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ESTCP
ENVIRONMENTAL SECURITY TECHNOLOGY CERTIFICATION PROGRAM

DEMONSTRATION PLAN

Demonstration and Verification of a Turbine Power Generation System Utilizing Renewable Fuel: Landfill Gas

SERDP/ESTCP Project #EW-200823
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REVIEW NOTICE

This report has been peer and administratively reviewed by Southern Research Institute, the U.S. Environmental Protection Agency and the U.S. Department of Defense ESTCP program, and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Greenhouse Gas Technology Center

A U.S. EPA Sponsored Environmental Technology Verification Organization

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This Demonstration/Test and Quality Assurance Plan has been reviewed and approved by the Greenhouse Gas Technology Center Project Manager, Quality Assurance Manager and Center Director; the U.S. Department of Defense ESTCP EW Program Manager; and the U.S. EPA APPCD Project Officer and Quality Assurance Manager. Work was funded under ESTCP Project EW2008-23.

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List of Acronyms

Acronym	*Definition*
ADQ	Audit of data quality
BTU	British thermal units (energy, usually thermal or chemical)
BTU/h	British thermal units per hour (rate of energy transfer or use)
CARB	California Air Resource Board
CO	Carbon Monoxide
CO_2, CO_{2e}	Carbon Dioxide, Carbon Dioxide Equivalent
CT	Current Transformer
DoD	United States Department of Defense
DQO	Data Quality Objective
DRE	Destruction Removal Efficiency
ECAM	Environmental Cost Analysis Methodology
EPA	U.S. Environmental Protection Agency
ESTCP	U.S. Department of Defense Environmental & Security Technology Certification Program
ETV	Environmental Technology Verification program
GA EPD	Georgia Environmental Protection Department
LFG	Landfill Gas
LMOP	Landfill Methane Outreach Program (USEPA)
MQO	Measurement Quality Objective
NESHAP	National Emissions Standard for Hazardous Air Pollutants
NIST	National Institute of Standards and Technology
NMOC	Non-methane organic carbon
NO_x	Oxides of Nitrogen
PM 10	particulate matter with an aerodynamic diameter up to 10 µm
PM 2.5	particulate matter with an aerodynamic diameter up to 2.5 µm
QA/QC	Quality Assurance / Quality Control
SUT	System Under Test
THC	Total Hydrocarbons
TOC	Total Organic Carbon
TRS	Total Reduced Sulfur
USEPA	Environmental Protection Agency
VOC	Volatile Organic Compound
USACE	U.S. Army Corps of Engineers
scf	Standard Cubic Feet
psi	Pounds per Square Inch
ppm	Parts per Million
APB	Air Pollution Board
MSW	Municipal Solid Waste
eGRID	Emissions & Generation Resource Integrated Database
scfm	Standard Cubic Feet per Minute

MOA	Memorandum of Agreement
ASERTTI	Association of State Energy Research and Technology Transfer Institutions
NPT	National Pipe Thread
QMP	Quaity Management Plan
QAM	Quality Assurance Manager
ECAM	Environmental Cost Analysis Methodology
BLCC	Building Life-Cycle Cost
IRR	Internal Rate of Return
OMB	Office of Management and Budget

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This plan will appear both as a Demonstration Plan under DoD ESTCP -Project 200823 and as a Test and Quality Assurance Plan document SRI/USEPA-GHG-QAP-50 under the U.S. EPA ETV program.

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1.0 INTRODUCTION

1.1 Background

The U.S. Department of Defense (DoD) occupies over 620,000 buildings at more than 400 installations in the U.S, spending over $2.5 billion on energy consumption annually. Reductions in energy consumption from these facilities and utilization of renewable energy sources has become a primary goal of the DoD for several reasons: (1) to reduce emissions and environmental impacts related to power production and consumption in response to air pollution and climate change issues; (2) to reduce costs associated with energy consumption, resulting in additional resources aimed at the DoD primary mission; and (3) to improve energy security, flexibility, and independence. More recently, these priorities have been re-enforced through the release of Executive Order 13423, Strengthening Federal Energy, Environmental and Transportation Management [1].

A potential resource for the production of renewable energy on-site – a secure and efficient process – is landfill gas from DoD owned landfills at domestic bases. As part of this project, Southern identified and collected data from 471 landfills operated within DoD. Landfills produce waste gas streams containing methane that is often vented to the atmosphere or destroyed via a flare. In addition, various other waste gas streams may exist at DoD sites as well (i.e., remediation systems, industrial processes, etc.). Destruction of these waste streams is often energy intensive, and results in significant emissions and generation of waste heat. Alternative solutions that reduce energy consumption at these sites and reduce the environmental impacts are desirable.

Southern has identified the FlexEnergy Powerstation™ 200 system as a technology that utilizes landfill or other very low quality waste fuels to provide efficient on-site power production. The system is potentially applicable to a variety of DoD sites, including landfills, facilities with anaerobic digesters for wastewater treatment, painting or printing operations, VOC remediation systems, as well as typical fossil fuel applications.

The FlexEnergy Powerstation™ utilizes, at its core, a conventional 250kW micro-turbine of proven design with many years of field operation. The modification made by FlexEnergy replaces the conventional combustion chamber with a thermal oxidizer, enabling the system to operate with very low heating value fuels.

Using this technology, the productive life of energy recovery systems at landfills may be substantially extended, as the quality of gas tapers off below the operating threshold of other typical technologies utilized in this application. In addition, the thermal oxidizer approach promises a higher destruction efficiency of Volatile Organic Compounds (VOCs) and other pollutants. The use of the oxidizer may also allow for simpler, less rigorous gas cleaning prior to use than other conventional systems.

1.2 Objective Of The Demonstration

The objective of this demonstration is to provide a credible, independent, third party evaluation of the performance and economics of the FlexEnergy technology in a landfill gas (LFG) energy recovery application. This evaluation will provide sufficient data to allow end-users, purchasers, and others to determine impacts of the technology and their applicability across DoD sites and other applications.

Success factors to be validated during this test include energy production and quality, emissions and emission reductions compared to existing systems, economics, and operability, including reliability and availability.

1.3 Drivers

Energy security, environmental sustainability, and long-term savings are all drivers for the subject technology.

On October 5, 2009 President Obama issued Executive Order 13514 [3] titled "Federal Leadership in Environmental, Energy and Economic Performance". Among other things, this Order challenges Federal agencies to increase energy efficiency, reduce direct and indirect greenhouse gas emissions and prevent pollution. Executive Order 13423, signed January 24, 2007, also directs Federal agencies to increase use of renewable energy. The Energy Independence and Security Act of 2007 also emphasizes the development and use of renewable energy. The Energy Policy Act (EPAct) of 2005 seeks to promote innovative technologies that avoid greenhouse gases, including renewable energy technologies.

The utilization of the Flex Powerstation™ using landfill gas has potential impacts in all of these areas by:

- Using a renewable fuel resource (landfill gas);
- Improving energy efficiency by reducing energy consumption associated with flare use, transmission losses, etc.;
- Reducing greenhouse gas emissions by producing electricity from gas that was formerly not utilized and combusted in the flare.

2.0 TECHNOLOGY DESCRIPTION

2.1 Technology Overview

FlexEnergy has developed the Flex Powerstation™ (Flex), a unique power plant that generates electricity from extremely low energy content gas. The Flex uses a proprietary thermal oxidizer system in place of the turbine's combustor to oxidize and destroy hydrocarbons in the waste fuel stream. The oxidizer allows the Flex to operate using fuel gas or vapor that is below the typical requirements for combustion by diluting methane gas to 15 BTU/scf or 1.5% methane. The Flex uses conventional, 'off-the-shelf' gas turbine/generator technology with a long history of reliable operation (Ingersoll Rand MT250 series microturbine).

For over ten years, FlexEnergy pursued the development of a power plant that could operate on a wide variety of low quality fuels. Research was supported by government grants from the Department of Energy, the National Renewable Energy Laboratory, California Energy Council, and other agencies. In 2002 FlexEnergy received a U.S. patent for a "Method for Collection and Use of Low Level Methane Emissions".

The original Flex was a catalytic combustor coupled with a 30 kW micro-turbine. Experience with the catalytic Flex led to the use of a non-catalytic thermal oxidizer. The catalytic combustor life was severely reduced by contaminants in the waste gas streams of interest. Thermal oxidizers are a proven solution to many of the problematic gases. Redesigning the Flex for the more robust and forgiving thermal oxidizer technology largely eliminates the need for fuel cleanup.

During normal operation, the fuel gas (or vapor) is diluted with ambient air to 15 BTU/scf and injected into the turbine's compressor. The compressed air/fuel mixture (~60 psi) is then preheated and enters the thermal oxidizer where it is heated further and contaminants are destroyed. Hot gas from the thermal oxidizer powers the turbine, which turns the generator, producing electric power. Exhaust gas from the turbine is used to preheat the air/fuel mixture entering the oxidizer.

During startup, the oxidizer must be preheated and the turbine brought to operating conditions before the system can operate in steady state 'Flex' mode. For this purpose, a startup system is provided consisting of supplemental fuel, a gas compressor, and combustors at the oxidizer inlet and outlet. Table 1 summarizes the operating states for the Flex and auxiliary systems (startup and blower skids). Figure 1 provides an overall schematic flow diagram for the Flex.

Table 1. Flex Operating States

	Start Initiation	Warm Up	Transition	Flex Mode	Continuous Operation
Gas Turbine Speed	low & ramping	ramping to full	full	full	full
Generator Output	no output	zero to ramping output	ramping to full output	full output	full output
Start Skid	on	on	on ramping to off	off	off
Blower Skid	off	off	off ramping to on	on	on

A prototype Flex oxidizer system was assembled in October, 2008, with the first successful system operation on 1.5% methane accomplished after 10 months of development testing. The prototype system re-packaging into the pilot field system was started in November, 2009. The pilot system was delivered to Lamb Canyon Landfill in Beaumont, California, in late May, 2010, and was successfully operated on landfill gas in June, 2010. As of September, 2010, the Flex had accumulated over 480 hours of operation on landfill gas. The pilot plant has also demonstrated the ability of the oxidizer-based system to continue operation during intermittent fuel supply interruptions. The pilot plant operation continues at Lamb Canyon Landfill for engineering control development and integration with the day to day operation at a landfill.

The Flex Powerstation™ is capable of utilizing other waste streams as the fuel input, such as paint booth or other VOC-laden industrial process exhausts, off-spec fuels, waste solvents, and other low BTU wastes. Demonstration of the operation of the turbine on other waste streams will be addressed in a second Flex Powerstation™ installation (to be determined). The present demonstration addresses landfill gas applications only.

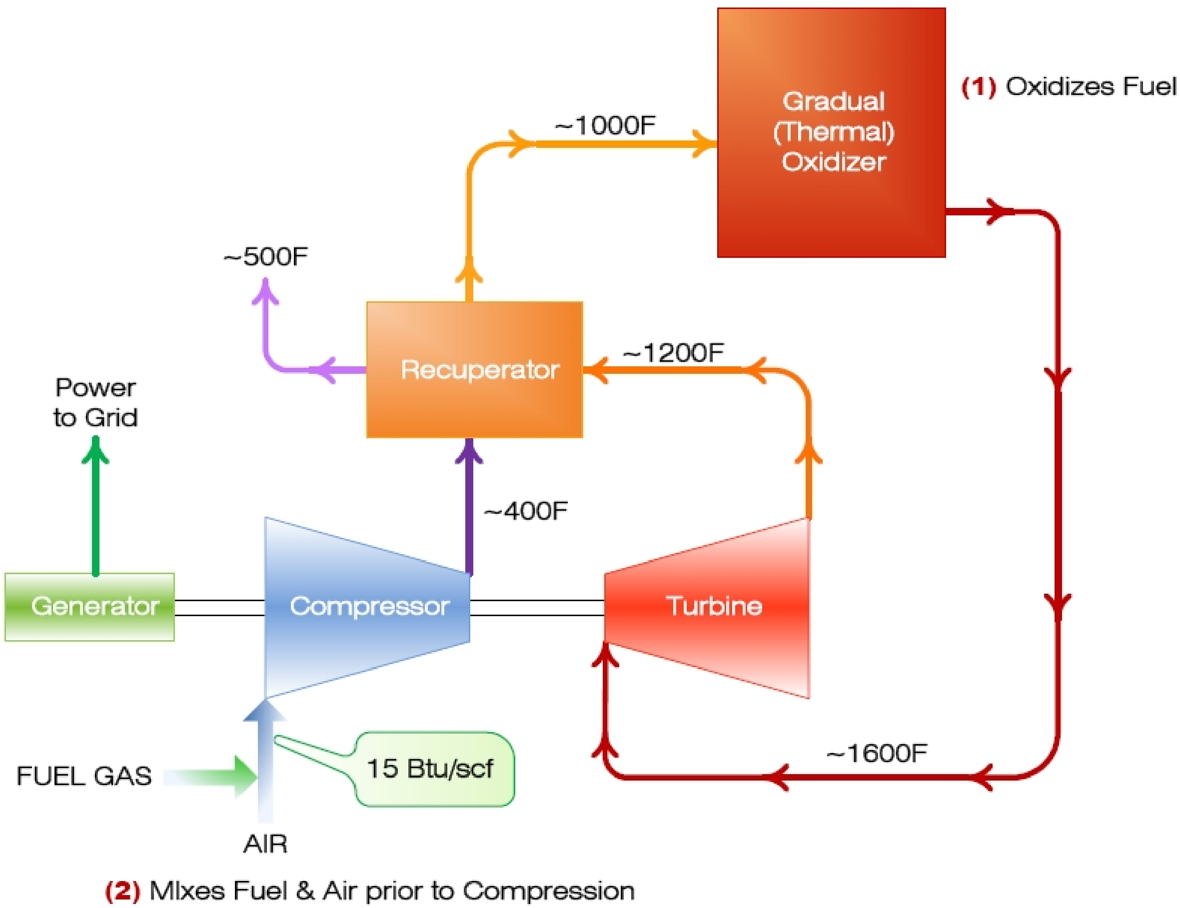


Figure 1. Flex Schematic

2.2 Advantages and Limitations of the Technology

The chief advantage of the Flex technology is the ability to utilize very low BTU fuel sources to provide electrical energy and heat. Since these low value fuel sources are often waste streams, a related advantage is reducing costs associated with treatment of these wastes and realizing offsets of energy and emissions associated with waste treatment. Because of the ability to utilize low-BTU gas, the energy generating potential of a landfill can be extended well beyond the period when methane concentrations are high enough to support combustion (typically limited to approximately 350 BTU/scf). This process also eliminated the need for a separate fuel compressor, as the blended low-BTU fuel-air mixture can be compressed by the turbine's integrated compressor.

