others:

1. Obtain necessary construction permits and licenses, construction drawings (including interconnecting piping drawings), field office space, telephone service, and temporary electrical service.

2. All site preparation, grading, locating foundation placement, excavation for foundation, underground piping, conduits and drains.

3. Demolition and/or removal of any existing structures, equipment or facilities required for construction, and installation of the Digester Gas Separation System.

4. Supply and install all specialty tanks, systems, or other linked equipment not in ESC Corp’s scope of work (as required), pads, and supports required for the ESC Digester Gas Separation System.

5. Provision and installation of all foundations, supply and installation of all embedded or underground piping, conduits and drains.

6. All backfill, compaction, finish grading, earthwork and final paving.

7. Receiving (preparation of receiving reports), unloading, storage, maintenance preservation and protection of all equipment, and materials provided by Digester Gas Separation System.

8. Installation of all equipment and materials provided by Digester Gas Separation System Supplier. Including post installation touchup painting.

9. Supply, fabrication, installation, cleaning, pickling, and/or passivation of all field welded stainless steel piping components.

10. Provide all imbedded and non-embedded pipe sections and valves for tank drains.

11. All cutting, welding, fitting, and finishing for all field fabricated piping.

12. Supply and installation of all flange gaskets and bolts for all piping components.

13. Supply and installation of all pipe supports beyond the skid boundaries as needed to make field connections and interconnects.

14. Provide, install and terminate all motor control centers, motor starters, panels (other than the Digester Gas Separation System PLC panel), transformers, and VFD’s.
15. Installation and termination of all control panels and instrumentation supplied by Digester Gas Separation System.

16. Install all sample pumps and sample lines required for the instrumentation provided by Digester Gas Pretreatment System Supplier.

17. Supply and installation of all drain lines beyond the battery limits of the ESC Corp scope of work equipment.

18. Labor and material for heat tracing and/or insulation on any components not part of the Digester Gas Separation System (ESC will install requisite insulation required by specification in the field).

19. Supply and install all electrical power and control wiring and conduit to the equipment served plus interconnection between the Digester Gas Separation System Supplier’s furnished equipment as required, including wire, cable, junction boxes, fittings, conduit, etc.

20. Provide all labor, materials, supplies and utilities as required for start-up, and performance testing including laboratory facilities and analytical work not specifically called out in Digester Gas Separation System supplier’s scope of supply.

21. Provide all anchor bolts and mounting hardware, except those specialty designed anchor-feet for H2S removal vessels’ seismic restraint.

22. Provide and install all piping required to interconnect to the Digester Gas Separation System Supplier skids.

23. Provide all nameplates, safety signs and labels.

24. Install all ESC-provided handrails, ladders, and access platforms that are included in the ESC Digester Gas Conditioning System supplier’s scope of supply.

25. The Contractor shall coordinate the installation and timing of interface points such as piping and electrical with the Digester Gas Separation System Supplier.

26. Supply and install all sunshields and/or additional enclosures as needed when installing Digester Gas Separation System equipment and instrumentation outdoors.

27. All other necessary equipment and services not otherwise listed as specifically supplied by the Digester Gas Separation System Supplier.
SECTION FIVE

ESC Corporation Pricing, Economic Summary, Terms, and Schedule
PRICING, TERMS AND SCHEDULE

Budgetary Economic Summary

Biogas pretreatment system (H2S, moisture, siloxane removal)

<table>
<thead>
<tr>
<th>Capital</th>
<th>Annual O&amp;M</th>
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</thead>
<tbody>
<tr>
<td>$184,600.00</td>
<td>$7,600.00</td>
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</table>

Biogas Separation System (compression, separation, controls)

<table>
<thead>
<tr>
<th>Capital</th>
<th>Annual O&amp;M</th>
</tr>
</thead>
<tbody>
<tr>
<td>$283,700.00</td>
<td>$2,500.00</td>
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</tbody>
</table>

RCNG Compression and Storage System (4,600 psig and 3-vessel storage module)

<table>
<thead>
<tr>
<th>Capital</th>
<th>Annual O&amp;M</th>
</tr>
</thead>
<tbody>
<tr>
<td>$348,000.00</td>
<td>$2,500.00</td>
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</tbody>
</table>

RCNG dispensing System (2 each time-fill or fast-fill posts)

<table>
<thead>
<tr>
<th>Capital</th>
<th>Annual O&amp;M</th>
</tr>
</thead>
<tbody>
<tr>
<td>$4,800.00</td>
<td>Negligible</td>
</tr>
</tbody>
</table>

Total Capital: $821,100.00 USD, +/- 10% (Includes commissioning)
Delivery: Estimated 20 to 24 weeks from development of firm scope of work and authorization to proceed. Pricing is firm through 12/31/2014.
Estimated utilities = $500.00 per month

Terms of Payment

The terms of payment are as follows:

1. 10% of construction contract on execution of acceptable contract
2. 15% upon receipt of approved construction drawings, and notice to proceed
3. 65% on delivery
4. 5% delivery of O&M Manuals
5. 5% on start up

Notes: Payment shall not be contingent upon receipt of funds by the Contractor from the Owner. There shall be no retention in payments due to ESC Corporation. All other terms per our Standard Terms of Sale are attached. All payment terms are net 30 days from the date of invoice, except the original 10%, which is due upon receipt.
Price Escalation

The price in this proposal is subject to an adjustment per the following price escalation clause. For purposes of this escalation clause:

Due to continued volatility in the market for stainless steel plate and pipe ESC Corporation’s price may be subject to a price adjustment based upon the US BLS Producer Price Index for Metals and Metals Products WPU10.

If necessary the price in this proposal will be adjusted by comparing the index in effect at the time of shipment (Final PPI) to the index in effect on the date of the proposal (Initial PPI) according to the following formula. Price escalation factor = Initial PPI multiplied by (Final PPI – Initial PPI) divided by Initial PPI multiplied by 100.

Schedule

- Shop drawings will be submitted within 4-6 weeks of receipt of an executed contract by all parties, and initial 10% deposit.
- All equipment will be delivered within 20 – 24 weeks after receipt of written approval of the submitted shop drawings.
- Installation manuals will be furnished per contract specifications.
- Operation and Maintenance Manuals will be submitted within 30 days after delivery of all goods.
- Service and maintenance agreement per appendix C

Economic Summary (Prices are subject to change with different gas composition)

Capital: $821,100.00 (Includes commissioning)

Estimated O&M + utilities = $1,750.00 per month

Maintenance, fluids, parts and labor: $500.00 per month

10.78 SCFM of 89.3% methane = 13,970,800 BTU/Day
GGE/day = 122.98 (13,970,880 BTU/113,602 BTU/Gal)
Estimated CNG value = $338.19/day (@ $2.75/GGE
Estimated annual value = $111,602.70 (at 330 days of continuous production)

Payback calculation:

Annual revenue = $111,602.70
Annual costs = $27,000.00
Annual profit excluding cost of money, depreciation and taxes = $84,602.70.
$84,602.70/12 = $7,050.22 per month.
$821,000.00/$7,050.22 = 116.5 months.
SECTION SIX

ESC Corporation
Standard Terms of Sale
1. **Applicable Terms.** These terms govern the purchase and sale of the equipment and related services, if any (collectively, "Equipment"), referred to in Seller’s purchase order, quotation, proposal or acknowledgment, as the case may be ("Seller’s Documentation"). Whether these terms are included in an offer or an acceptance by Seller, such offer or acceptance is conditioned on Buyer’s assent to these terms. Seller rejects all additional or different terms in any of Buyer’s forms or documents.

2. **Payment.** Buyer shall pay Seller the full purchase price as set forth in Seller’s Documentation. Unless Seller’s Documentation provides otherwise, freight, storage, insurance and all taxes, duties or other governmental charges relating to the Equipment shall be paid by Buyer. If Seller is required to pay any such charges, Buyer shall immediately reimburse Seller. All payments are due within 30 days after receipt of invoice, except for original 10% deposit. Buyer shall be charged the lower of 1 ½% interest per month or the maximum legal rate on all amounts not received by the due date and shall pay all of Seller’s reasonable costs (including attorneys’ fees) of collecting amounts due but unpaid. All orders are subject to credit approval.

3. **Delivery.** Delivery of the Equipment shall be in material compliance with the schedule in Seller’s Documentation. Unless Seller’s Documentation provides otherwise, Delivery terms are F.O.B. Seller’s facility.

4. **Ownership of Materials.** All devices, designs (including drawings, plans and specifications), estimates, prices, notes, electronic data and other documents or information prepared or disclosed by Seller, and all related intellectual property rights, shall remain Seller’s property. Seller grants Buyer a non-exclusive, non-transferable license to use any such material solely for Buyer’s use of the Equipment. Buyer shall not disclose any such material to third parties without Seller’s prior written consent.

5. **Changes.** Seller shall not implement any changes in the scope of work described in Seller’s Documentation unless Buyer and Seller agree in writing to the details of the change and any resulting price, schedule or other contractual modifications. This includes any changes necessitated by a change in applicable law occurring after the effective date of any contract including these terms.

6. **Warranty.** Subject to the following sentence, Seller warrants to Buyer that the Equipment shall materially conform to the description in Seller’s Documentation and shall be free from defects in material and workmanship. The foregoing warranty shall not apply to any Equipment that is specified or otherwise demanded by Buyer and is not manufactured or selected by Seller, as to which (i) Seller hereby assigns to Buyer, to the extent assignable, any warranties made to Seller and (ii) Seller shall have no other liability to Buyer under warranty, tort or any other legal theory. If Buyer gives Seller prompt written notice of breach of this warranty within 18 months from delivery or 1 year from beneficial use, whichever occurs first (the "Warranty Period"), Seller shall, at its sole option and as Buyer’s sole remedy, repair or replace the subject parts or refund the purchase price therefore. If Seller determines that any claimed breach is not, in fact, covered by this warranty, Buyer shall pay Seller its then customary charges for any repair or replacement made by Seller. Seller’s warranty is conditioned on Buyer’s (a) operating and maintaining the Equipment in accordance with Seller’s instructions, (b) not making any unauthorized repairs or alterations, and (c) not being in default of any payment obligation to Seller. Seller’s warranty does not cover damage caused by chemical action or abrasive material, misuse or improper installation (unless installed by Seller). THE WARRANTIES SET FORTH IN THIS SECTION ARE SELLER’S SOLE AND EXCLUSIVE WARRANTIES AND ARE SUBJECT TO SECTION 10 BELOW. SELLER MAKES NO OTHER WARRANTIES OF ANY KIND, EXPRESS OR IMPLIED, INCLUDING WITHOUT LIMITATION, ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR PURPOSE.

7. **Indemnity.** Seller shall indemnify, defend and hold Buyer harmless from any claim, cause of action or liability incurred by Buyer as a result of third party claims for personal injury, death or damage to tangible property, to the extent caused by Seller's negligence. Seller shall have the sole authority to direct the defense of and settle any indemnified claim. Seller’s indemnification is conditioned on Buyer (a) promptly, within the Warranty Period, notifying Seller of any claim, and (b) providing reasonable cooperation in the defense of any claim.

8. **Force Majeure.** Neither Seller nor Buyer shall have any liability for any breach (except for breach of payment obligations) caused by extreme weather or other act of God, strike or other labor shortage or disturbance, fire, accident, war or civil disturbance, delay of carriers, failure of normal sources of supply, act of government or any other cause beyond such party's reasonable control.