Thermal oxidation is an effective means of destroying non-methane organic carbon compounds (NMOC) and other organic pollutants. As a result, Flex emissions are expected to be as good as or lower than alternate LFG destruction/utilization technologies. In addition, the oxidizer prevents NO_x formation, a significant advantage, while fully destroying CO and VOCs.

For LFG applications, the Flex does not require a complex gas cleanup system – often a significant issue, as particulates formed from siloxane oxidation are trapped within the oxidizer and other potential pollutants are oxidized in the system.

The 250kW Flex system should have wide applicability, as a single unit can be used with fuel sources as small as 3 million BTU/hr and multiple units can utilize larger sources. Since the unit is fuel flexible and adapts to fuel concentration, it can also be utilized with somewhat variable fuel sources.

The chief limitation of the Flex system is that it is as yet unproven in its many potential applications beyond energy recovery from landfill gas, and has only been shown in limited demonstration. Achievement of all power production goals, emission goals, and equipment reliability, as well as system economics, has not been fully demonstrated beyond the current pilot facility. In addition, in the current Flex design, the fuel source is diluted with air to 15 BTU/scf heat content and injected directly into the turbine's compressor. Some potential fuel sources may require gas cleaning, cooling, or other pretreatment to avoid excessive compressor maintenance.

3.0 PERFORMANCE OBJECTIVES

The performance objectives for the demonstration system relate to the environmental, economic and operational impacts of the Flex system compared with baseline conditions at the test site. The baseline consists of operation of the host landfill with the existing landfill gas extraction and open flare destruction system.

The system under test (SUT) includes the Flex system (oxidizer and turbine) and associated support equipment (i.e., LFG blower and system startup components) and excludes the existing LFG extraction and open flare destruction system.

Data requirements and success criteria for the primary objectives for this demonstration are given in Table 2 with details provided in the remainder of this section.

Table 2: Performance Objectives

Objective	Metric	Data Requirements	Success Criteria
3.1 Energy: Verify power production & quality.	Net real power delivered (kWh); frequency (Hz), power factor (%); total harmonic distortion (THD)	Long term, continuous monitoring of generator power output and parasitic loads. Short term verification of power quality parameters.	Nominal 200kW gross continuous (1750 MWh/yr) less de-rating depending on ambient conditions (to be established). Power quality meets utility inter-connection requirements.
3.2 Emissions: Verify emissions meet regulatory requirements and are lower than best alternate LFG emissions control technology.	lb/hr, lb/MWh or ppm emitted	Emissions measurements of CO_2, NO_x, SO_2, CO, TRS, PM (2.5 and 10), THC and methane (thus NMOC).	Emissions meet or exceed CARB 2013 requirements for distributed generation and host site air permit requirements. Emissions are lower than EPA AP-42 typical values for best alternate LFG control technology (boiler/steam turbine).
3.3 Emissions: Verify NMOC destruction efficiency	Percent destruction efficiency for NMOC.	Field emissions measurements at recuperator exhaust and analysis of LFG samples at Flex inlet.	NMOC Destruction efficiency exceeds 98 percent and meets or exceeds the EPA AP42 typical destruction efficiency for Boiler/Steam Turbine (98.6%).
3.4 Emissions: Verify greenhouse gas emissions reductions.	Metric tons CO_2e/yr reduction relative to site specific baseline conditions.	Power generation offsets based on local utility emission factors.	Greater than 800 metric tons CO_2e avoided emissions due to power generation (above baseline). Greater than 8000 metric tons CO_2e reduction due to destruction of CH_4. Greater than 10% increase in GHG reduction compared to flare only.
3.5 Assess economic performance	Simple payback (years), NPV ($)	Capital and operating/ maintenance costs. Revenue based on electric energy production offset, including renewable power cost increment.	Simple payback < 5 years; Positive NPV.
3.6 Determine system availability/reliability and operating impacts.	Percent availability/reliability, plus descriptive narrative of installation, operation, maintenance requirements.	Daily log of normal operations, scheduled and unscheduled downtime, problems and causes/responses. Documentation of system installation requirements (permits and approvals, etc.) and operational requirements (staffing).	Availability exceeds 95%. Reliability exceeds 97%. Operability is acceptable.

3.1 Power Production and Quality

Demonstrating Flex power production is a key component of this demonstration in order to verify that the Flex meets target power output specifications and because project revenues and GHG reductions depend largely on the energy recovered. Power quality must be verified to meet utility interconnection requirements.

The Flex Powerstation's™ electrical efficiency and an estimate of potential heat recovery will also be determined as part of this demonstration. These determinations are not considered formal performance objectives and do not have specific success criteria but are included for informational purposes. The Flex system to be demonstrated here will not utilize heat recovery.

3.1.1 Metric and Data Requirements

The power production metric is net real power delivered (kWh). Net power output is gross output less continuous (blower and controls) and intermittent (startup) parasitic loads. Net power production will be monitored continuously throughout the one year demonstration period to allow for determination of the total integrated power output over the full year of demonstrated operation and provide for determination of seasonal de-rating factors.

Gross and net power output will be monitored by separately metering gross power output and parasitic loads. All parasitic loads will be aggregated together and measured at a single bus. Bidirectional power will also be monitored at the utility interconnect, a meter provided by Flex and the local utility, Flint Energies. The monitored gross power output less net monitored power should match the bidirectional meter data at the interconnection.

The power quality metrics are voltage (V), current (A), frequency (Hz), power factor (%), and total harmonic distortion (THD). Power quality will be verified at the point of interconnection during system commissioning.

The data requirements for electrical efficiency include net power output and heat input. Heat input (BTU/hr) will be determined from LFG flow and methane concentration measurements at the Flex inlet. These parameters will be monitored continuously during the one year demonstration period. Electrical efficiency is expected to be approximately 22% or 15000 BTU/kWh (based on turbine manufacturer specifications).

To estimate heat recovery potential, exhaust gas temperature and mass flow will be measured during the intensive monitoring period. The potential heat recovery estimate will be based on characteristic specifications for heat recovery systems frequently installed with micro-turbines. Preliminary estimates show the heat recovery potential to be over 1 million BTU/hr.

3.1.2 Success Criteria

The target power output for the Flex 250 unit is 200kW (maximum 210 kW) at 60 degrees F and allowing for ambient condition dependent de-rating. Output will decrease at higher temperatures or lower pressures and increase at lower temperatures due to the effect of inlet gas temperature on turbine performance. The annual average ambient temperature for the Ft. Benning demonstration site is 64 degrees F [19].

The power quality must meet or exceed the requirements of the local utility (Flint Energy) for interconnection. The power output specifications for the Flex turbine are 3 phase, 480VAC, 60 Hz, 4 wire wye, 300 amps nominal (250 kW). As this type of turbine has been installed in many other utility interconnection applications, the output will meet Flint Energy's requirements without modification.

3.2 Emissions

Low air pollutant emissions (primarily NO_x, CO and NMOC) are a key performance claim for the Flex technology, and verification of low emissions is, therefore, a key component of the demonstration. The overall goal is to demonstrate that Flex emissions are likely to meet the potentially applicable emission standards, and, particularly, any emissions limits that may be set for operations at the Ft. Benning test site.

Air permitting for the Ft. Benning Flex demonstration will be handled as an 'off-permit request' as the GA EPD Air Pollution Branch (APB) does not consider the Flex to be a significant source and is not subject to NSPS requirements. Documents have been submitted to the APB describing the technology and Ft. Benning installation, estimating potential to emit and documenting compliance testing at the Lamb Canyon demonstration site.

3.2.1 Metric and Data Requirements

Emissions standards or limits are stated in various units/activity factors in regulations; for example, ppm, lb/hr, lb/MWhr, lb/MMscf LFG, lb/MMscf methane. During the emissions test, sufficient data will be collected to report emissions in any of these terms.

While it is anticipated that emissions limits will be imposed only for NO_x, CO and NMOC, other pollutants are of interest, and Southern plans to conduct emissions testing for CO_2, NO_x, SO_2, CO, TRS, PM (2.5 and 10), THC and methane (thus NMOC).

The emissions test will take place during the intensive monitoring period after the Flex has been operational for at least 1000 hours. The emissions test will be treated as a compliance test requiring three sampling/analysis runs of one hour each according to EPA reference methods (see section 5 for more detailed information).

3.2.2 Success Criteria

As the Flex is a unique modification of conventional gas turbine technology, it is not clear whether existing standards for gas turbines may be applied by local permitting authorities. Southern conducted a review of emissions standards that may be applicable to Flex systems installed in the United States. This included:

- California Air Resources Board (CARB) standards for distributed generation [1],
- South Coast Air Quality Management District (SCAQMD) permit for the ongoing 100kW Flex demonstration project [2]
- Typical SCAQMD permitting levels (as reported by Flex)
- Georgia Environmental Protection Division standards for gas turbines [3]
- US EPA New Source Performance Standards for gas turbines utilizing landfill gas [4]
- EPA AP-42 typical emissions for best LFG control technology (2008 draft update) [5]

Emissions limits from these standards were converted to a common lb/hr basis for the Flex 200kW unit (using nominal exhaust flow and fuel efficiency) and compared. The CARB 2013 standards were found to be the most stringent. The CARB standards apply to any distributed generation unit operated in California. For the purpose of this demonstration, the CARB standards are used as the success criteria for emissions. For the Flex 200kW unit, the CARB 2013 standards are the following:

- NO_x = 0.014 lb/hr,
- CO = 0.02 lb/hr,
- NMOC = 0.004 lb/hr.

Meeting the CARB standards will also meet EPA AP-42 typical emissions for best alternate control technologies (enclosed flare or boiler/steam turbine, depending on pollutant). In addition, AP-42 gives typical emission factors for total PM for LFG emissions control devices. For the Flex 200 unit, this amounts to an emission limit of 0.009 lb/hr PM to meet AP-42's best alternate LFG control technology (boiler/steam turbine).

The NSPS are the only emissions standards reviewed that provide an emission limit for SO_2. The NSPS standard is 150 ppm (or <8000 ppm total fuel sulfur content). For the Flex 200kW unit, this amounts to an emissions limit of about 4 lb/hr.

3.3 Destruction Efficiency

EPA regulations (NSPS and NESHAP) require a 98 percent NMOC destruction efficiency for landfills over a certain capacity or that may emit over a certain quantity of NMOC. Therefore, verifying the NMOC destruction efficiency of the Flex is an important performance objective for this demonstration.

3.3.1 Metric and Data Requirements

Destruction and removal efficiency (DRE) is determined by comparing the mass flow rate of a pollutant at the inlet and outlet of a control device. The DRE is given by the difference between the inlet and outlet mass flows divided by the inlet mass flow and multiplied by 100 to yield a percentage. During the intensive monitoring period, NMOC mass flows will be determined at the Flex inlet at the same time that NMOC emissions are measured at the Flex exhaust. Three, one-hour determinations will be made.

3.3.2 Success Criteria

The 1996 EPA Standards of Performance for New Stationary Sources (NSPS) and Guidelines for Control of Existing Sources, as well as the 2003 National Emission Standards for Hazardous Air Pollutants (NESHAP), require "large" municipal solid waste (MSW) landfills to collect LFG and combust it to reduce NMOC by 98 percent (or to an outlet concentration of 20 parts per million by volume). A "large" landfill is defined as having a design capacity of at least 2.5 million metric tons and 2.5 million cubic meters and a calculated or measured uncontrolled NMOC emission rate of at least 50 metric tons (megagrams) per year. [6]

The demonstration site landfill has a capacity of roughly 1 million tons, so this landfill is exempt from these standards. However, for the purpose of this demonstration, 98 percent NMOC destruction efficiency is taken as minimum success criteria for the Flex.