9. **Cancellation.** If Buyer cancels or suspends its order for any reason other than Seller’s breach, Buyer shall promptly pay Seller for work performed prior to cancellation or suspension and any other direct costs incurred by Seller as a result of such cancellation or suspension.
10. **LIMITATION OF LIABILITY.** NOTWITHSTANDING ANYTHING ELSE TO THE CONTRARY, SELLER SHALL NOT BE LIABLE FOR ANY CONSEQUENTIAL, INCIDENTAL, SPECIAL, PUNITIVE OR OTHER INDIRECT DAMAGES, AND SELLER’S TOTAL LIABILITY ARISING AT ANY TIME FROM THE SALE OR USE OF THE EQUIPMENT SHALL NOT EXCEED THE PURCHASE PRICE PAID FOR THE EQUIPMENT. THESE LIMITATIONS APPLY WHETHER THE LIABILITY IS BASED ON CONTRACT, TORT, STRICT LIABILITY OR ANY OTHER THEORY.

11. **Miscellaneous.** If these terms are issued in connection with a government contract, they shall be deemed to include those federal acquisition regulations that are required by law to be included. These terms, together with any quotation, purchase order or acknowledgement issued or signed by the Seller, comprise the complete and exclusive statement of the agreement between the parties (the "Agreement") and supersede any terms contained in Buyer’s documents, unless separately signed by Seller. No part of the Agreement may be changed or cancelled except by a written document signed by Seller and Buyer. No course of dealing or performance, usage of trade or failure to enforce any term shall be used to modify the Agreement. If any of these terms is unenforceable, such term shall be limited only to the extent necessary to make it enforceable, and all other terms shall remain in full force and effect. Buyer may not assign or permit any other transfer of the Agreement without Seller’s prior written consent. The Agreement shall be governed by the laws of the State of Washington without regard to its conflict of laws’ provisions.
SECTION SEVEN

Appendices A-C
(to be provided later)
Additional Cost Estimate Information

The economic evaluation estimated the construction costs, the annual operations and maintenance costs, and calculated a present worth assuming a 20-year lifespan. A present worth (or sometimes called present value) analysis is an estimate of the value an investment of money has over a fixed lifespan in today’s dollars. The analysis uses a key variable called the discount rate to calculate the present worth. The discount rate represents the average cost of capital used for the investment. For example, it could represent the interest paid for borrowed money used to pay for a project or could represent the amount of interest earned if the capital was invested in something else (like bonds or a savings account). Using the discount rate will account for inflation rising for both expenditures (like labor and material cost) and savings (the value of electricity generated in the future). If a present worth has a positive value, the annual operations and maintenance income and/or savings are less than the expenditures. If it is negative, it means the cost of operating the alternative is more than any income and/or savings realized. In this analysis, a discount rate of 2% was used. The total present worth of each alternative is the initial construction cost plus the O&M present worth.

The table below summarizes the initial construction cost, the estimated annual O&M cost, the O&M present worth over 20 years, and the total present worth.

### Summary of Alternatives Analysis

<table>
<thead>
<tr>
<th></th>
<th>Remove Existing IC Engine (Add Boiler/Flare)</th>
<th>Microturbines</th>
<th>CNG Vehicle Fill Station</th>
<th>Pipeline Injection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction Cost</td>
<td>($1,170,000)</td>
<td>($2,200,000)</td>
<td>($2,900,000)</td>
<td>($8,400,000)</td>
</tr>
<tr>
<td>Annual O&amp;M Savings/Cost (2014 dollars)</td>
<td>($24,000)</td>
<td>$7,600</td>
<td>$24,000(^1) / ($65,000)(^2)</td>
<td>($31,000)</td>
</tr>
<tr>
<td>Annual O&amp;M Present Worth (20 year lifespan)</td>
<td>($380,000)</td>
<td>$100,000</td>
<td>$400,000(^1) / ($1,020,000)(^2)</td>
<td>($500,000)</td>
</tr>
<tr>
<td>Total Present Worth</td>
<td>($1,550,000)</td>
<td>($2,100,000)</td>
<td>($2,500,000)(^1) / ($3,920,000)(^2)</td>
<td>($8,900,000)</td>
</tr>
</tbody>
</table>

1. Facility and public fueling station (i.e., all available biogas utilized as CNG for the fleet and sold to the public)
2. Facility-only public fueling station (i.e., biogas only used for facility CNG fleet vehicles; reminder of biogas is flared)
Greenhouse Gas Emission Offset

The table below summarizes the estimated amount of greenhouse gas (GHG) offset for each alternative.

### Carbon Offset Credit

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Boilers and Flare</td>
<td>0</td>
<td>0</td>
<td>1,825</td>
<td>97</td>
<td></td>
<td>97</td>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td>Microturbines</td>
<td>553</td>
<td>246</td>
<td>1,825</td>
<td>97</td>
<td>343</td>
<td>343</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Biomethane - CNG Vehicle Fill Station (all fuel used)</td>
<td>-610</td>
<td>-271</td>
<td>1,825</td>
<td>97</td>
<td>1,367</td>
<td>373</td>
<td>-102</td>
<td>-0.30</td>
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<tr>
<td>Biomethane - CNG Vehicle for LGVSD Fleet (20 gallon/day equivalent used)</td>
<td>-125</td>
<td>-56</td>
<td>1,825</td>
<td>97</td>
<td>273</td>
<td>14</td>
<td>56</td>
<td>0.16</td>
</tr>
<tr>
<td>Biomethane - Pipeline Injection</td>
<td>-340</td>
<td>-151</td>
<td>7,026</td>
<td>373</td>
<td>221</td>
<td>221</td>
<td>0.65</td>
<td></td>
</tr>
</tbody>
</table>

*a* Includes parasitic loads, electrical conversion efficiency, and expected run time  
*b* Includes thermal conversion efficiency, heat recovery efficiencies, and 100% run time  
*c* Assumes all heat conversion technologies are 70% efficient  
*d* Assumes vehicle fuel conversion is 20% efficient  

Vehicle Fuel Efficiency References:


### Greenhouse Gas Emission Factors

<table>
<thead>
<tr>
<th>Source</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2e Generated from Purchased Power Emission Factor (PG&amp;E)</td>
<td>444.6</td>
<td>kg CO₂/MWh</td>
</tr>
<tr>
<td>CO2e Generated from Purchased Power Emission Factor</td>
<td>130.3</td>
<td>kg CO₂/MMBTU</td>
</tr>
<tr>
<td>CO2e Generated from Natural Gas</td>
<td>53.0</td>
<td>kg CO₂/MMBTU</td>
</tr>
</tbody>
</table>

The Climate Registry: [http://www.theclimateregistry.org/resources/protocols/general-reporting-protocol/#jump3](http://www.theclimateregistry.org/resources/protocols/general-reporting-protocol/#jump3)
Availability of Small Internal Combustion Engines

Currently, there are two companies that market and manufacture engines for use in biogas application in the United States: GE and Caterpillar. Over the past few years, GE and Caterpillar have made acquisitions of several engine manufacturers and each has consolidated the engine market into segments. For example, Waukesha, the maker of the engine currently used at LGVSD was purchased by GE, as was Jenbacher, an Austrian company that specializes in biogas fueled engines. GE made the decision to only make Jenbacher engines available for biogas applications and market Waukesha mainly to the oil and gas industry. Similarly, Caterpillar purchased MWM, a German engine manufacturer specializing in biogas fueled engines. Neither Jenbacher nor MWM manufacture engines smaller than 300 kW. Smaller engines could be found that are designed to run on natural gas, but they will not function when fueled with biogas which has a much lower energy value. Another important issue is maintenance. Running an engine designed for natural gas with biogas would likely void any warranties, and maintenance service contracts would be difficult to obtain. Smaller engines are available for purchase from outside the United States, but maintenance contracts, which are vital to long term engine operation would not be available from the manufacturer. It would be highly risky to purchase an engine from anyone outside of the manufacturers listed above.

Sludge Heat Exchanger Recommendations

Although the inside of the existing sludge heat exchanger was not examined, most heat exchangers in digested sludge service generally have long life spans of over 25 years. The existing spiral type heat exchanger, which is over 30 years old, may be approaching the end of its useful life and it is recommended that a new sludge heat exchanger be installed. Over time, sludge can foul the inside passages, decreasing the heat transfer capacity even if they are regularly cleaned. Although spiral heat exchangers are compact, using very little space, and can be highly efficient, the relatively small pathway for sludge can become clogged or fouled over time. Cleaning out the spiral pathway can be a difficult maintenance problem, taking significant amounts of time. A tube-in-tube heat exchanger would be an alternative.
The amount of available space inside the digester building is small, so a spiral type heat exchanger may be the only heat exchanger option. However, if the microturbine alternative is selected, a tube-in-tube heat exchanger could be considered since the likely location of the heat exchanger would be where the existing engine is located. If any of the other alternatives are selected, the space where the engine is located would be needed for the second boiler. In those cases, a new spiral heat exchanger would be recommended to replace the existing one in the same location.

**Additional Microturbine Operations Information and Site Visits**

It was requested that more information regarding the details of operating and maintaining microturbines be obtained and a site visit to a wastewater facility operating them be arranged. Although multiple site visits may provide valuable additional information, the schedule may not allow for more than one visit.

The following items are recommended:

1. CH2M HILL designed, constructed, and operates a wastewater treatment facility for Spokane County, Washington, where several microturbines of the same size recommended for LGVSD are being used. There have been several important lessons learned from this project that can be shared with LGVSD. A conference call with the Spokane County operations staff could quickly be scheduled with LGVSD staff for initial information, with a follow up site visit arranged as well.

2. During the past decade, microturbines have also been installed at several California wastewater treatment plants. CH2M HILL is in the process of contacting the plants to determine the operational status of the microturbine systems and suitability for site visits (ideally in May 2014). Once this task has been completed, tours of the convenient sites can be arranged.

3. Schedule a meeting between LGVSD and the local Capstone Turbine representative, Regatta Solutions. The purpose of this meeting is to make contact with the provider of both the turbines and the gas cleaning systems to discuss procurement and maintenance contract options.
Las Gallinas Valley Sanitation District - Biogas Utilization Technologies Evaluation, Combined Microturbines and CNG Vehicle Fill Station

Combined Microturbine and CNG Vehicle Fill Station

The possibility of combining a microturbine system with a compressed natural gas (CNG) vehicle fill station is explored below. In this evaluation, a short description of the concept, alternatives on operation, and capital costs are summarized. More detailed assumptions regarding the operation of each system will need to be discussed and agreed upon before updated operation and maintenance (O&M) costs or present worth calculations can be completed.

Description

As a reminder, 50,000 cubic feet per day (cfd) was assumed to be produced by the digesters. Individual descriptions of the microturbine and CNG vehicle fill system are included in the LGVSD Biogas Utilization Evaluation Technical Memorandum. Since each system requires the biogas to have moisture, hydrogen sulfide, and siloxanes removed, they could take advantage of utilizing one gas cleaning system. Once the flow stream passes through gas cleaning, it would split between the vehicle fill system, microturbines, and the hot water boiler since each has different requirements for chemical composition and pressure. The vehicle fill system requires carbon dioxide to be removed and to be pressureized to 4,500 pounds per square inch (psi). Microturbines require gas at approximately 100 psi, but the gas does not need any further treatment. The boilers run at low pressure and do not need any additional pressure or treatment.