EPA AP-42 typical destruction efficiency for an enclosed flare is 97.7% and is 98.6% for a boiler/steam turbine. Therefore, the Flex should also meet or exceed 98.6 percent NMOC DRE.

As part of the test, measurements will also be made that will allow determination of the DRE for methane. The DRE for methane should exceed 99% [7].

3.4 Greenhouse Gas Reductions

One of the key drivers for ESTCP Sustainable Infrastructure Energy & Water Projects is to demonstrate GHG reductions.

The primary GHG reduction for the Flex demonstration is the result of electric utility emissions offset by the power produced by the Flex. There are some other potential GHG reductions attributable to the Flex (see below). These reductions will be considered in the Flex performance assessment. However, the quantitative success criterion is based on Flex power production alone.

The Flex also destroys methane, and this is a much larger GHG reduction. However, methane is also destroyed by the existing candlestick flare at the demonstration site, so any incremental reduction would be due to increased methane destruction efficiency of the Flex over the Flare. This incremental reduction cannot be determined quantitatively, however, since the methane destruction efficiency of a candlestick flare cannot be readily measured. In any case, this is likely to be a very small increment. In EPA's LMOP Landfill Gas to Energy calculator, it is assumed that the methane destruction efficiency for all LFG to energy devices is 100 percent. [8].

Another potential source of GHG reductions or increases attributable to the Flex and compared to the baseline is a reduction in supplementary fuel usage for the existing flare. The flare is supplied with a propane fuel source; however, the propane is used only to maintain the pilot flame and fuel use over time has been insignificant (personal communication from Fred Portofe of J2 engineering, Ft. Benning's flare operation contractor). There is not expected to be any significant change in propane use with the Flex installed.

Finally, there may be net (over baseline) GHG reductions attributable to the Flex resulting from the ability of the Flex to utilize low methane LFG in future years after the LFG heat content falls below the minimum required for flare operation (200 BTU/hr) [9] [40 CFR 60.18 and 63.11] or after LFG extraction and destruction is no longer required to mitigate offsite migration of LFG. Such reductions, however, cannot be quantified with any precision, and are beyond the scope of the one year demonstration period, so will not be accounted for in this demonstration.

3.4.1 Metric and Data Requirements

The GHG reduction metric is metric tons CO_2e reduction per year based on avoided emissions for utility electric power generation for the State of Georgia. Emission factors for carbon dioxide, methane, and nitrous oxide from the most recent eGRID database [10] will be weighted by current EPA accepted global warming potentials (e.g., Table ES-1 in EPA's 2010 GHG Inventory) [11] to arrive at the total combined CO_2e emission factor in metric tons/MWh. Currently, this factor is 0.64 metric tons/MWh.

In addition to the emission factors, the required data are the same net power production measurements for the power production objective (section 3.1).

3.4.2 Success Criteria

Based on current emission factors, the Flex is expected to avoid emissions of 800 metric tons CO_2e per year due to power generation.

More than 8000 metric tons CO_2e emissions are expected to be reduced directly by the Flex through the destruction of methane. The destruction of methane is not a *net* reduction over baseline conditions, since the existing flare also destroys methane.

Accounting for the expected proportion of LFG flow to Flex and the Flare, the additional avoided GHG reductions provided by the Flex amount to about a 10 percent GHG reduction compared to the baseline flare.

These calculations use formulae adapted from EPA's LMOP GHG emissions reductions calculator [8] adjusted for estimated capacity factors specific to Flex and site specific emission factors.

3.5 Economics

To be economically viable, the value of the power produced by the Flex must offset the capital, operating and maintenance costs of the Flex over a reasonable period of time.

3.5.1 Metric and Data Requirements

The metrics used to assess Flex economic performance will be standard indicators of economic performance including the simple payback period and net present value. These indicators are determined from the initial capital and incremental operating and maintenance costs for the SUT, offset by the value of the electric power produced over time with proper accounting for the time value of money.

Capital and operating/maintenance costs will be compiled based on actual and projected expenditures using appropriate discount rates as detailed in Section 7 of this plan.

The cost of installing and operating the existing gas collection and flare system at the Ft. Benning demonstration site will not be included in this analysis as these systems are part of the baseline in this case. However, for sites without a gas collection and flare system, costs for these components may be included. While not part of this demonstration, such costs will be estimated in planned guidance and outreach materials.

3.5.2 Success Criteria

The simple payback period should be less than 5 years with net present value (NPV) greater than zero. Because Flex is a developmental technology, the payback period for the Ft. Benning installation may exceed 5 years. The payback period for a more typical, future commercial installation will be estimated and presented in the final report based on projected capital and annual operating costs.

3.6 Operability

In order to be successful, the Flex system must provide sufficient availability, reliability and ease of use so that the economic value of power production is realized and no undue burden is placed on operations staff.

3.6.1 Metric and Data Requirements

Availability is a quantitative metric that is given as the percentage of time that the system is either operating or capable of operation if down for unrelated reasons (such as power failure or failure of the LFG collection system). The data requirements are power production data logged as described in section 3.1 and operational logs providing details of the causes and circumstances for each period when the Flex is not producing power at expected levels.

Reliability is both a quantitative and qualitative metric that assesses the robustness of the system in terms of likelihood of failure or operational problems, the consequences of such problems, and the ability to recover. Reliability will be assessed quantitatively in accordance with ANSI Standard 762 which uses a specific categorization of operating and downtime hours. Reliability will also be assessed qualitatively based on the operating experience of project participants (including Southern Research, Flex and local operators). Operating experience will be documented with narrative descriptions from Southern Research and Flex and interviews with operating staff at the conclusion of the project.

Ease of use is a qualitative metric that will be based on operating experience during the demonstration period as documented by narratives and interviews with operators and project participants during and at the conclusion of the project. The ease of use assessment will encompass the entire design and installation process, including permitting and other approval requirements. The acceptability of a newly introduced technology is partly dependent on the subjective experience of operations and maintenance personnel. If these personnel require highly specialized training, or intensive permitting and approval processes, the cost of installation, training, and operations increases. Difficulty with system operation can also reduce availability, since when the system fails it is less likely that someone with the correct expertise will be immediately available.

Details for calculating availability and reliability and the required content of operations logs, narratives and interviews are given in section 6.6.

3.6.2 Success Criteria

The Flex system is designed for unattended 24/7 operation and is expected to be available at least 95 percent of the time and achieve a quantitative reliability rating of 97 percent or greater. The system should receive a positive qualitative assessment of overall reliability and ease of use.

4.0 FACILITY/SITE DESCRIPTION

The Flex demonstration will take place at the 1st Division Road landfill at Fort Benning, Georgia.

4.1 Facility/Site Selection

Southern Research previously prepared an inventory of all Department of Defense (DoD) established landfills with information suitable for assessing the usable energy production potential for each site as well as factors that may influence commercial and technical decision-making with respect to recovery of that energy.

As part of this effort, site selection criteria were developed and candidate sites were identified and evaluated for the Flex demonstration.

Because extended productive life of landfill gas power is one of the claims of the technology, it is desirable to demonstrate on a mature, closed landfill. To meet program funding requirements, the site should have an existing gas collection/flare system that is in a good state of repair and may be operated throughout the planned demonstration program period. The gas production level should be expected to be able to support at least one 200 kW FlexEnergy turbine (>3 million BTU/h average rate) for at least five years. Electrical interconnection should be reasonably accessible to the location of the gas collection system and location of the Flex Powerstation™ equipment. The site should be representative of typical target application landfills at DoD bases in terms of age and size.

The 1st Division Road landfill at Ft. Benning meets all of these criteria. Fort Benning indicated immediate interest in participation when first contacted in 2007 and has consistently backed up this interest by providing supporting data and documentation promptly as and when requested. On-site meetings have taken place with the following:

- Anna Butler, USACE, Savanah District, Technical Manager (project champion)
- Dorinda Morpeth, USACE, Environmental Program Manager, Solid Waste & Recycling (on-site Ft. Benning)
- Tannis Danley, USACE Environmental (on-site Ft. Benning)
- John Brendt, Chief of Environmental Division, Ft. Benning
- Vernon Duck, Energy Manager, Ft. Benning
- Benny Hines, Public Works Manager, Ft. Benning

All have indicated a high degree of support for the project.

4.2 Facility/Site Location, Operations and Conditions

The 1st Division Road Landfill is located on Ft. Benning grounds near the intersection of 1st Division Road and US highway 27/280 (see Figure 2). The landfill contains approximately 48 acres of fill material at an average depth of 30 feet (approximately 2.3 million cu yd). The landfill is unlined, and capped with a geosynthetic clay liner with at least 24 inches of drainage material and six inches of vegetative cover. Based on the waste acceptance rate and the volume of the landfilled waste, the landfill is estimated to contain approximately 1 million tons of total waste.

The landfill accepted municipal solid waste and construction/demolition debris for more than 12 years starting in 1985 until closure in 1998. The waste acceptance rate was approximately 175 tons per day. In 1993, three methane and ten groundwater monitoring wells were installed along the western property boundary. Methane levels exceeding the lower explosive limit were detected in the wells. In 1996, seven additional methane and eight additional groundwater monitoring wells were installed. In 1998, 39 passive landfill gas vent wells were installed in compliance with the Georgia DNR approved closure plan. In 1999, three additional methane monitoring wells were installed off-site to the west of the landfill due to elevated methane detected at the landfill boundary.

In 2003, landfill gas generation rates were quantified based on vent performance tests. Based on this, the landfill was estimated to be capable of producing 700 scfm of landfill gas at 40 to 50 percent methane from 2005 through 2020-2025. Up to 40 percent of the total landfill gas generated was estimated to be escaping through westward migrating gas. [12]

In 2004, 18 of the 39 passive vent wells were converted to an active extraction system and an open ‘candlestick’ flare system was installed to safely destroy the collected gas (figure 3). This measure was intended to mitigate problems with westward migration of the gas offsite.

In 2008, the gas extraction system was overhauled due to subsidence of the landfill material having caused the underground piping of the gas collection system to become ineffective. Improvements were made to enhance landfill cover and drainage and the gas collection headers were installed on adjustable supports above ground.

Due to continued problems with offsite methane migration, the gas collection system has been recently expanded to 31 wells (completed as of October 2010) and an additional blower installed to increase gas extraction. Figure 4 shows the complete gas collection system as modified in September 2010. Equipment is currently being installed to measure the aggregate landfill gas flow rate from the expanded gas collection system.

Monthly wellhead monitoring data from June ’08 through January ’11 show aggregate landfill gas production rates averaging 190 scfm (range 2 to 635 scfm) at an average methane content of 42 percent (range 26 to 58 percent) – or an average of 4.8 MMBTU/hr. This value is thought to be an underestimate of the production rate since wellhead flow rates of zero were frequently recorded where it is likely that there was some flow at these wellheads that was not detected by the wellhead monitoring instrument

(LandTec GEM2000). Monitoring was conducted only at the wellheads and there has historically been no monitoring of the total gas extraction/flaring rate.

Since October 2010, with the expanded extraction system completed, monthly measurements of methane concentration and LFG flow rate have been conducted at the flare giving a better indication of the landfill gas production rate. In addition, since late January 2011, flow data have been obtained at the flare on a daily basis and methane concentration data obtained approximately weekly. Over this period, the heat content of the LFG has ranged from 6.5 to 8 MMBTU/hr. Over this period, methane and CO_2 concentration readings at the flare have ranged from only about 25 to 30 percent (each). This may indicate that ambient air is being drawn into the landfill or that there are leaks in the extraction system. Work is ongoing to balance the extraction system and troubleshoot any problems.

The Flex Powerstation™ will require about 3-4 MMBTU/hr to operate (at nominal conditions). There appears to be sufficient gas production to operate the Flex 250 unit. The existing flare will continue operation during the Flex demonstration and will consume all excess gas. The flare requires a minimum 200 BTU fuel heat content to operate within regulatory requirements.

The electric power supplier is Flint Energies on base, with power supplied to the base via Georgia Power, which has two entry points on the base. All sub-metering within the base by Flint Energies is for the purpose of allocating operational costs within Fort Benning. The power generated by the Flex Powerstation™ will solely offset on-base consumption and no commercial export agreement with the utility will be required. The point of interconnection is within approximately 100 yards of the present flare and head of the collection system. There is space adjacent to the existing pad suitable to support an additional pad for the FlexEnergy system. Electrical interconnection with the grid will be performed with Flint Energies. Flint operates the electric power distribution system on the base. Flint Energies will be contracted by Flex Energy to perform the interconnection work.

Figure 2: First Division Road Landfill

Figure 3: Collection System & Flare (subsequently fenced)

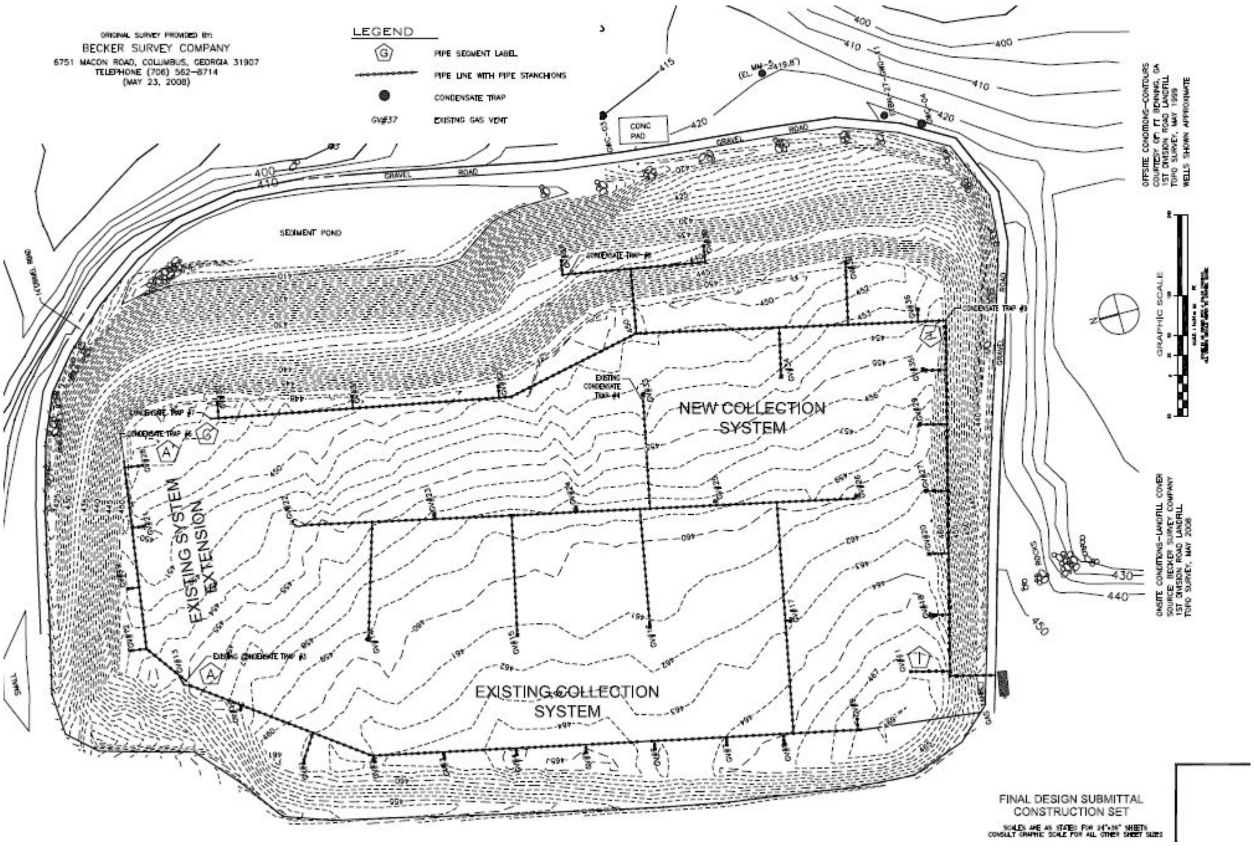


Figure 4: 1st Division Road Landfill Collection System (courtesy USACE)

4.3 Site-Related Permits and Regulations

Several permit modifications and internal approvals are required in order to commence construction and installation of the Flex Powerstation™ at the Ft. Benning site. Permits and approvals include the following:

- Site plan drawings have been submitted to the Georgia EPD Solid Waste Department to obtain a minor modification to the landfill permit to allow locating the Flex equipment approximately 25 feet south and east of the existing flare enclosure within a fenced area of 39 X 56.5 feet.
- A Record of Environmental Consideration (Form 144) has been prepared by Dorinda Morpeth and submitted for internal review to obtain necessary approvals from Ft. Benning environmental and public works departments to begin construction.
- Southern Research has confirmed that there are no ESTCP engineering review/approval requirements before construction may commence.
- The GA EPD Air Permit Engineer has indicated that the air permit modification can be handled as an off-permit request, as the planned turbine installation is considered an insignificant source and NSPS does not apply. Information on potential emissions and other aspects of the project has been submitted to the GA EPD for review.

- A Memorandum of Agreement (MOA) has been prepared and submitted for approval by Ft. Benning's Energy Manager and Garrison Commander. The MOA provides a basic description of the project, funding, duration, and outlines the responsibilities of each party involved.
- A hazard assessment and site health and safety plan will be prepared and presented to the Ft. Benning Energy Manager for approval.
- An electrical interconnection agreement will be established between Ft. Benning and Flint Energies, with all information submitted in October, 2010, and a draft agreement under review.

Southern has determined that there are no additional permit or regulatory requirements necessary to construct and operate the Flex system at Ft. Benning.

5.0 TEST DESIGN

The demonstration test is designed to provide data as required to satisfy project objectives as stated in Section 3, and provide additional information as needed to ensure the quality and representativeness of these data.

As this is a distributed generation project with combined heat/power applicability and is supported by EPA's Environmental Technology Verification (ETV) program, the ETV Generic Verification Protocol for Distributed Generation and Combined Heat and Power Field Testing [13] applies. All testing and data analysis methods and QA/QC requirements in this demonstration plan conform to the Generic Protocol.

5.1 Conceptual Test Design

At a minimum, all that is required to demonstrate Flex performance objectives is monitoring the net power production, conducting an emissions test, and compiling and analyzing economic and operational data. In addition to these basic requirements, the following additional supporting determinations will be made:

- The heat input to the system will be measured so that system efficiency can be determined.
- Ambient conditions will be monitored in order to determine variation in power output and system efficiency with varying temperature, humidity and barometric pressure.
- Selected Flex parameters (oxidizer inlet/outlet temperatures, LFG feed rate) will be monitored as an indication of overall system 'health' and operational status (e.g., normal operations). Exhaust temperature will be monitored in order to support an estimate of the heat recovery potential of the system (the system to be installed at Ft. Benning is not equipped for heat recovery).
- Landfill gas extraction system health and gas production will be monitored via monthly wellhead checks and flow and methane concentration of the LFG delivered to the flare.

5.2 Baseline Characterization

The baseline system for this demonstration is the existing LFG extraction system and open candlestick flare. The overall LFG extraction rate and gas quality are inconsequential to the objectives of this demonstration so long as sufficient methane is produced to operate the Flex. Excess LFG will be consumed by the flare. The majority of GHG reductions attributable to the Flex result from utility offsets due to the power produced. Thus, the existing 'baseline' system plays no significant role in determining performance objective results for this demonstration apart from the estimated cost of installing a gas extraction system and flare if it does not already exist at a given site.

5.3 Design and Layout of Technology Components

Figure 5 is a site plan of the layout of the Flex system components in relation to the existing flare pad located immediately south of the landfilled area. The function of each of these components has been described in section 2 above.

Figure 6 is a schematic diagram of the Flex system and the existing LFG collection/flare system showing the location of each measurement to be made in support of quantitative determination of performance objectives.