In the LGVSD Biogas Utilization Evaluation TM, it was assumed that only one major biogas utilization technology would be selected and installed to minimize capital and operational costs, maximize beneficial use of the biogas, and provide adequate heat for the digesters. The two most viable technology options that maximize renewable use of the biogas are microturbines and a CNG vehicle fill station. The microturbines option includes two 65 kW microturbines that produce enough waste heat to match the amount of heat required by the digester on an annual average basis, so boiler usage would be minimized. The option for a CNG vehicle fill station would only be used after digester heating requirements have been fulfilled by hot water from boilers.

LGVSD is interested in the possibility of developing a biogas utilization system that integrates both microturbines and a CNG fueling station. This option would provide operational flexibility for use of the biogas and enable the use of a renewable fuel source for both the WWTP’s power demand and the LGVSD fleet. Two possible scenarios of the integrated system are presented in the flow diagrams in Figures 1 and 2. The first scenario includes a “quick” CNG filling station that produces CNG for 2 hours each day. The second scenario includes a slow-fill CNG filling station that fills vehicles with fuel overnight for approximately 12 hours. The slow-fill station assumes the use of a single-vehicle refueling device¹ that enables a simpler filling station that could be expanded to multiple devices as LGVSD converts its fleet to CNG over time. Both scenarios would rely on both the existing boiler as a backup heat source for the digesters and the flare for use during CNG production and microturbine maintenance. It is assumed that use of the biogas for

¹ An example of a single-vehicle CNG refueling device is the Phill® by BRC FuelMaker at http://www.cngnow.com/vehicles/refueling/Pages/refueling-at-home.aspx. This device and similar units cannot be recommended by CH2M HILL until research has been carried out to ascertain whether a single-vehicle product exists that is proven to reliably work in industrial applications. Slow fill systems are also available from the biomethane processing equipment vendors that were used as the basis of evaluation in the Biogas Utilization Evaluation TM.
digester heat would take priority before using it to fuel vehicles and that up to 20 gallons of gasoline equivalent (GGE) would be produced per day for LGVSD fleet vehicle use. In integrated microturbine/CNG system would require a sound control system with specialized programming that enables reliable storage and utilization or flaring of the biogas under all possible operating circumstances. For comparison purposes, Figure 3 depicts a gas flow schematic with only a microturbine system installed.

**Quick CNG Processing**

In this scenario, the CNG system runs at it’s maximum capacity of 38,900 cfd for a 2 hour period per day to produce 20 GGE for vehicle fuel. Two 65 kW microturbines are then operated for the remaining 22 hours while the CNG vehicle fill system is operational for fueling vehicles. If heat is needed, the boiler would need to run on propane for the approximate 2 hour period that CNG is being produced. As described in the LGVSD Biogas Utilization Evaluation TM, the carbon dioxide removal unit wastes some gas in the process, so up to 11,100 cfd of gas would be flared while the CNG system is operating.

**Slow CNG Processing**

In this scenario, biogas would need to be processed at a rate of 9,300 cfd over a 12 hour period. This leaves 40,700 cfd available for either microturbines or the boiler. The Figure 2 below assumes that the microturbines use all of this remaining gas. Since the amount of biogas is no longer enough to reliably run two 65 kW microturbines, three 30 kW microturbines are assumed. Three 30 kW microturbines may not produce enough waste heat to keep the digesters at their correct operating temperature, so additional heat will be required from the boilers. The boilers will either need to run off of a backup fuel (propane) or the microturbines will need to be stopped while the boiler runs to produce enough heat for the digester. The amount of gas required to run three 30 kW microturbines is less than the amount of gas produced, so the remaining gas would then be flared for the 12 hours per day that the vehicle fuel system is not operating. This gas could be used to produce more vehicle fuel, but it is unclear if there would be enough demand to use the additional vehicle fuel.

**Capital Costs**

A combined microturbine and CNG vehicle fill station could take advantage of a single gas cleaning system, but nearly all other systems would still need to be purchased and installed. The capital costs are summarized in Table 1 below.
<table>
<thead>
<tr>
<th>Description</th>
<th>Equipment</th>
<th>CNG Vehicle Fill Station</th>
<th>Combined Microturbines and CNG Vehicle Fill Station (Quick)</th>
<th>Combined Microturbines and CNG Vehicle Fill Station (Slow)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microturbine</td>
<td>$380,000²</td>
<td>$380,000²</td>
<td>$310,000³</td>
<td></td>
</tr>
<tr>
<td>Gas Conditioning System</td>
<td>$440,000</td>
<td>$440,000</td>
<td>$440,000</td>
<td>$440,000</td>
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<tr>
<td>CO2 Removal System</td>
<td>$284,000</td>
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<td>$284,000</td>
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<tr>
<td>CNG Compression and Storage</td>
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<td>$348,000</td>
<td>$348,000</td>
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<tr>
<td>CNG Dispensing System</td>
<td>$5,000</td>
<td>$5,000</td>
<td>$5,000</td>
<td></td>
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<tr>
<td>Hot Water Boiler (standby)</td>
<td>$85,000</td>
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<tr>
<td>Waste Gas Burner (standby)</td>
<td>$90,000</td>
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<tr>
<td>Low Pressure Gas Storage</td>
<td>$175,000</td>
<td>$175,000</td>
<td>$175,000</td>
<td>$175,000</td>
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<td>Sludge Heat Exchanger</td>
<td>$35,000</td>
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<td>$35,000</td>
<td>$35,000</td>
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<tr>
<td>Pump and piping connecting to existing hot water system</td>
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<td>$15,000</td>
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<td>Electrical switchgear</td>
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<tr>
<td>Demolition</td>
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<tr>
<td>Lighting</td>
<td>$5,000</td>
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<td>$5,000</td>
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<tr>
<td>Site Work (vehicle driveway/parking)</td>
<td>$15,000</td>
<td>$15,000</td>
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<td>Equipment Installation</td>
<td>$110,000</td>
<td>$146,000</td>
<td>$156,000</td>
<td>$149,000</td>
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<tr>
<td>Piping and valves</td>
<td>$104,000</td>
<td>$146,000</td>
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<tr>
<td>Electrical</td>
<td>$55,000</td>
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<td>Instrumentation</td>
<td>$55,000</td>
<td>$73,000</td>
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<tr>
<td>SUBTOTAL of New Equipment and Facility Improvements</td>
<td>$1,440,000</td>
<td>$1,930,000</td>
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<td>$2,160,000</td>
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<tr>
<td>Contractor Markups and Contingency</td>
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<td></td>
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<tr>
<td>Mob/Bonds/Permits/Insurance</td>
<td>$70,000</td>
<td>$100,000</td>
<td>$110,000</td>
<td>$110,000</td>
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<td>SUBTOTAL</td>
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<td>$2,360,000</td>
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<td>SUBTOTAL</td>
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<td>Contractors Profits</td>
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<td>Contingency</td>
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<td>$820,000</td>
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<td>SUBTOTAL with Contractor’s Markups and Contingency</td>
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<td>$3,040,000</td>
<td>$3,550,000</td>
<td>$3,420,000</td>
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<tr>
<td>Non-Construction Costs</td>
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<td>Engineering, Legal, Admin</td>
<td>$680,000</td>
<td>$910,000</td>
<td>$1,070,000</td>
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<tr>
<td>TOTAL CONSTRUCTION COSTS</td>
<td>$2,900,000</td>
<td>$4,000,000</td>
<td>$4,600,000</td>
<td>$4,500,000</td>
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</table>
Table Notes:
1. Cost reflects a class 4 estimate which has an accuracy of approximately -20% to +35%.
2. Microturbine costs assume three Capstone C65 units, two duty and one standby, and includes heat recovery modules.
3. Microturbine costs assume four Capstone C30 units, three duty and one standby, and includes an external heat recovery system.

There are a few differences in the above cost table compared to the cost tables included in the LGVSD Biogas Utilization Evaluation. New low pressure gas storage was added in response to LGVSD review comments (see LGVSD Biogas Utilization Evaluation, Board Meeting Response TM) and an unanticipated cost update from the CNG vehicle fill station manufacturer was received after the TM's were published. The total capital cost of combining microturbines with a CNG vehicle fill station represents approximately $1,700,000 more than installing the microturbines alone. The maintenance costs would also increase, and since operating the CNG vehicle costs more than it saves in purchasing CNG or gasoline elsewhere, this system would negatively affect the present worth analysis. It is approximated that the operating cost of producing CNG for vehicles would cost around $10 per GGE, once equipment capital costs are included over a 20 year lifespan the cost per GGE increases to $38.

Grant / Alternative Funding Opportunities
Projects involving renewable energy utilization have potential for obtaining funding from outside resources. These funds may be in the form of grants or low cost loans. At this stage of project development it is not possible to pinpoint any specific program where funding could potentially be obtained, but if the selected alternative is qualified and is approved, outside funding may be possible. While, there are not many funding opportunities for LGVSD due to the small scale of the biogas utilization alternatives, grant and loan opportunities should continue to be monitored, including opportunities for disadvantaged or rural communities that LGVSD may be eligible for based on the relatively small population it serves. Also given LGVSD's small size, multi-jurisdictional “teaming” opportunities in the region should be considered since many awards are given to applicants that provide economies of scale in offsetting carbon intensive fuel production, reducing GHGs, increasing renewable energy, etcetera. Table 2 below summarizes some of the current opportunities for outside funding.
### Outside Funding Opportunities

**Summary of Currently Available Grants and Loans**

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Grant/Loan</th>
<th>Description</th>
<th>Website</th>
<th>Application Deadline</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microturbines, CNG vehicle conversions, or CNG fueling station</td>
<td>Cap &amp; Trade Funding for Bioenergy Projects - California Assembly Budget Committee FY 2014/15 Proposed Budget</td>
<td>S$800 - $1,040 million is being negotiated for the FY 2014/15 state budget between the Governor, Assembly and the Senate for state greenhouse gas (GHG) reduction activities. Funding proposed to fund categories, such as: energy efficiency upgrades to State and public buildings through a revolving fund loans for public buildings, High Speed Rail construction, intercity rail, low-emission vehicle rebates and incentives, fire prevention and urban forestry, waste diversion, reducing agricultural waste, state GHG reduction activities, wetland restoration, water use efficiency, and other activities by State departments that reduce Greenhouse Gas emissions.”</td>
<td><a href="http://abgt.assembly.ca.gov/sub3/hearingagendas">http://abgt.assembly.ca.gov/sub3/hearingagendas</a></td>
<td>TBD in FY 2014/15</td>
<td>Funding for GHG reduction or low emission vehicles may provide opportunities for LGVSD biogas end-use options in the future. CASA is advocating for incentives to assist POTWs in developing beneficial uses for biogas, i.e., combined heat and power, converting methane to low carbon fuel, etc.</td>
<td>Governor, Assembly and Senate are not yet in agreement on how to allocate funding.</td>
</tr>
</tbody>
</table>

| CNG Vehicle Fill Station | Carl Moyer Memorial Air Quality Standards Attainment Program | Provides funding to encourage the voluntary purchase of cleaner-than-required engines, equipment, and emission reduction technologies for vehicles. Plays a complementary role to California’s regulatory program by funding emission reductions that are surplus, i.e., early and/or in excess of what is required by regulation. | [http://www.arb.ca.gov/msprog/moyer/guidelines/current.htm](http://www.arb.ca.gov/msprog/moyer/guidelines/current.htm) | Continuous; first come first serve | Program funds engine replacements & retrofits, new vehicle purchases, fleet modernization, equipment replacements, and vehicle retirements. | Focus is on vehicles, not stationary sources like microturbines. Funding for stationary sources only applies to the agricultural industry. Funding only awarded to projects without regulatory drivers. |
| CNG Vehicle Fill Station | California Energy Commission Alternative and Renewable Fuel and Vehicle Technology Program | Provides up to $100 million per year toward the development and deployment of low-carbon alternative fuels, fueling infrastructure, and advanced vehicle technologies. | [http://www.energy.ca.gov/2013publications/CEC-600-2013-003/CEC-600-2013-003-LCF.pdf](http://www.energy.ca.gov/2013publications/CEC-600-2013-003/CEC-600-2013-003-LCF.pdf) | TBD for F.Y. 2014/15 F.Y. 2013/14 applications were due 3/11/14 | Potential funding for the production of low carbon biofuels, such as CNG from biogas. $39 million awarded to 12 biomethane production projects to date. $17.5 million awarded to 48 natural gas fueling infrastructure projects to date. $33.5 million awarded to 3 natural gas vehicle deployment projects to date. | Scoring criteria focuses on a project’s ability to compete in the commercial California marketplace, increase the in-state production of low carbon biofuels, and advance the state-of-the-art in biofuels production technology. Only $1.5 million will be awarded in CA in F.Y. 2014/15 for natural gas fueling infrastructure. |