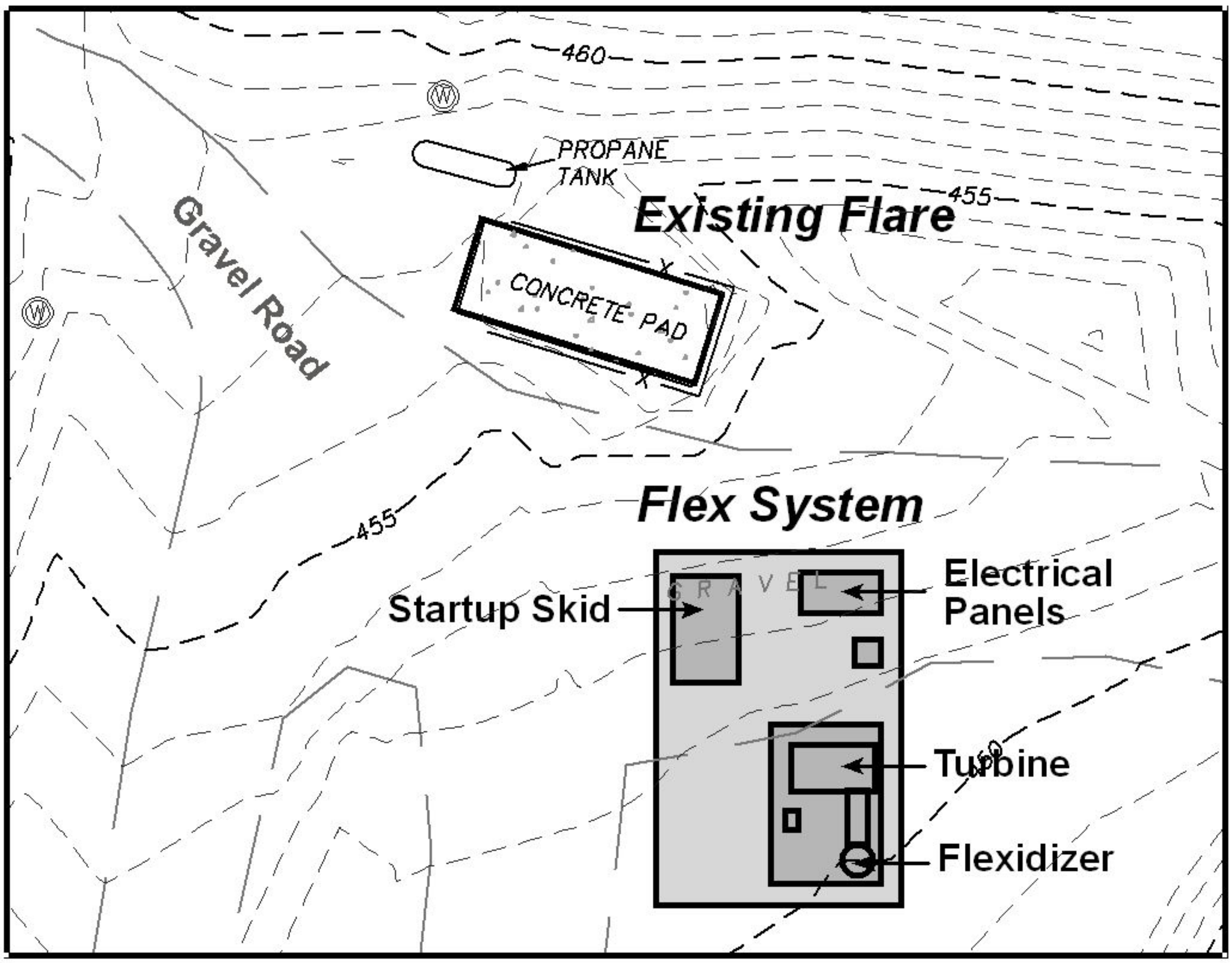


Figure 5: Flex System Site Plan – Ft. Benning Installation

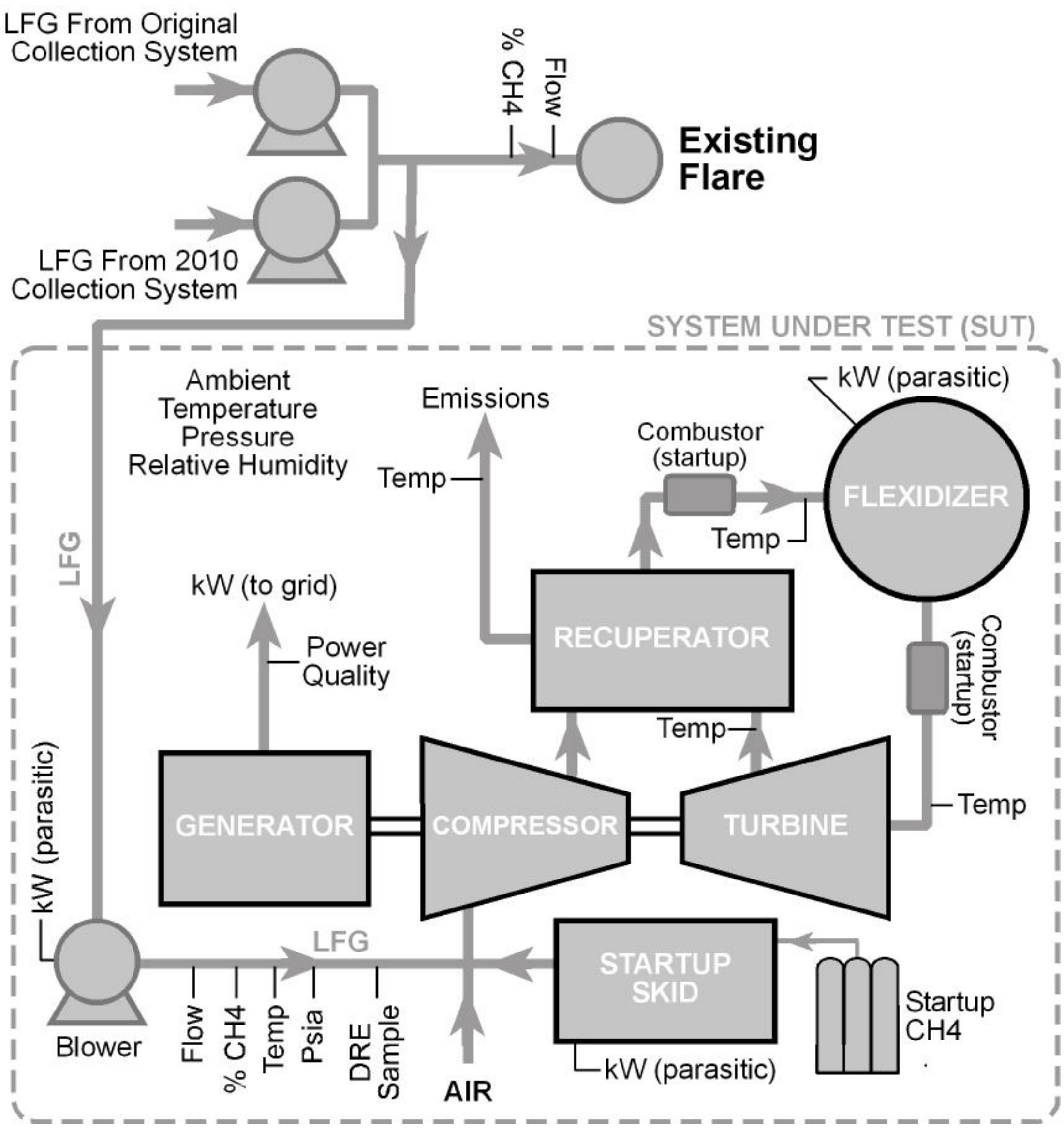


Figure 6: Flex System Monitoring Schematic

5.4 Operational Testing

The following sections describe each operational phase of the Flex performance assessment. These phases include acceptance testing, system installation and commissioning, steady state operations and emissions testing.

Formally, this demonstration plan is only concerned with the steady state operations and emissions testing phases; however, Southern will follow and document the acceptance testing and commissioning phases to capture any information relevant to understanding Flex performance.

The timeline for the operational phases is given in Table 3 below.

Table 3: Operational Timeline

Date	Operational Phase
September 2010	IR Turbine installed and commissioned at Alturdyne for acceptance testing.
October/November 2010	Oxidizer delivered and integrated with IR turbine at Alturdyne. Begin fully integrated acceptance testing.
November 2010	Groundbreaking at First Division Road landfill. Site preparation including concrete pads, electrical service, piping etc.
January/February 2011	Delivery and assembly of complete Flex system at First Division Road Landfill.
February/March 2011	System commissioning and shakedown.
April 2011	Begin Flex operations at First Division Road. Start of one year monitoring period.
July/August 2011	Emissions testing (after 1000 hours operation).
April 2012	End of one year monitoring period. System ownership and operation assumed by Ft. Benning.

5.4.1 Acceptance Test

Flex Energy is assembling a system identical to the system to be installed at Ft. Benning at a test facility at Alturdyne in El Cajon, California. The purpose of the test system is to finalize controls integration with the IR 250 turbine and to conduct performance testing on the full scale oxidizer/turbine unit. This testing will take place concurrently with site preparation and construction activities at the Ft. Benning demonstration site. The overall goal of the test is to achieve 200 kW output using dilute natural gas and to confirm emissions meet CARB DG 2013 standards. The testing will also verify that operating conditions are within expected ranges (e.g., heat input, temps, flows, pressures), and that controls function within specifications, including response to subsystem failure (e.g., power outage, fuel supply outage) and response to changes in fuel gas composition or flow. This test system will then be available for installation at the second ESTCP demonstration site (to be determined) while matching components have been delivered to Ft. Benning for installation. Flex Energy will prepare a report of acceptance test results and Southern will review the report and maintain a copy in project files.

5.4.2 Commissioning

After the final system design is complete but before commissioning may begin, Southern and Flex Energy will conduct a hazard and operability review (HazOp) to identify any and all potential hazards associated with Flex operation, determine the likely frequency and consequences of each hazard, and assess the severity of those consequences. Likely hazards associated with significant potential for injury or property damage property must be mitigated before operations may begin.

Installation and commissioning of the Ft. Benning system will take place during the first few months of 2011. Flex system components will be commissioned and tested individually and as a fully integrated system. Southern will prepare a narrative description of commissioning activities documenting any problems encountered and corrective actions taken.

During commissioning, values of steady state operating parameters (such as oxidizer temperatures) will be determined so that steady state conditions are well defined for demonstration analyses.

5.4.3 Steady State Operations at Ft. Benning

Full operation of the Flex system is expected to begin by April, 2011, the formal start of the one year demonstration period. During this period, continuous monitoring of gross and net power output will be conducted, along with monitoring of heat input (LFG flow and methane concentration delivered to the Flex), Flex system 'health' parameters, landfill gas extraction system parameters, and ambient conditions, as shown in Figure 6.

Propane consumed for Flex system startup(s) will also be recorded. The propane startup system will be equipped with a calibrated orifice flow element and differential pressure transmitter to monitor startup fuel flow rate and totalized usage. Propane fuel deliveries and a log of site glass readings on the propane storage tank will also be recorded to confirm startup fuel usage.

All monitoring instruments will be connected to a data acquisition and storage system with remote access capability. Table 4 is a list of monitoring measurements, instruments and measurement parameters.

On the same data acquisition system, Southern will also acquire data from a number of sensors integral to the Flex Powerstation™ control system. These data will be used as indicators of system status and will aid screening of results so that steady state operation is accurately represented in the data analyses. These parameters are listed in Table 5.

Finally, during the steady state monitoring period, Southern will also obtain flow and methane concentration data for the flare feed, as well as monthly well head data for the LFG extraction system. These monthly data consist of measurements at each wellhead of LFG flow and concentrations of methane, carbon dioxide and oxygen, as well as concentration at the flare inlet using a portable LandTec GEM2000 landfill gas meter. The LFG flow to the flare will be measured continuously downstream of the Flex takeoff, indicating net flow to the flare when the Flex is operating. These data will be used to monitor the status of the LFG extraction system and characterize the LFG supply. The wellhead data will be obtained monthly from USACE via their contractor, J2 Engineering.

Parasitic electrical loads are loads required for Flex operation that net against the gross power output. The wiring for the Flex system is configured such so all parasitic loads will be measured together from a single 3-phase 480V 4-wire Wye bus with a single power meter. Table 6 lists the parasitic loads and the associated nominal and max current for each load. The gross generator output from the Flex will be measured by a separate power meter. A bi-directional power meter will also be installed at the utility interconnect. The Flex system will record data from this meter.

The LFG feed gas flow and methane concentration to the Flex will be measured on the 4 inch line from the Flex supply blower to the compressor air inlet plenum (see Figure 5 above). These instruments, along with the DRE sample port (see section 5.4.4) will be located along a spool piece provided with a bypass so that the instruments may be serviced without taking the Flex offline. To ensure reliable flow measurements, the flow element will be located 10 diameters (40 inches) downstream and 5 diameters (20 inches) upstream from any obstruction to flow, although the area-averaging type flow element that will be used requires only a minimum of two diameters straight run of pipe upstream. The additional straight run is planned as a precaution should an alternate flow measurement device become necessary. The LFG feed gas spool piece configuration is illustrated in Figure 7 below. The differential pressure transducer must be mounted as close as possible to the flow element with the impulse lines arranged so that any condensation will drain away from the transducer.

Measurement	Required for:	Tag	Units	Nominal	Low	High	Accuracy	Output	Power	Mfg	Model
LFG Volume Flow to Flex	Heat Input to Flex	LFG_Flex	cfm	120	24	340	2% of reading	4-20 mA	24VDC 1A	Air Monitor Corporation	LO-flo/SS Pitot Traverse Station Model FR (4 inch flange to 3 inch station) with VELTRON DPT-plus transmitter
LFG Methane Concentration to Flex	Heat Input to Flex	CH4_Flex	%	45	0	100	0.2% FS	4-20 mA	24VDC 1A	BlueSens	BCP-CH4
LFG Temperature to Flex	Temperature corrections for flow and CH4 concentration	Temp_Flex	deg F	65	0	120	0.2 deg F	4-20 mA	24VDC 1A	Omega	PR18-2-100-1/4-6
Gross Power (Bi-directional)	Power Production	PM_Gross	kW	200	0	250	1% of reading	pulse to 4 Hz	none	Wattnode	WNB-3Y-480-P
Total Parasitic Load	Net Power Production	PM_Par	kW	30	0	120	1% of reading	pulse to 4 Hz	none	Wattnode	WNB-3Y-480-P
Ambient Temperature	Performance relative to ambient conditions	Temp_Amb	deg F	85	0	120	1 deg F	4-20 mA	6 to 24 Vdc	Omega	HX94AC
Ambient Pressure	Performance relative to ambient conditions	Pres_Amb	in Hg	26	30	32	1% FS	4-20 mA	10 to 30 Vdc @ 10 mA	Omega	PX429-26BI
Ambient Relative Humidity	Performance relative to ambient conditions	RH_Amb	%	60	0	100	2.5% RH	4-20 mA	6 to 24 Vdc	Omega	HX94AC

Table 4. Instrument Specifications for Continuous Monitoring

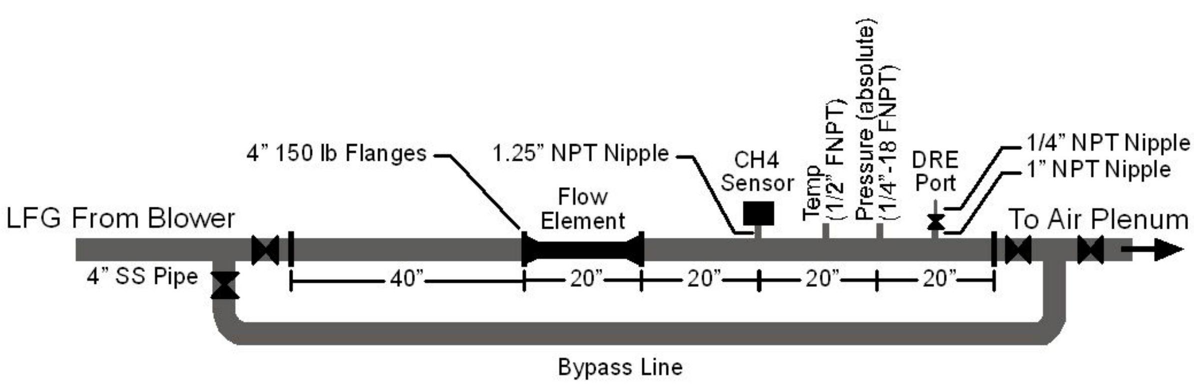
Table 5. Supplementary Data to be Acquired from Integral Flex Sensors

Measurement	Required for:	Tag	Units
LFG Mass Flow	Flex operation + cross check on SRI sensor	LFG_Flex2	cfm
LFG Methane Concentration	Flex operation + cross check on SRI sensor	CH4_Flex2	%
Bi-directional Power	Flex operation + cross check on SRI sensor	BPW_Flex	kW
Flexidizer Inlet Temp	Flex system 'health' indication	TT_GIT	deg F
Flexidizer Outlet Temp	Flex system 'health' indication	TT_GET	deg F
Turbine Exit Temp	Flex system 'health' indication	TT_TET	deg F
Recuperator Exhaust Temp	Flex system 'health' indication + heat recovery estimates	TT_EGT	deg F

Table 6. Parasitic Loads

	Nominal (Amps)	Nominal (kW)	Maximum (Amps)	Maximum (kW)
Flexidizer Heater Group 1 (480 V)	22	10.6	22	10.6
Flexidizer Heater Group 2 (480V)	22	10.6	22	10.6
LFG Supply Blower (480V)	8	3.8	8	3.8
Start Skid (480V) (Two compressors, chiller, pump and transformer). Startup only.	0	0	162	77.8
Auxilliary Panel 'L' (240V)	25	6.0	40	9.6
Total	77	31.0	254	112.4

Figure 7: LFG Measurement Configuration Detail



5.4.4 Emissions and Destruction Efficiency Testing

After approximately 1000 hours of steady state operation in full Flex mode, an emissions test will be conducted. It is desirable to conduct the test once the system has fully stabilized and after a sufficient period has elapsed that the emissions measurements may be considered representative of normal operations.

The emissions test will be a fully rigorous compliance test using standard EPA compliance test methods (see Table 7 below). Three 1-hour test runs will be conducted to determine mass emissions (e.g., lb/hr) of the pollutants listed in Table 7. The test is intended to demonstrate that Flex emissions meet or exceed the most stringent applicable air quality standards (see section 3.2).

The emissions testing will be conducted by Integrity Air Monitoring, Inc. (Integrity Air). Integrity Air is a fully certified emissions testing contractor. Integrity Air has performed satisfactorily on previous demonstration and verification projects for Southern Research.

To comply with EPA methods, the exhaust stack will be fitted with two sampling ports (4 inch ID close nipples with caps) located at the same elevation on the stack at 90 degrees to each other. The ports must be located a minimum of two stack diameters downstream of any obstruction to flow and one half diameter upstream. The Flex stack is a straight run 17.8 inches inside diameter and 70.3 inches long. Thus, centering the ports at 53.4 inches (3 diameters) downstream of the base of the stack will meet EPA requirements. A scaffold or platform will be provided at 15-18 inches below the center of the ports to provide safe access for testing personnel and support for the sampling trains.

For the emissions test, two 15 Amp 120 V circuits will be required near the stack and one 480V 30 Amp circuit will be required at the test trailer.

Destruction Efficiency

Determination of NMOC and methane destruction efficiency will be made based on concurrent concentration and flow measurements at the inlet and exhaust of the Flex.

Southern's experience with compliance testing and the experience of Integrity Air indicates that, to conform with commonly accepted practice, the DRE inlet sampling location would be in the diluted gas stream - downstream of where the LFG feed gas and dilution air are mixed before entering the Flex compressor. However, due to the configuration of the inlet air plenum on the IR turbine, it is not possible to obtain a representative flow measurement of the diluted stream. Therefore, the inlet DRE samples will be obtained from a port located in the LFG supply line to the Flex compressor (see Figure 5) to provide inlet NMOC mass flow with at least as much accuracy as sampling in the diluted stream. South Coast AQMD approved the same method for the regulatory compliance test at FlexEnergy's Lamb Canyon pilot plant [14].

The LFG supply line is a 4 inch stainless steel pipe. The sampling port is a 1 inch diameter pipe stub welded to the 4 inch pipe and fitted with a 1 inch gate or ball valve. Downstream of the valve, a ¼ inch male NPT nipple will be provided to attach the dilution probe. The flow measurement will be obtained from Southern's flow element (LFG_Flex).

Table 7. Pollutants and Emissions Test Methods

Parameter	EPA Reference Method
Volumetric Flow	1, 2, 3A & 4
CO_2, SO_2, NO_x, and CO	3A, 6C, 7E & 10 (respectively)
Total Reduced Sulfur (TRS)	16A (Modified to use an SO_2 analyzer in place of wet chemistry/titration)
THC/NMOC	25A & 18 (NMOC as THC less methane)
PM_{10}/$PM_{2.5}$	OTM-27 and OTM-28

5.5 Sampling Protocol

The only samples to be collected for the demonstration are associated with the emissions and destruction efficiency testing described above. All samples will be obtained in accordance with the corresponding EPA reference or equivalent methods.

5.6 Equipment Calibration and Data Quality

5.6.1 Calibration of Equipment

All monitoring equipment installed by Southern (see Table 4) will be newly purchased and have a manufacturer's calibration valid for at least the duration of the one year demonstration period. Data collected from these instruments is sufficient to satisfy demonstration performance objectives and meet QA requirements.

The selected pressure/flow transmitter has the capability to automatically re-zero itself at a predetermined interval without interrupting data acquisition. The automatic zeroing circuit eliminates output signal drift due to thermal, electronic or mechanical effects, as well as the need for initial or periodic transmitter zeroing. The selected methane sensor uses infrared optical sensing that is inherently accurate and stable and does not require recalibration. The power meters are equipped with status LEDs that indicate calibration faults.

All sensors will be installed and initial sensor function checks conducted according to manufacturer specifications. Following installation, source to data checks will be conducted in the field to verify that the data acquisition properly receives and processes incoming signals. All checks will be documented in field log books, digitized, and stored as part of project files.

All data will be accessible remotely via a cellular router internet connection. During operation, sensor data will be checked for reasonableness and consistency weekly. The methane and flow data will be cross checked against similar measurements obtained from Flex system sensors. Gross and net power production measurements will be cross checked against data from the bi-directional utility interconnect meter.

5.6.2 Quality Assurance

Requirements

As this project is funded under the DoD's ESTCP, this demonstration plan has been prepared in accordance with ESTCP guidance and the QA requirements therein. This project is unique; however, in that it is also receives technical guidance and QA review support through EPA's ETV program. As such, the demonstration test also conforms to EPA NRMRL QA requirements. As this project is not intended to support development of environmental regulations or standards, Southern has determined that it is appropriately classified as a NRMRL Category III project. As this project is intended to demonstrate the performance of technologies under defined conditions, it is subject to NRMRL QAPP Requirements for Measurement Projects. This demonstration plan incorporates all required QA elements in EPA Guidance for Quality Assurance Project Plan (EPA/QA G5).

Data Quality Objectives for Critical Results

The critical results necessary to satisfy performance objectives are the net power production and emissions measurements. Thus, specific data quality objectives must be established and met for these results to ensure that results are of sufficient quality to satisfy the decision making needs of Flex, ESTCP, EPA and other stakeholders.

For power production, the ultimate question to be answered is whether the Flex will produce sufficient power to offset the capital and operation costs of the system over a reasonable period of time (5-7 years). Thus, for the purpose of establishing a data quality objective, a 1 percent uncertainty in monthly aggregate power production would be a very conservative data quality objective.

The combined accuracy of the power meters and associated current transformers is ± 1.1% for each reading. Readings will be taken at 5 minute or shorter intervals. In one month (30 days), 5-minute readings amount to 8640 readings. At a nominal 200kW output, propagating the 1.1% reading uncertainty over one month (8640, 5-minute readings) gives a combined absolute uncertainty of ± 17 kWhr per month out of 144,000 kWhr generated, or just over 0.01% uncertainty. This analysis neglects the covariance term in the error propagation; however, this covariance should be small for steady state operations. This analysis demonstrates that the measurement uncertainty is far more than adequate to meet the needs of decision makers.

It is expected to have near 100 percent data capture for the power measurements; however, a percentage data capture objective, by itself, is not especially relevant. It is more important to capture changes in power output and identify the conditions causing those changes. Should a power meter fail, corrective action will be initiated immediately; however, a second power meter is integral to the Flex system and data will be available to fill in any gaps. Moreover, if operating conditions remain consistent (as evidenced by Flex operating parameters that will be logged), it may be safe to assume that power output is also consistent. In summary, the power meters are expected to be reliable, but there is more than one backup should a meter fail.

The quality of the emissions measurements will be assured by adhering to quality assurance requirements in the associated EPA reference methods cited above (Table 7). The emissions test report will include documentation of all calibration and QA/QC checks conducted. The data quality objective for the emissions measurements will be satisfied if the EPA QA/QC requirements are documented to be met. Achievement of QA/QC requirements will be verified by Southern's QA manager as part of the audit of data quality. If the requirements are not met, the tests will be repeated.

The quality of all raw data from Southern's continuous monitoring instrumentation will be assured by observing instrument calibration, installation and data review requirements as described above (section 5.6.1). In the event that any problems are encountered, corrective action will be immediately initiated by the Project Manager. All problems and corrective actions will be fully documented and the impact of any problems on data quality will be assessed and reported.

Ancillary Data Quality

The quality of supporting data obtained from Flex instrumentation (see Table 5) and from the LFG extraction system will be verified via reasonableness and consistency checks. Calibration certificates and documentation of QA/QC checks will be obtained as available. The impact of any problems on data quality will be assessed and presented in final reports. These supporting data are not critical measurements and do not directly affect achievement of data quality objectives, so stringent QA/QC requirements are unnecessary. That said, these data do contribute to the understanding of Flex performance during the demonstration so, should any problems occur, Southern will work with Flex or base personnel to correct the deficiency in a timely manner.

Data Review and Validation

All data will be reviewed on an ongoing (weekly) basis by project staff and classified as valid, invalid or suspect. Data review will consist of (for example):

- verifying that data collection is complete for all sensors
- examining raw data values and trends for consistency and reasonableness,
- making comparisons between related measured parameters and calculated values for agreement within process operating parameters
- flagging incomplete, invalid or suspect data and documenting the reason for the flag
- initiating investigative or corrective actions as needed.

In general, valid data results from measurements that meet the required QA/QC checks, are collected when an instrument was verified as being properly calibrated and functioning, and that are consistent with system operating parameters and reasonable expectations.

Reported results will incorporate all valid data. Analysts may or may not consider suspect data, or it may receive special treatment as will be specifically indicated. The impact on data quality of any problems or issues that arise will be fully assessed, documented and reported. Any limitations on the use of the resulting data will be fully assessed and reported.

Data Management

Field data will be collected, stored, and retrieved from Southern's data acquisition system (DAS) at the demonstration site. The DAS will be equipped with a web-based cellular link so that data may be accessed and DAS settings configured remotely from any location.

Southern will retrieve data from the DAS Southern Research at the first of each week during the one year demonstration period. The field team leader is responsible for ensuring that all electronic and hard copy data, forms and logs are accounted for, properly completed and stored in project files according to the Southern Research Quality Management Plan and other applicable policies and procedures. The project manager will periodically review project files and verify that all data, reference sources, critical project documents and correspondence necessary to support the data analysis and reporting are accounted for. Before results are reported, the QA manager will conduct an audit of data quality; which includes verifying that all results can be traced to raw data and supporting documentation.

Raw data will be compiled into spreadsheets for analysis with links or references to the original data source and storage location. All analyses and calculations will reference conversion factors and constants from known sources properly identified within the analytical spreadsheets.

Independent Review

Southern's QA manager (QAM) is administratively independent from project management.

The QAM has reviewed this demonstration plan to ensure that it fully satisfies project objectives and complies with ESTCP guidance and EPA/ETV QMP requirements.

On a monthly basis during the demonstration period, the QAM will verify with project staff and management that data reviews and all required QA/QC activities have been completed and that any necessary corrective actions have been implemented. The QAM will be notified by the project manager whenever a data quality problem is encountered and the QAM may assist in assessing and documenting the impact on data quality of any such problems.

At the completion of the demonstration, the QAM will conduct an audit of data quality (ADQ). The ADQ consists of following each data stream from raw data to final results to ensure that all required QA/QC is complete and documented, and that calculations are correct and results and uncertainties correctly reported. The QAM will also review the final report to ensure that reported results and uncertainties accurately reflect the data collected.

All QAM reviews and audits will be documented in memoranda submitted to the project manager.

6.0 PERFORMANCE ASSESSMENT

The following sections describe the analyses and computations required to obtain final results for each performance objective from the data collected as described in sections 3 and 5.

A number of the analyses described below depend on the definition of steady state Flex operations. Steady state operation has been defined by Flex as periods when the Flex is operating in full 'Flex mode', that is, when the startup equipment is no longer operational and the Flex is running from dilute LFG only. It is possible that there will be some variation in power production or generating efficiency during steady state conditions. During commissioning, quantitative steady state operating conditions (such as oxidizer temperatures) will be determined by Flex engineers, so that data analyses will be well defined.

6.1 Power Production

The following quantities are of interest in the analysis of the power production data:

- Peak gross and net power production
- Sustained or steady state net power production
- Net annual power production.

Net power production during any given time interval is the gross power production less the parasitic load. The peak power production will be reported as the average of the upper 5% of logged power data. The number of hours at this production will also be reported. Sustained power production will be reported as the power production range that is maintained during periods of steady state operation as defined by FlexEnergy engineers (e.g., in terms of Flexidizer temperature bands). Annual power production will be computed as the integral (summation) of power production over logged time periods (e.g., 5 minute) over the one year demonstration period.

Net annual power production will also be reported minus the energy consumed in the form of propane startup fuel. The startup fuel energy will be calculated by multiplying the total amount of propane used for startups during the year, by the heat content of propane (e.g., 12,600 BTU/lb) converted to kWh (3413 BTU/kWh).

As discussed above (section 5.6.2), during steady state operations, the propagated uncertainty in net power production computations decreases as more data are collected over time. Since the uncertainty in a single measurement of power production is only slightly more than 1 percent, the uncertainty in the aggregate power production over a period as short as one day is very small (ca. 0.1% or smaller).

Results will be obtained as described below for the related supplementary objectives of determining generating efficiency, ambient condition dependent or seasonal de-rating curves, and heat recovery potential.

Generating Efficiency

The product of LFG flow (scfm), methane concentration, and the heat content of methane gas (1012 BTU/scf) gives the heat input to the Flex in BTU per unit time (e.g., BTU/hr). The generating efficiency of the Flex is the power generated (kWh/BTU) divided by the heat input (BTU).

Steady state generating efficiency will be computed as the average generating efficiency over steady state periods of operation. The analysis will seek to characterize and determine the causes of any changes observed in generating efficiency during nominally steady state operations.

Overall generating efficiency will be computed over a period to include one start up cycle (when net power production is negative) and 3 months (0.25 year or 2190 hours) of steady state operation (when net power production is positive). A cold startup is assumed to be necessary no more than 4 times per year. Startup fuel use will be taken into account in determining average generating efficiency as described above.