FIGURE 1 - CNG VEHICLE FILL STATION RUNNING 2 HRS/DAY
DIGESTER

(50,000 cfd)

H2S REMOVAL

MOISTURE REMOVAL

SILOXANE REMOVAL

GAS STORAGE TANK

(9,300 cfd, for 12 hrs/day)

CO2 REMOVAL SYSTEM

CNG COMPRESSOR

CNG STORAGE TANKS

(9,300 cfd, for 12 hrs/day)

MICROTURBINES,
3 @ 30 kW ea. (plus 1 standby)

WASTE HEAT OUTPUT – 6,720,000 Btu/day

MICROTURBINES,
3 @ 30 kW ea. (plus 1 standby)

HEAT OUTPUT – 1,655,000 Btu/day

HOT WATER BOILER

(0 cfd)

BACKUP FUEL, APPROX 2 HR/DAY

FIGURE 2 - SLOW FILL CNG VEHICLE FILL SYSTEM
DIGESTER

H2S REMOVAL

MOISTURE REMOVAL

SILOXANE REMOVAL

GAS STORAGE TANK

MICROTURBINE

GAS COMPRESSOR

WASTE HEAT OUTPUT – 7,634,000 Btu/day

MICROTURBINES, 2 @ 55 Kw (plus 1 standby)

HEAT OUTPUT – 47,000 Btu/day

FLARE

(50,000 cfd)

HOT WATER BOILER

(0 cfd)

BACKUP FUEL, APPROX 3 MIN/DAY

FIGURE 3 - MICROTurBINES ONLY
ATTACHMENT A

AGREEMENT
FOR CONSULTATION AND PROFESSIONAL ENGINEERING SERVICES
_________________________________________ PROJECT
(JOB NO. _____-__)

THIS AGREEMENT made this _____ day of ________________, _______ by and
between the LAS GALLINAS SANITARY DISTRICT (hereinafter referred to as “District”),
and ______________________________________, whose address is,
_________________________________________________ hereinafter referred to as
“Consultant”);

WITNESSETH:

IN CONSIDERATION of the mutual covenants and conditions herein contained, the
parties do hereby agree as follows:

1. General

DISTRICT engages CONSULTANT to furnish the services hereinafter mentioned upon
the covenants and conditions of this Agreement, at the compensation herein stipulated, and
CONSULTANT accepts said engagement upon said terms.

2. Duties of Consultant; Services to be Performed by Consultant

CONSULTANT shall perform such duties and services as are listed on Exhibit A
attached hereto, and is hereby referred to and made a part hereof by reference. Said services
shall be completed according to the time schedule contained in Exhibit A.

3. Services or Materials to be Performed or Furnished by District

DISTRICT shall perform such services or furnish such materials to CONSULTANT in
connection with this Agreement as are set forth on Exhibit B. If there are no entries on said
Exhibit B, DISTRICT, shall not be required to provide any services or furnish any materials to
CONSULTANT. Unless otherwise provided on Exhibit B, all said services and materials to be
furnished by DISTRICT will be without cost to CONSULTANT.

4. Payment by District: Time and Manner of Payment

DISTRICT shall pay CONSULTANT, for all services to be rendered and all materials to
be furnished under this Agreement, the amount specifically set forth and in the manner
specifically set forth on Exhibit C. CONSULTANT agrees to accept said sum as full
compensation for all services due under this Agreement. Notwithstanding any other language in
the Agreement or any exhibits, CONSULTANT agrees that it will perform all tasks for a sum not
to exceed ______________________________________ ($___________ U.S.
Dollars). This is an Agreement for a specific task as defined in Exhibit A, Consultant Services
(Scope of Work), for ________________________________________________, and CONSULTANT has accurately determined the price of those tasks.

5. **Authorization To Perform Services**
   The CONSULTANT is not authorized to perform any services, or incur any costs whatsoever under the terms of this Agreement until receipt of written authorization from the DISTRICT.

6. **Additional Work**
   CONSULTANT shall be entitled to extra compensation for services or materials not otherwise required under this Agreement or described in Exhibit A, provided that DISTRICT shall first have identified the services or materials as extra, and requested such extra services or materials in writing, but in no event shall DISTRICT be liable for payment unless the amount of such extra compensation shall first have been agreed to in writing by DISTRICT.

7. **Professional Skill**
   CONSULTANT represents that it is skilled in the professional calling necessary to perform the work agreed to be done by it under this Agreement. CONSULTANT represents and warrants to DISTRICT that it has all licenses, permits, qualifications that are legally required for CONSULTANT to practice its profession and that CONSULTANT shall, at its sole cost and expense, keep all such licenses, permits, and approvals which are legally required for CONSULTANT to practice its profession in effect. DISTRICT relies upon the skill of CONSULTANT to do and perform its work in a skillful manner, and CONSULTANT agrees to thus perform its work, and the acceptance of its work by DISTRICT shall not operate as a release of CONSULTANT from said Agreement. For purposes of this Agreement, “skillful manner” shall mean the standard of care prevailing in the industry in the San Francisco Bay Area during the term of this Agreement.

8. **Equal Employment Opportunity**
   CONSULTANT shall not discriminate against any employee or applicant for employment because of race, religious creed, color, national origin, amnesty, physical handicap, medical condition, marital status or sex of such person as provided in Section 12940 of the Government Code.

9. **Compliance with Laws**
   CONSULTANT shall comply with all federal, state and District laws, statutes, ordinances, rules and regulations and the orders and decrees of any courts or administrative bodies or tribunals in any manner affecting the performance of the Agreement. Any suit or action by either party shall be brought in the Superior Court for the County of Marin, California. The laws of the State of California shall govern this Agreement.

10. **Independent Contractor; Not An Agent**
   CONSULTANT, at all times during the term of this Agreement is acting as an independent contractor in furnishing the services or materials and performing the work required by this Agreement and is not an agent, servant or employee of DISTRICT. Notwithstanding any
other DISTRICT, state or federal policy, rule, regulation, law, or ordinance to the contrary, CONSULTANT and any of its employees, agents, and subcontractors providing services under this Agreement shall not qualify for or become entitled to, and hereby agree to waive any and all claims to, any compensation, benefit, or any incident of employment by DISTRICT, including but not limited to eligibility to enroll in the California Public Employees Retirement System (PERS) as an employee of DISTRICT and entitlement to any contribution to be paid by DISTRICT for employer contributions and/or employee contributions for PERS benefits.

Except as DISTRICT may specify in writing, CONSULTANT shall have no authority, express or implied, to act on behalf of DISTRICT in any capacity whatsoever as an agent or pursuant to this Agreement to bind DISTRICT to any obligation whatsoever.

11. Time

CONSULTANT shall devote such time to the performance of services pursuant to this Agreement as may be reasonably necessary for satisfactory performance of CONSULTANT’S obligations pursuant to this Agreement.

12. Indemnity

CONSULTANT agrees to indemnify and save harmless and defend with counsel acceptable to DISTRICT, the DISTRICT, its officials, officers, employees, agents, and volunteers from and against any and all losses, liability, suits, actions, costs, expenses, claims, causes of action and damages (including costs of defense) arising out of any personal injury, bodily injury, loss of life, or damage to property, or any violation of any federal, state, or municipal law or ordinance to the extent caused, in whole or in part, by recklessness, the willful misconduct or negligent acts or omissions of CONSULTANT, its officers, employees, agents, consultants, subcontractors or any officer, agent or employee thereof but excluding liabilities due to the sole negligence or willful misconduct of the DISTRICT or any third party. For purposes of Section 2782 of the Civil Code the parties hereto recognize and agree that this Agreement is not a construction contract. By execution of this Agreement, CONSULTANT acknowledges and agrees that CONSULTANT has read and understands the provisions hereof and that this paragraph is a material element of consideration. DISTRICT and CONSULTANT agree that this Agreement is consistent with Section 2782.8 of the Civil Code.

13. Insurance: Public Liability, Workers’ Compensation, Errors and Omissions

CONSULTANT shall procure and maintain for the duration of the contract insurance against claims for injuries to persons or damages to property which may arise from or in connection with the performance of the work hereunder by the CONSULTANT, its officers, subcontractors, agents, representatives, or employees.

CONSULTANT shall be required to meet all District Insurance Requirements. See Exhibit D for District Insurance Requirements.

14. Consultant Professional Team

CONSULTANT shall provide and maintain the professional team to perform and furnish the materials in connection with this Agreement whose names and capacities are set forth on Exhibit E. In the event that any member of said team shall leave the employ of CONSULTANT
or be transferred to another office of CONSULTANT, CONSULTANT shall so advise DISTRICT and replace that member with a new member who is competent to perform the required work and who shall be satisfactory to DISTRICT. Such other agents or employee contractors or subcontractors not listed on Exhibit E as may be required to perform any portion of this Agreement shall be competent and shall be suitably experienced in the function which they perform.

15. Notices

Unless otherwise provided herein, all notices required hereunder shall be given by certified mail, postage prepaid and addressed to the party at the address indicated in the opening paragraph of this Agreement provided, however, that in lieu thereof, notice may be given by personal delivery to the party at said address.

16. Title to Documents

All original calculations, photographs, maps, drawings, plans, design notes and other material or documents developed or used in connection with the performance of this Agreement shall be the property of DISTRICT provided, however, that CONSULTANT may provide DISTRICT with legible photostatic copies thereof in lieu of the originals upon approval by DISTRICT representative. All such material and documents shall remain confidential and may not be divulged, published or shared by CONSULTANT without the prior written consent of DISTRICT. Any plans and specifications shall bear the name of the CONSULTANT together with his certificate number, if any. If CONSULTANT’S working papers or product includes computer generated statistical material, CONSULTANT shall provide the material including the data base upon which it is based to DISTRICT in a mutually agreed upon computer machine-readable format and media.

17. Assignment

Neither party shall assign or sublet any portion of this Agreement without the written consent of the other party in writing.

18. Termination

Without limitation to such rights or remedies as DISTRICT shall otherwise have by law, DISTRICT shall also have the right to terminate this Agreement for any reason upon seven (7) days’ written notice to CONSULTANT. This Agreement may also be terminated by either party upon seven (7) days’ written notice should the other party fail substantially to perform in accordance with this agreement through no fault of the other or if the project is stopped by conditions beyond the control of the DISTRICT.

In addition to terminating this Agreement if CONSULTANT materially breaches any of the terms of this Agreement, DISTRICT’S remedies shall include, but not be limited to:

- Retain the plans, specifications, drawings, reports, design documents, and any other work product prepared by CONSULTANT pursuant to this Agreement;
- Retain a different consultant to complete the work described in Exhibit A not finished by CONSULTANT; and/or
This description of DISTRICT's remedies does not otherwise limit DISTRICT's remedies at law or equity.

19. **Entire Agreement; Amendment**

   This writing constitutes the entire Agreement between the parties. Any prior agreements of any nature merge into this Agreement. No modification hereof shall be effective unless such modification is in writing signed by all parties to this Agreement.

20. **No-Waiver; Construction**

   Failure on the part of either party to enforce any provisions of this Agreement shall not be construed as a waiver of the right to compel enforcement of such provisions or any other provision. The singular number shall include the plural, and the masculine gender shall include the feminine gender and neuter gender whenever the context of this Agreement permits.

21. **Validity**

   The invalidity in whole or in part of any provision of this Agreement shall not void or affect the validity of any other provision of this Agreement.

22. **Mediation**

   Should any dispute arise out of this Agreement, the parties shall meet in mediation and attempt to reach a resolution with the assistance of a mutually acceptable mediator. Neither party shall be permitted to file a legal action without first meeting in mediation and making a good faith attempt to reach a mediated resolution. The costs of the mediator, if any, shall be shared equally by the parties. If a mediated settlement is reached, neither party shall be deemed the prevailing party for purposes of the settlement and each party shall bear its own legal costs.

23. **Attorney’s Fees**

   If a party brings any action, including an action for declaratory relief, to enforce or interpret the provisions of this Agreement, the prevailing party is entitled to reasonable attorneys’ fees in addition to any other relief to which that party may be entitled. Such fees may be set by the court in the same action or in a separate action brought for that purpose.

24. **Survival**

   All obligations arising prior to the termination of this Agreement and all provisions of this Agreement allocating liability between DISTRICT and CONSULTANT survive the termination of this Agreement.

25. **Conflict of Interest**

   CONSULTANT may serve other clients, providing that activities in the service of other clients do not place CONSULTANT in a “conflict of interest” as that term is defined in the Political Reform Act codified at California Government Code § 81000 *et seq.* or Section 1090 *et seq.* of the Government Code.
26. **Severability**

If a court of competent jurisdiction finds or rules that any provision of this Agreement is invalid, void, or unenforceable, the provisions of this Agreement not so adjudged shall remain in full force and effect. The invalidity in whole or in part of any provision of this Agreement shall not void or affect the validity of any other provision of this Agreement.

27. **Consultant Nondisclosure**

   a. CONSULTANT will not directly or indirectly use (other than for the DISTRICT), publish, or otherwise disclose at any time (except as CONSULTANT’S duties may require), either during or subsequent to the performance of consulting services, any of DISTRICT’s confidential information (whether or not conceived, originated, discovered, or developed in whole or in part by CONSULTANT) as defined below.

   b. “Confidential information” means information or material that is not generally available to or used by others, or the utility or value of which is not generally known or recognized as standard practice whether or not the underlying details are in the public domain, including without limitation:

   - Information or material that relates to DISTRICT’S inventions, technological developments, “know how”, purchasing, accounting, merchandising or licensing;
   - Trade secrets;
   - Software in various stages of development (source code, object code, documentation, diagrams, flow charts), designs, drawings, specifications, models, data and customer information; and
   - Any information of the type described above that DISTRICT obtained from another party and that the DISTRICT treats as proprietary or designates as confidential, or is obligated to do so by virtue of a third-party agreement, whether or not owned or developed by the DISTRICT.

   c. The obligations of confidentiality imposed herein will not apply to confidential information that:

   - Is or has been generally available to the public by any means, through no fault of CONSULTANT and without breach of these provisions.
   - Is or has been lawfully disclosed to CONSULTANT by a third party without an obligation of confidentiality being imposed upon CONSULTANT.
   - Has been disclosed without restriction by the DISTRICT or by a third party owner of confidential information.
   - Was required to be disclosed pursuant to law.

   d. CONSULTANT agree to deliver to DISTRICT promptly on request, or on the date of termination of CONSULTANT’S services, all documents, software, including any copies, and other materials in CONSULTANT’S possession pertaining to the business of DISTRICT and originating with the DISTRICT that came into CONSULTANT’S possession.
e. The disclosure of confidential information shall not be construed as granting either a license under any patent, patent application or any right of ownership in said confidential information.

f. CONSULTANT acknowledges and agrees that in the event of a breach or threatened breach of any provisions of this Agreement, the DISTRICT shall have no adequate remedy at law and shall therefore be entitled to enforce any such provision by temporary or permanent injunctive or mandatory relief obtained in any court without the necessity of proving damages, posting any bond or other security, and without prejudice or diminution of any other rights or remedies which may be available at law or in equity.

28. Additional Provisions, Exhibits

Additional provisions of this Agreement are set forth on Exhibits A through Exhibit F. All Exhibits shall be attached to, and are hereby referred to and made a part hereof by reference.

IN WITNESS WHEREOF, the parties have hereunto set their hands the day and year first above written.

LAS GALLINAS VALLEY SANITARY DISTRICT

By _____________________________________________
Mark R. Williams, General Manager Date

______________________________________________
Signature Date

By _____________________________________________
Print Name Title

NOTE: The following exhibits are hereby incorporated into this agreement by this reference:

Exhibit A: Consultant Services (Scope of Work)
Exhibit B: Services or Materials to be Performed or Furnished by District
Exhibit C: Payment Schedule
Exhibit D: District Insurance Requirements
Exhibit E: Consultant Team
Exhibit F: 1. Contractor/Consultant Safe Work Requirements
               2. Confined Space Entry Program
Exhibit A

Consultant Services (Scope of Work)

(Placeholder)
Exhibit B

Services or Materials to be Performed or Furnished by District

1. Contract Documents – Bidding Forms, Contract Forms, and General Conditions
Exhibit C

Payment Schedule

(Placeholder)
Exhibit D

District Insurance Requirements

Consultant shall procure and maintain for the duration of the contract insurance against claims for injuries to persons or damages to property which may arise from or in connection with the performance of the work hereunder by the Consultant, his agents, sub-consultants, sub-contractors, representatives, or employees.

**Minimum Scope of Insurance**

Coverage shall be at least as broad as:

1. Insurance Services Office Commercial General Liability coverage (occurrence Form CG 00 01).
2. Insurance Services Office Form Number CA 0001 covering Automobile Liability, Code 1 (any auto), Code 9 (hired) and 9 (non-owned).
3. Workers’ Compensation insurance as required by the State of California and Employer’s Liability Insurance.
4. Errors and Omissions Liability insurance appropriate to the consultant’s profession. Architects’ and engineers’ coverage is to be endorsed to include contractual liability.

**Minimum Limits of Insurance**

Consultant shall maintain limits no less than:

<table>
<thead>
<tr>
<th>Coverage Description</th>
<th>Minimum Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Liability:</td>
<td>$1,000,000 per occurrence for bodily injury, personal injury and property damage. If Commercial General Liability Insurance or other form with a general aggregate limit is used, either the general aggregate limit shall apply separately to this project/location or the general aggregate limit shall be twice the required occurrence limit.</td>
</tr>
<tr>
<td>Automobile Liability:</td>
<td>$1,000,000 per accident for bodily injury and property damage.</td>
</tr>
<tr>
<td>Employer’s Liability:</td>
<td>$1,000,000 per accident for bodily injury or disease.</td>
</tr>
<tr>
<td>Errors and Omissions Liability:</td>
<td>$1,000,000 per claim, and $2,000,000 aggregate.</td>
</tr>
</tbody>
</table>

**Higher Limits of Insurance**

If the Consultant maintains higher limits than the minimums shown above, the District requires and shall be entitled to coverage for higher limits maintained by the Consultant.

**Other Insurance Provisions**
The insurance policies are to contain, or be endorsed to contain, the following provisions:

1. **Additional Insured Status**

   The District, its officers, officials, employees, and volunteers are to be covered as additional insureds on the auto policy with respect to liability arising out of automobiles owned, leased, hired or borrowed by or on behalf of the Consultant; and on the CGL policy with respect to liability arising out of work or operations performed by or on behalf of the Consultant including materials, parts, or equipment furnished in connection with such work or operations. General liability coverage can be provided in the form of an endorsement to the Consultant’s insurance (at least as broad as ISO Form CG 20 10, 11 85 or both CG 20 10 and CG 23 37 forms if later revisions used).

2. **Primary Coverage**

   For any claims related to this contract, the Consultant’s insurance coverage shall be primary insurance as respects the District, its officers, officials, employees, and volunteers. Any insurance or self-insurance maintained by the District, its officers, officials, employees, or volunteers shall be excess of the Consultant’s insurance and shall not contribute with it.

3. **Notice of Cancellation**

   Each insurance policy required above shall state that coverage shall not be canceled, except with notice to the District.

4. **Waiver of Subrogation**

   Consultant hereby grants to District a waiver of any right to subrogation which any insurer of said Consultant may acquire against the District by virtue of the payment of any loss under such insurance. Consultant agrees to obtain any endorsement that may be necessary to effect this waiver of subrogation, but this provision applies regardless of whether or not the District has received a waiver of subrogation endorsement from the insurer.

5. **Deductibles and Self-Insured Retentions**

   Any deductibles or self-insured retentions must be declared to and approved by the District. The District may require the Consultant to provide proof of ability to pay losses and related investigations, claim administration, and defense expenses within the retention.

6. **Acceptability of Insurers**

   Insurance is to be placed with insurers with a current A.M. Best’s rating of no less than A:VII, unless otherwise acceptable to the District.

7. **Claims Made Policies**

   If any of the required policies provide coverage on a claims-made basis:
   a. The Retroactive Date must be shown and must be before the date of the contract or the beginning of contract work.
b. Insurance must be maintained and evidence of insurance must be provided for at least five (5) years after completion of the contract of work.

c. If coverage is canceled or non-renewed, and not replaced with another claims-made policy form with a Retroactive Date prior to the contract effective date, the Consultant must purchase “extended reporting” coverage for a minimum of five (5) years after completion of contract work.

8. Verification of Coverage

Consultant shall furnish the District with original certificates and amendatory endorsements or copies of the applicable policy language effecting coverage required by this clause. All certificates and endorsements are to be received and approved by the District before work commences. However, failure to obtain the required documents prior to the work beginning shall not waive the Consultant’s obligation to provide them. The District reserves the right to require complete, certified copies of all required insurance policies, including endorsements required by these specifications, at any time.

9. Subcontractors

Consultant shall require and verify that all subcontractors maintain insurance meeting all the requirements stated herein.

10. Special Risks or Circumstances

District reserves the right to modify these requirements, including limits, based on the nature of the risk, prior experience, insurer, coverage, or other special circumstances.
Exhibit E

Consultant Team

(Placeholder)
Exhibit F

1. Safe Work Requirements
LAS GALLINAS VALLEY SANITARY DISTRICT

SAFE WORK REQUIREMENTS
Updated May 11, 2010

SAFETY POLICY

(Note: “Contractor” or “Subcontractor” whenever mentioned in this appendix shall also mean “Consultant” or “Subconsultant” respectively.)

Contractors and their subcontractors working for the Las Gallinas Valley Sanitary District shall comply with all applicable federal, state, and local safety orders in the performance of any work on District projects. In addition, Contractors and their subcontractors shall comply with all safety regulations and procedures listed in this Safe Work Requirements. Contractors shall take any additional precautions necessary to prevent injury or damage to persons, property, or interference with District operations.