Seasonal de-rating

The Flex is expected to generate less power when ambient temperature is high, absolute humidity is low or barometric pressure is low. At Ft. Benning, seasonal variation in temperature is expected to have the largest effect. Southern will develop a seasonal de-rating curve showing the relationship of ambient temperature to power output once humidity and barometric pressure effects (if significant) have been removed.

Heat Recovery Potential

The Flex unit to be demonstrated at the 1st Division Rd. Landfill will not be equipped with heat recovery equipment as there is no local use for the recovered heat; however, it is of interest to know the heat recovery potential if this option were installed.

The heat recovery rate (BTU/hr) is calculated as the product of (1) the heat recovery fluid flow (gal/hr), (2) difference between supply and return temperatures from the heat exchanger (deg F), (3) heat capacity of the heat recovery fluid (BTU/lb deg F) and (4) heat recovery fluid density (lb/gal).

The exhaust gas temperature will be monitored. The exhaust gas mass flow will be measured during the emissions test at steady state conditions. These values will be applied along with Ingersoll Rand heat exchanger specifications and reasonable assumptions on the heat recovery fluid flow and inlet temperature to arrive at an estimate of heat recovery.

6.2 Emissions

Pollutant emission rate calculations (lb/hr) will be made according to standard EPA methods referenced in section 5.4.4, above. Emission rates in terms of lb/MWhr will be computed by dividing the lb/hr emission rates by the steady state power production in MW over one hour.

Mass emission rates will be assessed against regulatory limits and emission rates from alternate LFG utilization technologies as described in section 3.2 above.

6.3 Destruction Efficiency

Methane and NMOC destruction efficiency will be determined as described in Section 5.4.4 above. The results will be reported and compared with regulatory limits and best alternate control technologies as described in section 3.3 above.

6.4 Greenhouse Gas Reductions

As discussed above (section 3.4), the only significant GHG reduction attributable to the Flex is the utility generation offset due to the power produced by the Flex.

The annual GHG reduction (metric tons CO2e) is based on avoided emissions for utility electric power generation for the State of Georgia. Emission factors for carbon dioxide, methane, and nitrous oxide from the most recent eGrid database will be weighted by current EPA accepted global warming potentials (e.g., Table ES-1 in EPA's 2010 GHG Inventory) [11] to arrive at the total combined CO2e emission factor in metric tons/MWh. Currently, this factor is 0.64 metric tons CO_2e/MWh. This is shown in the equation below.

$$\text{R\_avoided (metric ton } CO_{2e}) = \text{Q (MWh)} \times \text{EF(metric ton } CO_{2e}\text{/MWh)}$$

Where,

- R_avoided are the utility emissions offset by power generation from landfill gas
- Q is the electric energy produced during the one year demonstration period.
- EF is the combined GHG emission factor

(Alternate equation text): utility emissions offset by power generation from landfill gas is equivalent to the electric energy produced during the one year demonstration period times the combined greenhouse gas emissions factor

To determine percentage GHG reduction, the avoided emissions due to power generation are divided by the direct emission reduction due to destruction of methane. The percentage reduction is the additional GHG reduction due to avoided utility emissions as a proportion of the emissions reduction due to the destruction of methane. This is shown in the equation below.

$$\text{Annual GHG Reduction (percentage)} = \frac{R\_avoided}{R\_direct} \times 100$$

Where,

- R_direct are the GHG emissions reduction due to the destruction of methane

(Alternate equation text): annual percent greenhouse gas emissions reduction is equivalent to greenhouse gas emissions avoided divided by technology direct greenhouse gas emissions, times 100

Any difference in methane destruction efficiency between the flare and the Flex is not accounted for. It is assumed that the flare and the Flex have the same (near complete) methane destruction efficiency. In any case, it is not possible to determine the methane destruction efficiency of the open, candlestick flare. The direct and avoided GHG emissions reductions are calculated using formulae adapted from EPA's LMOP GHG emissions reduction calculator. [8]

6.5 Economics

The life cycle economic performance of the Flex will be assessed based on standard economic indicators of financial performance including the net present value, and simple payback period. These indicators are derived from a cash flow analysis accounting for initial capital costs, ongoing operation and maintenance costs, and revenues representing the value of the power produced by the Flex system over the projected useful life of the system. Costs specifically associated with the demonstration program will be excluded as non-typical of a normal installation.

Details on the economic performance criteria, data collection, and analysis are provided in Section 7.0

6.6 Operability – Availability, Reliability and Ease of Use

In order to be successful, the Flex system must provide sufficient availability, reliability and ease of use so that the economic value of power production is realized and no undue burden is placed on operations staff. The Flex is intended to operate on a 24x7 basis with a level of attention similar to or lower than the level of attention generally required by similar LFG-to-energy equipment. Projected economics are based on periodic minor scheduled maintenance and infrequent unscheduled down time, as well the projected cost and down time associated with a major overhaul.

Availability is a quantitative metric that is given as the percentage of time that the system is either operating or capable of operation if down for unrelated reasons (such as power failure or failure of the LFG collection system). Reliability is both a quantitative and qualitative metric that assesses the robustness of the system in terms of likelihood of failure or operational problems, the consequences of such problems, and the ability to recover. Availability and reliability will be assessed quantitatively in accordance with ANSI Standard 762 which uses a specific categorization of operating and downtime hours. Reliability will also be assessed qualitatively based on the operating experience of project participants (including Southern Research, Flex and local operators). Qualitative reliability will be documented with narrative descriptions prepared by Southern Research and Flex and interviews with operating staff at the conclusion of the project.

To assess reliability, the following service parameters will be logged by Flex Energy operations staff.

- Service Hours (SH) = Hours unit is in actual operation or fully available for operation;
- Reserve Shutdown Hours (RSH) = Hours unit is shut down by choice, but could otherwise be available for operation;
- Planned Outage Hours (POH) = Hours for a shutdown defined in advance (i.e. site maintenance activities, inspection of components, planned system upgrades, etc.)
- Forced Outage Hours (FOH) = Hours for a shutdown period beyond the control of the operator – typically an immediate shutdown is required;
- Maintenance Outage Hours (MOH) = Hours for a shutdown due to a condition that requires shutdown prior to the next planned outage;
- Period Hours (PH) = total hours for a specified period = SH + RSH + POH + FOH + MOH

For any time period in which the system is not operating, the log will be completed and hours categorized in accordance with the above definitions.

Categories of down time may include:

- Turbine/Flex system failure/unscheduled maintenance
- Generator system failure/unscheduled maintenance
- Electrical/interconnection system failure/unscheduled maintenance
- Gas collection system failure/unscheduled maintenance
- Turbine system scheduled maintenance
- Generator system scheduled maintenance
- Gas collection system scheduled maintenance
- Safety shutdown (weather, fire, or other external reason)
- Other non-technical shutdown (commanded by base or other authorities).

Southern's analysts will review operational data for the system and maintenance logs and ensure any periods of shutdowns as observed in the data are properly documented in the logs. Analysts will also review the description of the outage hours to ensure that outage periods are properly categorized. Once categorized and reviewed, analysts will calculate the Reliability and Availability as follows:

$$\text{Reliability} = 1-(\text{Forced Outage Rate}) = \frac{\text{Period Hours (PH)} - \text{Forced Outage Hours (FOH)}}{\text{Period Hours (PH)}}$$

(Alternate equation text): System reliability is equivalent to period hours minus forced outage hours divided by period hours

$$\text{Availability} = \frac{\text{Service Hours (SH)} + \text{Reserve Shutdown Hours (RSH)}}{\text{Period Hours (PH)}}$$

(Alternate equation text): System availability is equivalent to service hours minus reserve shutdown hours divided by period hours

The operational log for the system will be maintained by Flex Energy operations staff and contain entries for each event or occasion when the system is inspected, adjusted, maintained, repaired or requires attention in any way. The log will be reviewed regularly (at least monthly) by Southern project staff.

Each entry will contain:

- Date/Time
- Names of the observer and participants in the event
- What alerted staff to the event – e.g., routine inspection, system alarm, notification
- Description of the event
- Cause of the event
- Actions taken including all steps leading to resolution
- Staff time and material resources required to resolve the event
- Service time parameters as defined above
- Comments on how easily the situation was resolved and any problems encountered.

In addition, system operators will be interviewed by Southern project staff upon system installation after receiving training, during periodic reviews of the log, and at the end of the extended test period. Interviews will be documented and stored as part of project files.

Finally, ease of use is a qualitative metric that will be based on operating experience during the demonstration period as documented by narratives and interviews with operators and project participants during and at the conclusion of the project. The acceptability of a newly introduced technology is partly dependent on the subjective experience of operations and maintenance personnel. If these personnel require highly specialized training the cost of training and operations increases, and availability is reduced. When the system fails, someone with the needed expertise is unlikely to be immediately available.

7.0 Economics

The purpose of this section is to identify the information that will be tracked during the demonstration and the methods that will be employed to establish realistic life cycle costs for implementing the technology. Table 8 provides an inventory of cost elements associated with the life cycle analysis along with a description of the data to be tracked and identification of the source of this information.

A number of resources have been used to guide the life cycle assessment approach for this demonstration. EPA's LMOP Handbook Chapter 4, Project Economics and Financing [15] provided general guidance on evaluating economics for landfill gas to energy projects. EPA's LMOP LFG_Cost model has been used as a guide to identify cost elements and default values particular to landfill gas to energy projects and may also be used to generate estimated costs for comparable technologies. The Environmental Cost Analysis Methodology Handbook [16] has also been consulted as a guide to conducting economic analyses where environmental costs are a factor. Though designed for buildings, the NIST Building Life Cycle Cost (BLCC) software [20] has applicability for renewable energy projects and Southern has determined that the BLCC software may be used to calculate LCC assessment parameters for this demonstration. Life cycle costing methods and data from NIST Handbook 135 [21] have been referenced in preparing the economic analysis approach.

Life Cycle Assessment

The simplified life cycle economic analysis will be based on capital and operation /maintenance costs and revenues associated with electricity production during the demonstration period and projected over the expected life of the Flex unit. Costs specifically associated with the demonstration program or with product development will be excluded as non-typical of a normal installation. The analysis is 'simplified' in the sense that it will not account for costs associated with financing or taxes, or for revenues associated with renewable energy credits, tax credits or incentives that may be available in some locales for landfill gas to energy or other waste to energy projects.

The life cycle economic performance of the Flex will be assessed based on standard economic indicators of financial performance including the net present value (NPV), internal rate of return (IRR) and simple payback period. These indicators are derived from cash flow analysis accounting for initial capital and installation costs, ongoing operation and maintenance costs, and revenues representing the value of the power produced by the Flex system over the projected useful life of the system. Current discount rates from OMB Circular A-94, Appendix C [22] will be applied. The 20-year real (non-inflated) discount rate for 2010 is 2.7%.

According to modeling predictions [12], the 1st Division Road Landfill should continue producing sufficient gas for Flex operations through 2020-2025 or longer. According to FlexEnergy, in a typical installation, the Flex should provide service for 20 years or longer. For the purpose of the economic assessment, the lifetime will initially be assumed as 20 years; however, this figure may be adjusted based on experience gained during the demonstration.

Revenues

At Fort Benning, the current value of electric power is $62/MW h. The incremental value of renewable power is assessed at $45/MWh. [17] Thus, the value of electric power produced today is $107/MWh, or nominally $150,000 per year for the Flex 200 unit. For future years, the value of electric power will be adjusted using GA Power avoided cost projections [18] and projected fuel price indices from the current annual supplement to the Life Cycle Costing Manual for Federal Energy Management Projects [NIST 135].

Scaling

Because the demonstration system is an actual full scale implementation of the technology, scaling is not a major concern. For application to larger landfill sites with greater rates of gas extraction, there may be savings associated with deployment of more than one Flex unit. Southern will work with FlexEnergy to develop costing guidelines for such installations. These guidelines will not be included in the performance assessment report, but will be incorporated in guidance documents and outreach tools.

Assumptions

Flex Energy staff and contractors will support operation and maintainance of the Ft. Benning installation remotely and with intermittent on-site support during the first year of operations. Minimal on-site staffing support by Ft. Benning will be required for operation. Ft. Benning will assume ownership and responsibility for operations and maintenance from the end of the demonstration period forward. Flex Energy will provide operations and maintenance training to Ft. Benning staff or contractors before the end of the demonstration period.

The analysis will be completed in *constant dollars* (excluding inflation). Therefore, all discount rates and price escalation rates will be entered in real terms (no inflation).

Initial investment costs will be assumed to be phased over a planning/construction/installation period equivalent, for this project, to the planned one-year period from 4/15/2010 – 4/15/2011.