Contractors shall be responsible for notifying employees, subcontractors, and invitees of these District Safe Work Requirements. No work within District facilities or on District contract work sites shall begin prior to such notification. Contractor shall not allow a new employee or new subcontractor to begin work on District projects without having conducted a full and proper safety orientation.

Contractors doing work at the Treatment Plant facility, lift stations or sewage conveyance systems shall schedule a safety orientation session for their site Superintendent and other Contractor-designated personnel with the Authorized District Representative prior to commencing work. The orientation session shall include emergency procedures, an explanation of applicable District safety policies, and any unique and inherent hazards of District facilities. It is then the responsibility of the Contractor's Superintendent or designated personnel to orient and so inform all personnel under the Contractor’s supervision.

The District may, in its sole discretion, either temporarily or permanently remove a Contractor’s employee from District work and/or terminate the Contractor’s right to proceed for any violation of applicable Cal/OSHA Construction Safety Orders or these District Safe Work Requirements.

DEFINITIONS

As used in this Safe Work Requirement, the following definitions are applicable:

A. **Parts and Materials:**
All products, materials, devices, systems, or installations installed by Contractor shall have been approved, listed, labeled, or certified as conforming to applicable governmental or other nationally recognized standards, or applicable scientific principles.
The listing, labeling, or certification of conformity shall be based upon an evaluation performed by a person, firm, or entity with appropriate registered engineering competence; or by a person, firm, or entity, independent of the manufacturer or supplier of the product, with demonstrated competence in the field of such evaluation.

B. **Contractor**

Designates “Contractor”, “Contractors”, “Sub-Contractors”, “Suppliers”, and all employees of each.

C. **Authorized District Representative**

The District’s Authorized Representatives shall be the employee(s) designated by the District to be responsible for communicating with the Contractor.

D. **District Jurisdiction**

For the purposes of these regulations, “District” Shall mean the Las Gallinas Valley Sanitary District.

E. **Treatment Plant and Facilities**

For the purposes of these regulations, “Treatment Plant & Facilities” shall include the District's Wastewater Treatment Plant, lift stations and sewage conveyance systems located within the boundaries of the District.

**EMERGENCY PROCEDURES**

A. **First Aid**

Contractors shall be responsible for providing first aid and medical treatment for their employees and for compliance with the first aid requirements of all applicable Cal/OSHA Construction Safety Orders.

Contractors shall be responsible for making prior arrangements for emergency medical care and for transportation of injured Contractor personnel.

B. **Fire**

When work is being performed which generates sparks or open flames, the Contractor will provide a fire watch, a person trained in the use of appropriate firefighting equipment, whose only task is to observe and extinguish fires. A District “Hot Works” permit must be filled out and turned into the Collection System / Safety Manager, or General Manager when the Safety Manager is not available, when work is completed. Contractor shall ensure that appropriate fire extinguisher(s) are available at the specific work site for use in case of a fire. All Contractor’s employees shall be properly trained to use them.

In the event of a fire, Contractor shall immediately notify the nearest District employee, and if possible, call emergency (911) and give the location of the plant, which is 300 Smith Ranch Rd. San Rafael. A map of the wastewater plant is included in this policy. Refer to Attachment A.
BASIC SAFETY RESPONSIBILITIES AT DISTRICT FACILITIES

A. COMMUNICATION
Contractor shall maintain close communication with the Authorized District Representative. Contractors should sign-in at the office at the beginning and end of each day along with a headcount of crew members.

B. RESPONSIBILITY
Contractor shall be responsible for initiating, maintaining, and supervising all safety precautions and programs in connection with the work. The Contractor shall take all necessary precautions for the safety of, and shall provide the necessary protection to prevent damage, injury or loss, to:

1. All employees on the work site and other persons and organizations who may be affected thereby.
2. All the work, materials, and equipment to be incorporated therein, whether in storage or off the site.
3. Other property at the site or adjacent thereto, including trees, shrubs, lawns, walks, pavements, roadways, structures and utilities not designated for removal, relocation, or replacement in the course of construction.

Contractor shall comply with all applicable laws and regulations (whether referred to herein or not) of any public agency having jurisdiction over the safety of persons or property, or the protection of persons from damage, injury, or loss, and shall erect and maintain all necessary safeguards for such safety and protection. Contractor shall notify owners of adjacent property and facilities when performance of the work may affect them, and shall cooperate with them in the protection, removal, relocation and replacement of their property and facilities.

Contractor shall designate a responsible representative at the site whose duty shall be the prevention of accidents. This person shall be the Contractor's Superintendent unless otherwise designated in writing by the Contractor to the District.

C. GENERAL SAFETY REGULATIONS
Basic Rules:

- Work shall not begin until the Contractor's personnel have been informed of the District's Safe Work Requirements and potential hazards. The District employee responsible for the project is responsible for advising the Contractor of the District’s Safe Work Requirements and potential hazards.

- All safety procedures applicable to the job being performed, including use of appropriate protection equipment, shall be followed.

- The Contractor’s personnel shall never operate, use, adjust, modify or relocate any District equipment, switches, valves, or other controls. The Authorized
District Representative must be contacted should operation, adjustment, modification, or relocation of District equipment be necessary.

· Contractor’s use of District instruments, tools, ladders, scaffolding or other equipment is not permitted except in cases of emergency as determined by a District supervisor or by permission from a senior Manager of the District.

· Drinking water shall be supplied by Contractor. **Do Not Drink Water from Hose Connections at any District Facility.**

1. Hose bib connections are located throughout the treatment plant. Most of these supply treated wastewater and may or may not be posted with signs reading “Do Not Drink.” In any case, _never_ drink water from hose bibs or hoses.

2. Water lines throughout the treatment plant are color coded (when not stainless steel) and labeled as follows:
   - Recycle Water Piping Purple
   - Domestic Water Piping Blue
   - Service Water Piping (Plant Effluent) Gray

3. Hose connections may be used to wash down equipment. Never hose down electrical or heated equipment of any kind. If an employee has used a gray or purple water hose for wash down, he/she should immediately wash their hands in domestic water with soap.

· NEVER make any connection to any water line without first verifying with the Authorized District Representative that contamination of the water lines will not occur.

· Use of alcoholic beverages and/or illegal drugs by Contractor or any employee is strictly prohibited. Smoking within the plant is prohibited. Use of prescription or non-prescription drugs which interfere with the individual’s ability to work safely is also prohibited.

· Contractor shall advise the Authorized District Representative of any employee with any medical conditions that could put the employee in danger.

**Personal Protection Equipment:**

· Contractor shall be responsible for providing and assuring use by employees of all OSHA required protective equipment.

· Approved respiratory equipment shall be worn when the possibility of exposure to hazardous dusts, vapors, fumes, mists, or gases exists. In addition to all other safety regulations, pipes or conduit should be mechanically BLOCKED off when being worked on. District safety procedures shall be followed when working on, but not limited to, the following systems:
  1) Natural gas and sludge gas (Methane)
  2) Ferrous Chloride
3) Polymer
4) Hypochlorite
5) Compressed Air
6) Sodium Bisulfite

· Contractor shall be responsible for determining the existence and location of such systems prior to commencement of work.

**Power Tools and Welding Equipment:**

· Gasoline and electrical powered hand tools shall be protected by approved ground fault circuit interrupters, or shall be double insulated. Cords shall be inspected daily prior to use. Damaged cords shall not be used on District work.

· Pneumatic driven power tools shall be disconnected from air lines when not in use. Hoses shall be inspected daily prior to use. Damaged hoses shall not be used on District work.

· Power tools shall be used only by trained personnel who have a valid license (when applicable, i.e., welding) in their possession. Proper warning signs shall be posted when these tools are in use.

· Electric and gas welding and cutting tools, including cords and gas hoses, shall be inspected daily prior to use. Damaged cords and gas hoses shall not be used on District work.

· Contractor and Contractor employees’ tools and equipment used on District work sites shall be in safe operating condition and shall conform to the requirements of Cal/OSHA regulations. All personnel using such tools shall be properly trained.

**D. BARRICADES AND SIGNS FOR TRAFFIC CONTROL**

All Contractors, permittees, or agencies doing work for District which requires traffic control shall:

1) Install and maintain required traffic devices.
2) Provide appropriately equipped flag persons when required.
3) Provide adequate safeguards for workers and District personnel.
4) Maintain access for District personnel to all District facilities.

All work on streets, roadways, or similar thoroughfares shall comply with the Federal Highway Administration’s “Manual on Uniform Traffic Control Devices for Streets and Highways” and any local ordinances. District Plant speed is maximum 10 mph.
SPECIAL PROCEDURES AND UNIQUE HAZARDS

A. CONFINED SPACE ENTRY
Confined spaces of all types exist throughout the District and throughout the plant and range from open trenches and manholes, to tanks, clarifiers and digesters. Contractors are required to meet Cal/OSHA safety standards for CONFINED SPACE ENTRY OPERATIONS, Title 8 Article 108 (Sections 5156-5159), or the most current CAL/OSHA applicable standards, and to provide a safe working environment for their employees. All Contractors directing or working in confined spaces are required to notify the Authorized District Representative. Contractors are responsible for all operations, testing, equipment calibration, ventilation, and entry per the Cal/OSHA standards. Contractors are responsible for all confined space permits and all appropriate equipment. Completed confined space permits are to be turned in to the District’s safety manager.

B. ELECTRICAL SUPPLY SYSTEMS
The treatment plant’s Electrical Supply System consists of one 85KW digester/methane gas fired engine driven generator, one 500KW diesel oil engine driven standby generator and one 380 KW trailer mounted standby generator, and solar power. All electrical power generated in the plant and PG&E power (beyond their transformer) is 480 volt, 3 phase, 60 Hz electricity and is delivered to one 480 volt switchgear panel. This panel is interconnected by cables and protected by breakers, relays and monitoring devices.

Electricity is dispersed from the switchgear through breakers and cables to motor control centers (MCC’s), to power panels, to transformers (voltage reducers), to lighting panels and to motor driven pumps and equipment. Lockable control stations are located at each piece of equipment. 480 volt, 208 volt and 120 volt electricity is used in the plant. Contact the duty operator prior to working on any piece of electrical equipment. Electricity is hazardous and can burn or kill people.

All work on electrical systems shall be done in accordance with the State of California, CAL/OSHA, Article 33, Electrical Requirements for construction work, Low Voltage Electrical Safety Orders.

C. FERROUS CHLORIDE SYSTEMS - AS OF 04/2010 FERROUS CHLORIDE IS CURRENTLY NOT BEING USED
The Ferric Chloride System consists of a large steel cylindrical (rubber lined) storage tank with loading and unloading nozzles, pressure relief valve and a positive displacement pump with feed rate adjustment. Shut-off valves are located before and after the pump. Before working on this system, close all valves and disconnect the pump from electricity.

Ferric Chloride is a dangerous chemical which will attack the skin, eyes and the mucous membranes of the mouth, throat and lungs. Contact the plant duty operator prior to working on this system.
D. **DIGESTER GAS SYSTEM**
The Digester Gas System consists of one steel tank, associated piping, compressors, flare, etc. Sludge is bacterially reduced in the tanks creating principally methane (CH₄) and other combustible hazardous gases, including hydrogen sulfide (H₂S). Hydrogen sulfide is toxic at very low concentrations. These gases are contained by the tank covers and piping which is located on overhead racks, in pipe trenches and buried throughout the plant. The gases are burned in large engines driving generators to make electricity for the plant. Heat from the engines is captured and piped to the digesters to heat the sludge, speeding up the digestion process.

Digesters and the stored gases within them are hazardous. No smoking, cutting, or spark-generating equipment is allowed on or within ten feet of any digester. Contact the duty operator prior to working on digesters.

E. **HYPOCHLORITE SYSTEM**
Hypochlorite, or concentrated chlorine bleach (12.5%), is used to disinfect, or kill bacteria and virus in the final effluent (water) discharged from the plant. Two tanks, one 6,000 gallons and one 3,400 gallons are used to store hypochlorite. Piping, valves, pumps, strainers (filters) and flow measuring and control equipment make up the system. Hypochlorite will attack clothing, skin, eyes and mucous membranes of the nose, mouth, throat and lungs. Contact the duty operator prior to working on the hypochlorite system.

F. **SODIUM BISULFITE**
Sodium bisulfite is used when neutralizing sodium hypochlorite. Two tanks, one 4,00 gallons and one 2,500 gallons are used to store sodium bisulfite. Piping, valves, pumps, strainers (filters) and flow measuring and control equipment make up the system. Sodium bisulfite is an irritant to eyes, skin and mucous membranes. Inhalation of mist may cause irritation to respiratory tract. Contact the duty operator prior to working on the sodium bisulfite system.

G. **GENERAL HAZARDS**
Throughout District’s treatment plant and facilities there are a number of extremely hazardous elements that are dangerous. They include, but are not limited, to:

- Flammable gas and petroleum.
- H₂S (hydrogen sulfide)
- Deep pools of liquid sewage which are rarely patrolled, and for which self-rescue is unlikely.
- Automatic start equipment.
- HBV (Hepatitis B Virus)
The undersigned acknowledges receipt of and has read and fully understands these District Safe Work Requirements.

**CONTRACTOR/CONSULTANT**

Signed: __________________________

Name: ____________________________

Title: ____________________________

Date: ____________________________

Company: _________________________
Exhibit F

2. Confined Space Entry Program
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SPECIAL ENTRY PROCEDURES 3

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INTRODUCTION

The purpose of Las Gallinas Valley Sanitary District's confined space entry program is to protect employees who work in manholes, pump stations, tanks, or any other confined space that could expose employees to hazardous conditions or substances. The program establishes an entry permit system and procedures to ensure that potential hazards of each confined space are identified and evaluated and that appropriate safety precautions are taken before an employee enters the space.

Employees will be given an opportunity to participate in the development and implementation of LGVSD's confined space procedures. The program will be revised or procedures will be modified whenever suggestions or recommendations from employees would improve confined space safety.

The policies and procedures in this program are consistent with the requirements of Cal/OSHA General Industry Safety Orders, Title 8, Sections 5156 and 5157 and supersede previous confined space policies and procedures. The program applies to all employees who work in, or in connection with LGVSD confined spaces.

Confined spaces at LGVSD have been identified based on the definitions in Section 5157 as follows:

Confined Space is a space that:

1. Is large enough and so configured that an employee can bodily enter and perform assigned work; and
2. Has limited or restricted means for entry or exit; and
3. Is not designed for continuous employee occupancy.

Permit-Required Confined Space is a space that has one or more of the following characteristics:

1. Contains or has a potential to contain a hazardous atmosphere;
2. Contains a material that has the potential for engulfing an entrant;
3. Has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls or by a floor which slopes downward and tapers to a smaller cross section; or
4. Contains any other recognized serious safety or health hazard.

Non-Permit Confined Space is a space that does not contain (or with respect to atmospheric hazards, has no potential to contain) any hazard capable of causing death or serious physical harm.

Employees who work in or in connection with confined spaces are required to follow the procedures described in this program and to take all the appropriate precautions to ensure that the work is performed safely. At no time should an employee enter a confined space or perform work in the space unless it can be done safely.
PERMIT-REQUIRED CONFINED SPACEs

The tables on pages B-4 and B-5 list confined spaces at LGVSD that require a permit to enter. Potential hazards associated with these spaces include engulfment, toxic gases, explosive or flammable gases, oxygen deficiency, electrical and mechanical hazards, and may under certain circumstances involve heat stress. Warning signs will be posted at wet wells and similar locations to inform employees that the space requires a permit to enter. To prevent unauthorized entry, each of these spaces will be secured.

Using the entry permit, a non-entry evaluation must be done so that potential hazards can be identified and the appropriate safety precautions taken. The types of hazards that may be encountered, pre-entry safety checks, and the types of safety equipment that will be used are entered on the permit. Only the person designated as the entry supervisor has the authority to authorize the entry permit. At least three employees are required for a permit-required confined space entry which would include an attendant and a standby rescuer.

The tables on pages B-4 and B-5 that list permit-required confined spaces at LGVSD are not all-inclusive. Other spaces may be determined to be permit-required after evaluating the conditions or circumstances of the entry. The type of work to be performed in the space could introduce hazards to an otherwise safe space. Working with flammable or toxic substances, welding or other hot work, or drifting vapors from outside sources would make a space hazardous or potentially hazardous and therefore require a permit to enter.

ALTERNATE ENTRY PROCEDURES

Alternate procedures are allowed in permit-required spaces where it can be demonstrated and documented that the only hazard or potential hazard is an atmospheric one, and that continuous forced air ventilation alone will maintain the space safe for entry. A trained, qualified employee may enter these confined spaces without an attendant or rescue preparations provided the following conditions are met.

1. All unsafe conditions are eliminated before the confined space cover is removed.
2. The entrance to the space is guarded with a railing or other type of barrier to prevent an accidental fall through the opening and to protect employee in the space.
3. The atmosphere is tested before entry in the following order: O2, LEL/LFL, H2S.
4. No entrance is made until hazardous atmosphere is eliminated.
5. There is no hazardous atmosphere when employees are in the space.
6. Continuous forced ventilation is used.
7. The air supply is clean and will not increase hazards.
8. The air supply is directed to area where employees are working.
9. The atmosphere is tested every 15 minutes to ensure a hazardous atmosphere is not developing.
10. Records of pre-entry and entry monitoring data and inspection data are maintained.
11. The entrant certifies, in writing, that the required pre-entry measures have been taken.
12. Monitoring and inspection data, and the certification information are made available to each employee entering the space.

If a hazardous atmosphere develops in the space, or other hazards arise, alternate procedures can no longer be used and the space must be reclassified as a fully permitted space.

SPECIAL ENTRY PROCEDURES
There are a few confined spaces at LGVSD that are not considered permit-required confined spaces. As far as can be determined, these spaces do not contain any known hazard. However, as a precautionary measure, employees are required to follow certain special procedures before entering these spaces.

1. Test the atmospheric conditions prior to entry.
2. If atmospheric conditions are acceptable, entry can be made.
3. If atmospheric conditions are not acceptable, use alternate procedures.
4. If any other hazardous condition exists, follow permit-required confined space procedures.

THE ENTRY PERMIT SYSTEM
Confined space entry permits are to be issued for a specific purpose, a specific work crew, and for a specified period of time. The entry permit is a written authorization of the location and type of work to be done. It also authorizes the personnel assigned to the job, and verifies that potential hazards have been evaluated and controlled or eliminated, that proper safety precautions have been taken, and it is safe for workers to enter. The permit must be kept at the work site (outside the space) for the duration of the work and cancelled after the work is completed.

HOT WORK PERMIT
A hot work permit must be issued for any work that produces heat, sparks or flame in a permit-required confined space. This includes but not limited to brazing, cutting, grinding, soldering, and welding.

TABLE 1: MAIN PLANT PERMIT-REQUIRED CONFINED SPACES (SEE NEXT PAGE)
<table>
<thead>
<tr>
<th>MAIN PLANT</th>
<th>Permit-Required</th>
<th>Alternate or Special Procedure</th>
<th>MAIN PLANT</th>
<th>Permit-Required</th>
<th>Alternate or Special Procedure</th>
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</thead>
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<tr>
<td>Marinwood Pump Station</td>
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<td>Deep Bed Filter</td>
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<td>Pre Wet Well Structure</td>
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<td>Weir Overflow Pit</td>
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<td></td>
<td>Scum Pit</td>
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<tr>
<td>Weir Overflow Pit</td>
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<td>Clarifier Return Pit</td>
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<td>Underdrain</td>
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<td>F4 - DBF Effluent Box</td>
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<td>DBF Effluent Weir Box/Plant Water Pump</td>
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</table>

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### TABLE 2: RECLAMATION, COLLECTION SYSTEM, AND PUMP STATIONS PERMIT-REQUIRED CONFINED SPACES

<table>
<thead>
<tr>
<th>Location</th>
<th>Permit-Required</th>
<th>Alternate Procedure</th>
<th>Location</th>
<th>Permit-Required</th>
<th>Alternate Procedure</th>
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<td>Valve Pit</td>
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<td>Flow Meter Pit</td>
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<td>Dry Well</td>
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<td>Comminutor Deck</td>
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<td>Valve Pit</td>
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<td>Civic Center North</td>
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<td>Pond Diverson Gate Boxes</td>
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<td>Wet Well</td>
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<td>Pond Influent/Effluent Boxes</td>
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<td>Valve Pit</td>
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<td>Sludge Ponds (3)</td>
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<td>Marin Lagoon (9)</td>
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<td>All Manholes</td>
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<td>SPECIAL ENTRY PROCEDURES (SP)</td>
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<td>1. Test atmospheric conditions</td>
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<td>4. If any other hazardous condition exists, follow permit-required confined space procedures.</td>
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DUTIES OF ENTRY TEAM

A permit-required confined space entry team will include an entry supervisor, entrant(s), and at least one attendant. Before an employee begins confined space work, the work must be authorized by the District Manager or Plant Superintendent. In the absence of the District Manager and Plant Superintendent, the designated employee-in-charge may authorize the work.

As long as each individual can fully perform his/her duties, an entry supervisor may be the same person as the entrant or the attendant. The safety precautions that should be taken with a permit-required confined space entry will vary depending on the types of hazards or potential hazards involved. Regardless of the types of hazards, it is the District's policy that in addition to an attendant, a standby rescuer must be part of the entry team.

Duties of Entry Supervisor

1. Verifies that acceptable entry conditions exist.
2. Ensures acceptable entry conditions are maintained.
3. Verifies that the information and procedures on the entry permit are accurate and complete.
4. Verifies that the equipment specified on the permit is in place and in good condition.
5. Reviews permit conditions and procedures with entrants and attendants.
6. Ensures unauthorized persons do not enter the space.
7. Signs the permit to authorize entry.
8. Cancels and files permit.

Duties of Entrant

1. Properly uses the safety equipment and tools supplied.
2. Promptly notifies the attendant if any prohibited condition exists or any warning signs or symptoms appear.
3. Quickly evacuates space if an order is given by the attendant or entry supervisor, if any prohibited condition is detected, or if an alarm is activated.
4. Maintains communication with the attendant to enable attendant to monitor status of space conditions and the entrants.
5. Adheres to the procedures and precautions indicated on the permit and provided in training.

Duties of Attendant

1. Remains outside the permit space until relieved by another attendant.
2. Maintains communication with entrants.
4. Monitors activities inside and outside the space.
5. Orders entrants to evacuate if a prohibited condition exists, or behavioral effects of hazardous exposure are detected, or activities outside space could endanger entrants, or attendant cannot effectively perform all required duties.
6. Ensures unauthorized persons stay away from the space.
7. Performs non-entry rescue procedures or initiates on-site rescue operations.
8. Summons additional rescue services, when needed.

ENTRY PROCEDURES

Pre-Entry

1. Notify other work groups or employees who may be affected by any interruption in service.
2. Determine (by entry supervisor or other qualified person) what hazards or potential hazards are within the confined space.
3. Check that all safety equipment is available and in good working condition.
4. Check that atmosphere monitoring equipment has been calibrated as recommended by manufacturer.
5. Without entering space:
   a) Test atmosphere and record readings on permit.
      
      Acceptable atmospheric conditions: Oxygen not less than 19.5% or more than 23.5%, LEL/LFL not more than 10%, H2S not more than 10 ppm, CO not more than 25 ppm.
   b) Ventilate the space or check that ventilation system is operating properly.
6. Ensure that all affected employees observe pre-entry atmospheric testing.
7. Set up barrier around entrance to prevent accidental falls and to protect employees from vehicles, or falling objects.
8. Check for physical hazards such as poor footing, structures and equipment that hinder movement, and extreme temperatures or humidity that could affect worker safety.
9. Secure and lock out all energy sources (electrical, mechanical, hydraulic, pneumatic, chemical) that are potentially hazardous to confined space workers. Follow lockout/tagout procedures.
10. Disconnect, blind, or block lines to prevent development of hazardous conditions.
11. Use continuous forced air ventilation. Ensure that there is no recirculation of exhausted air from blowers or the introduction of contaminants from the outside, such as traffic exhaust, or vapors or toxic substances from other areas. Place blowers at least 10 feet away from opening of space.
12. Entry supervisor reviews and authorizes entry permit if the space is safe to enter, and all preparatory steps required for safe entry have been taken.

Entry

1. Only employees who have been trained on LGVSD's confined space entry and work procedures are allowed to work in or around confined spaces.
2. Only the work activity specified on the authorized permit is to be performed in the confined space.
3. At least one attendant is required for confined space work.
4. If at any time during the performance of confined space work, dangerous atmospheric conditions develop, work must stop and the space evacuate immediately.
5. An attendant must be stationed outside the space at all times during the confined space operations and remain in constant communication with workers in the space.

6. The attendant must order evacuation of the space whenever:
   a) A condition not allowed on the permit is observed
   b) Unusual behavior is observed
   c) An outside situation endangers the confined space workers
   d) The attendant must leave the work station

7. The permit must be cancelled if the air becomes hazardous after entry.

8. Respiratory equipment must be worn whenever a safe atmosphere cannot be assured after implementing pre-entry procedures.

Post-Entry

The entry supervisor:

1. Cancels the permit by entering date and time of cancellation and signature.
2. On the reverse side of the permit, makes note of any problems encountered during entry operations.
3. Places the cancelled permit in the safety files.
4. Notifies the Plant Superintendent if any equipment, safety gear or tools need to be repaired or replaced.

RESCUE PROCEDURES

It is the District's policy that all employees who work in or in connection with confined spaces must be trained in rescue procedures. Members of a permit space entry team must be knowledgeable of the hazards or potential hazards, be able to recognize the signs and symptoms of exposure, be trained in the selection and use of personal protective equipment, and be certified in first-aid and cardiopulmonary resuscitation. Prior to each entry the team will plan and prepare for non-entry and entry rescues and ensure that at least one standby is immediately available to provide rescue services.

Self-Rescue

If possible, entrants should immediately leave the confined space:

1. When an alarm sounds.
2. At the first sign of any exposure symptoms.
3. When ordered to evacuate by attendant or entry supervisor.

Non-Entry Rescue

If entrants cannot immediately evacuate the space at the first sign of trouble, the attendant should attempt a non-entry rescue by retrieving the entrant using a harness and hoisting equipment. The
attendant must not enter the space unless relieved by another attendant. Retrieval systems must be used in vertical permit spaces more than 5 feet deep.

**Entry Rescue**

Rescuers are to assume that a hazardous atmosphere exists if an entrant has slurred speech, appears dizzy, disoriented, confused, unconscious, or displays any unusual behavior, or if communication with the entrant is lost. A self-contained breathing apparatus must be worn for entry rescues if a hazardous atmosphere is suspected or if there is any chance that it can develop. Call 911 for assistance or if specialized equipment is needed to remove a worker.

**Outside Rescue Services**

Although outside rescue services may be present at the time of the entry or summoned to give assistance and support in an emergency, members of the entry team must be prepared to give immediate assistance to any of the entrants who may need it.

**NON-PERMIT CONFINED SPACES**

All confined spaces are considered permit-required until pre-entry procedures demonstrate otherwise. A confined space may be designated a non-permit space, or a permit-required confined space may be reclassified a non-permit space if all hazards have been eliminated. Because atmospheric hazards are controlled with ventilation and not eliminated in spaces, these spaces cannot be classified as non-permit spaces.

**CONTRACTORS**

Contractors and subcontractors who plan to work in LGVSD confined spaces will be given all available information on LGVSD confined space hazards, the permit system, and entry procedures. Contractors are required to use a permit system for entry into LGVSD permit-required confined spaces. Contractors are also required to coordinate work and entry activities whenever LGVSD employees and contractor employees will be working in or near the permit spaces.

At the conclusion of the contractor's work, the LGVSD supervisor in charge will debrief the contractor to determine if any hazards were encountered or created during entry.

**TRAINING**

All employees who work in or around confined spaces must be trained before performing any confined space work. At a minimum, the training will include:
1. Hazards of confined spaces.
2. Signs and symptoms of hazard exposure.
3. Duties of entrant, attendant, and entry supervisor.
4. Pre-entry and entry procedures.
5. LGVSD confined space permit system.
6. Selection and use of personal protective equipment.
7. Atmosphere test equipment.
8. Rescue procedures and equipment.
9. First Aid.

In addition, employees involved in confined space work will participate in simulated rescue operations at least once per year. Review training will be provided whenever the need is indicated, such as changes in procedures, introduction of new equipment, the hiring of new employees or whenever deficiencies in implementing the program are observed.

Training records will be maintained which will include names and signatures of trainees and trainers, dates and content of training. These records will be made available for inspection to employees or their representatives.
**LGVSD CONFINED SPACE ENTRY PERMIT**

Date issued: ________________ Permit Expiration Date/Time: ______________________

Location/Description of Space: _____________________________________________________

Reason for Entry: ________________________________________________________________

**Work Site Permit:**

Authorized entry permit and monitoring data must remain at the work site until the job is complete.

**IN CASE OF EMERGENCY**

CALL 911

Entry Supervisor: ________________________________________________________________

Authorized Attendants and Initials ___________________________________________________________________________________________

Authorized Entrant and Initials __________________________________________________________________________________________

Note: Indicate which attendant is assigned standby rescue duties. Initial of attendants and entrants indicate they understand their assignments, responsibilities and duties.

### Pre-Entry Checks (complete before obtaining work authorization):

- [ ] Notified other work groups.
- [ ] Notified office personnel.
- [ ] Checked that entry team training is current.
- [ ] Reviewed entry procedures with team.
- [ ] Set up barrier at entrance to space.
- [ ] Checked that gas detection equipment calibration is current.
- [ ] Performed pre-entry atmosphere tests.
- [ ] Checked ventilation system.
- [ ] Checked for physical hazards.
- [ ] Secured and locked out energy sources.
- [ ] Blocked or disconnected lines.
- [ ] Discussed potential hazards with team.
- [ ] Reviewed emergency response procedures.
- [ ] Obtained work authorization signatures.

### Potential Hazards:

- [ ] Oxygen deficiency
- [ ] Oxygen enrichment
- [ ] Flammable gases or vapors
- [ ] Toxic gases or vapors
- [ ] Mechanical hazards
- [ ] Electrical hazards
- [ ] Engulfment/entrapment
- [ ] Noise
- [ ] Heat/Cold
- [ ] Falls
- [ ] Falling objects
- [ ] Other

### Safety Equipment:

- [ ] Gas detection equipment w/spare batteries
- [ ] Safety harness
- [ ] Safety line
- [ ] Wristlets
- [ ] Hoisting equipment
- [ ] Manhole hook
- [ ] Barricades, cones, tape
- [ ] Portable blower and hose
- [ ] Explosion-proof lighting
- [ ] Non-sparking tools
- [ ] Tool bucket and line
- [ ] Ladder
- [ ] First aid kit
- [ ] Fire extinguisher
- [ ] Radio communication equipment
- [ ] Cell phone
- [ ] SCBA
- [ ] Hard hat
- [ ] Goggles, face shield
- [ ] Gloves
- [ ] Rain suit
- [ ] Rubber boots
- [ ] Other ____________________________

### Hot Work:

Does the entry involve hot work?   [ ] Yes   [ ] No  If Yes, complete and attached a hot work permit.

### Special Instructions:

____________________________________________________________________________________

____________________________________________________________________________________

### Street Address:

____________________________________________________________________________________

**Monitoring Data:** Record monitoring data at 15-minute intervals on the reverse side of this permit.

**Acceptable Atmospheric Conditions:**

- Oxygen not less than 19.5% or more than 23.5%, LEL/LFL/not more than 10%, H₂S not more than 10 ppm.

### Work Authorization Signatures

All confined space work must be authorized by the General Manager, Plant Manager or Collection Crew Manager

Work authorized by: ________________________________________________________________

Date/Time: ___________________________

### Entry Authorization

I certify that the confined space work authorized by this permit has been reviewed with the entry team and that acceptable entry conditions exist and the necessary equipment for safe entry has been provided.

Entrant signature: ________________________________________________________________

### Permit Cancellation

Date: ____________________________

Time: ____________________________

Entry supervisor signature: ____________________________
**LGVSD HOT WORK PERMIT**

This form is to be filled out by employee before performing hot work.

Name: _______________________________________________________________________________________________

Date: __________________ Time: ______________ Location of job: ________________________________

Detailed description of job: ________________________________________________________________

___________________________________________________________________________________________

___________________________________________________________________________________________

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<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
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<tbody>
<tr>
<td>1.  If the job is planned to be done indoors, can it be done outdoors or in the welding shop?</td>
<td>□</td>
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<tr>
<td>If yes, move to one of these locations.</td>
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<td>2.  have all combustible materials (solids, liquids, gases) been removed from the work area?</td>
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<tr>
<td>3.  Are there any gas lines or other lines carrying combustible/flammable materials?</td>
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<td>4.  If yes, have all lines be disconnected, blanked or otherwise protected?</td>
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<td>5.  Has atmospheric test data been collected in the work area?</td>
<td>□</td>
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<tr>
<td>6.  Is a fire watch needed for this job?</td>
<td>□</td>
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<td>7.  Is a fire extinguisher or water hose available and ready to use at the job site?</td>
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<td>8.  Can flame or sparks ignite materials in work area or on lower floors or levels?</td>
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<td>9.  Are non-flammable tarps used to cover combustibles in the work area?</td>
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<td>10. Have affected employees reviewed or given specific safety instructions?</td>
<td>□</td>
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<tr>
<td>11. Have screens been set up in the work area?</td>
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Special precautions to be taken: ________________________________________________________________

___________________________________________________________________________________________

I have reviewed and approved this permit: ______________________________________________________

Date: __________________ Time: __________________

________________________________________________

Signature of District Manager

Please make note of any actions taken based on the above responses.
The undersigned acknowledges receipt of and has read and fully understands these District Confined Space Entry Requirements.

**CONTRACTOR/CONSULTANT**

Signed: ____________________________

Name: ____________________________

Title: ____________________________

Date: ____________________________