Table 8. Flex Demonstration Cost Elements

Cost Element	Description	Data Tracked During Demonstration	Data Source
	Investment (Capital) Costs		
Hardware capital costs	Direct costs for equipment and supplies associated with the system	Actual equipment and supply costs for the demonstration installation	FlexEnergy accounting (to be modified to add any costs discounted or remove costs specifically required for the demonstration program)
Design and Engineering Costs	Costs associated with typical engineering, equipment specification, engineering design, permitting. Does not include site selection costs. Does not include development costs.	If costs are tracked separately by FlexEnergy, actual costs will be specified. Otherwise, costs may be estimated as a percentage of total capital investment costs.	FlexEnergy accounting or estimates of engineering labor hours/rates or representative default values.
Supervision, Inspection, & Overhead Costs	Costs associated with supervision of the project (project management), inspections for permit/code compliance, permit fees, and	If costs are tracked separately by FlexEnergy, actual costs will be specified. Otherwise, costs may be estimated as a percentage of total	FlexEnergy accounting or estimates of supervisory labor hours/rates or representative default values.

Cost Element	Description	Data Tracked During Demonstration	Data Source
	overhead charges by supplier.	capital investment costs.	
Site Preparation Costs	Costs for grading, pads, fencing and utility interconnection.	Actual costs	FlexEnergy accounting and Ft. Benning contributions to site work.
Salvage Value	Residual value of any equipment at the end of service life – may include scrappage or resale, or may include offset of future costs if life of a specific component is beyond the overall system service life	None – assumed to be zero.	
Installation costs	Costs associated with the installation of the system, including site work, construction, commissioning, and startup costs.	Labor & materials required to install (actual and projected for commercial installation)	FlexEnergy accounting.
Operation and Maintenance Costs			
Routine system monitoring and supervision.	Periodic review of system operating parameters, response to remote alarms, adjustments to operating parameters as needed. Routine project management.	FlexEnergy or other operational staff (i.e., Ft. Benning) time.	FlexEnergy labor hours log or estimate.
Consumables	Regularly used products (non-utility) that are consumed during normal use and must be replaced.	Methane used for system startup. Oil, coolant and other consumables for turbine operation. Cost of oxidizer media is part of major overhaul cost.	FlexEnergy accounting.
Maintenance	Includes both scheduled and unscheduled maintenance activities required for Flex operation.	Frequency and costs of actual maintenance during demonstration period, including labor hours, parts, supplies and subcontracts.	Operations and Maintenance Monitoring Log.
Major Overhaul	Costs for major overhaul (labor/parts/supplies) and any costs or loss of revenue for associated downtime.	Estimates to be made based on oxidizer and turbine degradation during demonstration, plus manufacturer's judgment.	FlexEnergy and Ingersoll-Rand estimates.

Cost Element	Description	Data Tracked During Demonstration	Data Source
Hardware lifetime	Useful life of the system required for determination of lifecycle anaylsis time frame	Estimate based on component and oxidizer media degradation during the demonstration and/or manufacturer's estimates.	FlexEnergy and Ingersoll-Rand estimates.
Operator training	Formal training of on-site operators and mechanics to maintain and operate the system during normal operation.	Operator training costs (labor for trainer and operators).	Flex accounting and operator labor rate estimates.
Revenues			
Energy production	Value of electricity produced by the Flex and used within Ft. Benning, including a renewable energy premium.	Electric power production (MWh) and electricty prices, escalation rates and incremental value of renewable energy.	Power metering, electricity prices and escalation rates from sources cited above. Premium rates for renewable energy from DoD and other sources.

8.0 SCHEDULE OF ACTIVITIES

Figure 8 provides a summary of the tasks and schedule for all project activities. The projected schedule includes equipment installation beginning in November, 2010, testing initiated in April, 2011 and continuing through April, 2012, with data analysis and reporting occuring in mid 2012.

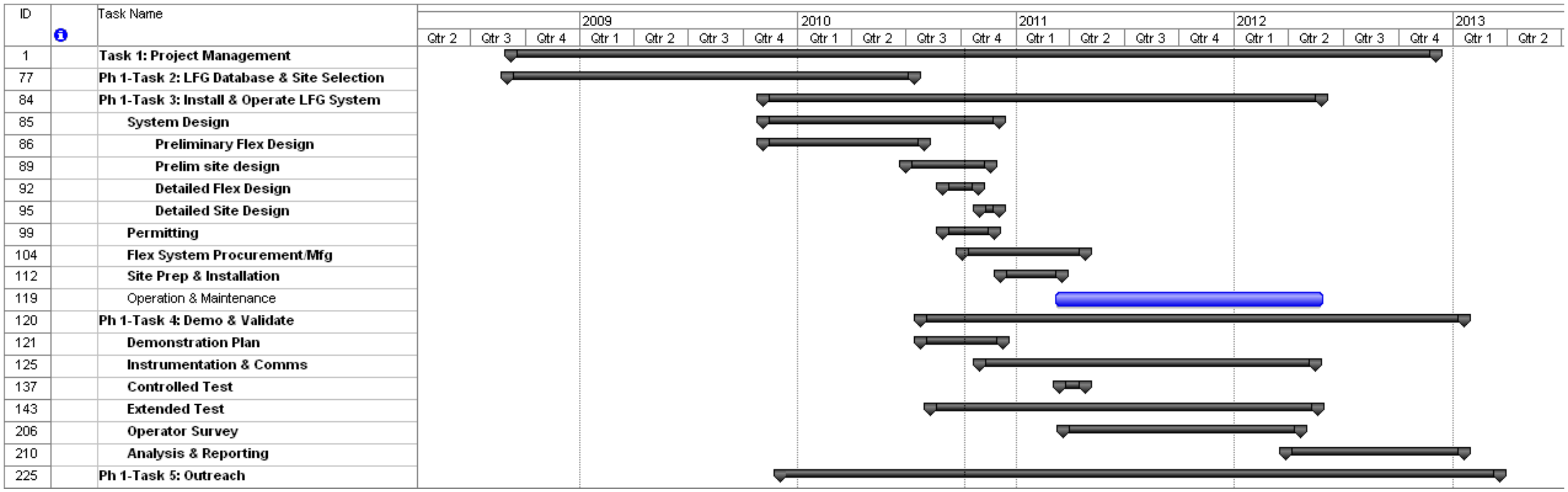


Figure 8. Proposed Project Schedule

9.0 MANAGEMENT AND STAFFING

Figure 9 provides an organization chart for the project staffing. All project team members will report to the Principal Investigator. Staff identified are qualified for the assignments indicated based on educational and on-the-job training experience in demonstration, assessment, analysis, and QA activities. Descriptions of the responsibilities and qualifications of staff are provided in the following section.

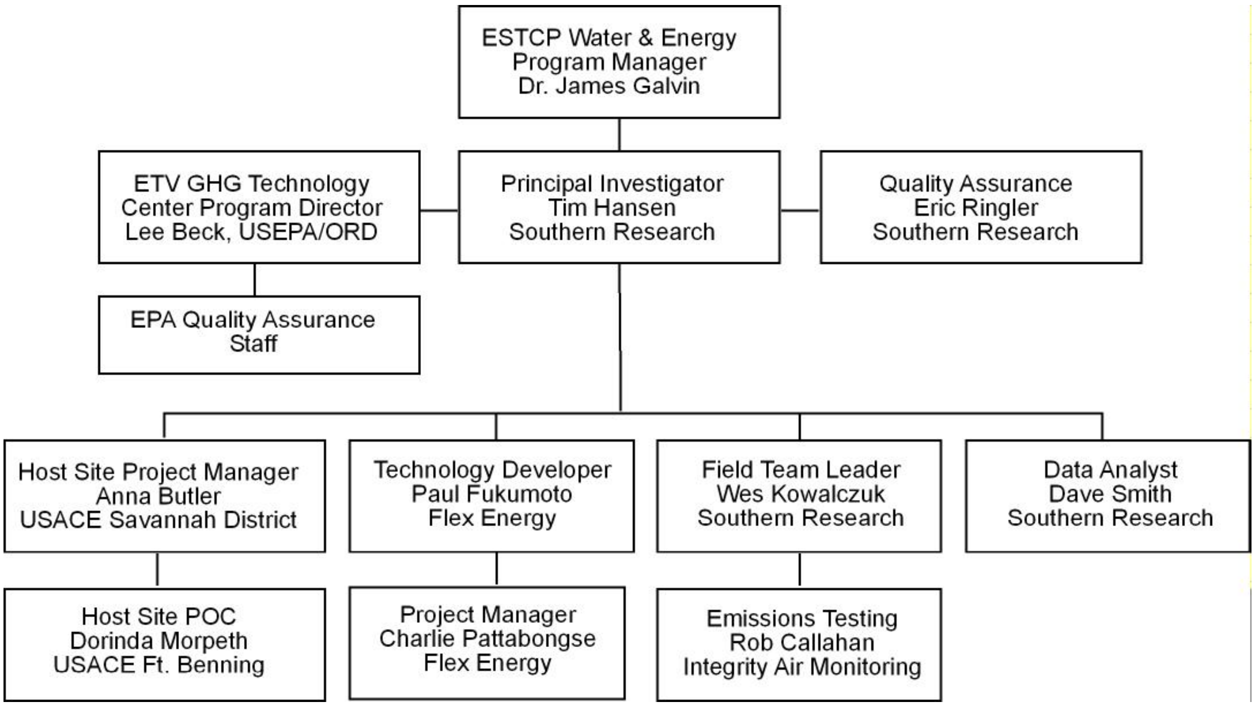


Figure 9. Project Organization and Staffing

Tim Hansen is the Principal Investigator and GHG Technology Center Director. He will:

- ensure manpower and material resources are available to complete the demonstration
- oversee staff and provide management support
- contribute technical expertise and provide guidance to the development and implementation of the demonstration plan, analysis of the data, and reporting of results
- interact with stakeholders, vendors and contractors to ensure goals and milestones are met and maintain effective communications between all participants
- submit Quarterly Progress Reports and Monthly Financial Reports to ESTCP
- review the Demonstration Plan, Final Technical Report and Cost and Performance Report to ensure they conform to ESCTP guidance and ETV principles. Submit these reports to ESTCP
- manage day to day project activities and track the project schedule and budget
- ensure that manpower and material resources are effectively deployed to achieve project activities
- assist in the preparation of Quarterly Progress Reports and Monthly Financial Reports
- ensure that the Demonstration Plan, Final Technical Report and Cost and Performance Report are prepared according to ESTCP guidelines and properly submitted for technical and QA review and approval
- verify that project data and other files are properly collected and stored

- verify that collected data are regularly reviewed and validated as required and that any problems are identified and effectively addressed
- ensure that data analyses are properly conducted in a timely manner and that uncertainties in the data are quantified or adequately characterized and fully reported
- ensure that corrective action is initiated for all issues identified, that problems are resolved and that the impact on data quality is assessed and reported.

Wes Kowalczuk will serve as the Field Team Leader. He will:

- provide field support for activities related to all measurements and data collected
- install and operate measurement instruments
- collect samples and coordinate sample analysis with the laboratory or testing sub-contractors
- ensure that QA / QC procedures and documentation requirements are adhered to
- identify any problems and initiate corrective actions.

David Smith will serve as the data analyst. He will:

- download and otherwise obtain data at prescribed intervals
- review data for completeness and validity
- flag any invalid or suspect data and initiate corrective action as required
- set up data analysis spreadsheets in accordance with this plan
- prepare data summaries and report tables.

The GHG Technology Center QA Manager, Eric Ringler, is administratively independent from the GHG Center Director and project management. Mr. Ringler will:

- ensure that all measurements and testing are performed in compliance with the requirements of this plan
- review test results and ensure that applicable internal assessments are conducted
- assess whether overall data quality is sufficient to satisfy each performance objective
- conduct or supervise an audit of data quality
- document all audit results and submit these to the Project Manager and Principal Investigator
- ensure that the impact on data quality of any problems is properly assessed, documented and reported
- review and approve the demonstration plan and final reports.

Rob Callahan of Integrity Air Monitoring, Inc. will oversee emissions and NMOC destruction efficiency testing according to EPA methods as described in section 5.4.4 of this plan.

EPA NRMRL staff, under the direction of Mr. Lee Beck will provide review and oversight activities including review and comment on the demonstration plan and final Demonstration Report and Cost and Performance Report.

10.0 REFERENCES

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APPENDICES

Appendix A: Points of Contact

Appendix B: Draft Health and Safety Plan (HASP)

Appendix A: Points of Contact

NAME	ORGANIZATION	PHONE	ROLE
Tim Hansen	Southern Research	919-282-1052	Principal Investigator
Paul Fukumoto	Flex Energy	949-636-7023	Program Manager
Anna Butler	USACE-Savannah District	912-652-5515	Technical Manager
Dorinda Mopeth	USACE, Fort Benning, GA	706-545-5337	Environmental Progam Manager

Appendix B: Draft Health and Safety Plan (to be modified based on Ft. Benning Requirements)

Site Name:	1st Division Road Landfill	**Southern Research Site Personnel:**		
Address:	Ft. Benning, GA	**Name1:**		
Contact Name 1:	Dorinda Morpeth	**Home Phone:**		
Contact Phone:	706-545-5337	**Name2:**		
Contact Name 2:	Anna Butler	**Home Phone:**		
Contact Phone:	912-652-5515			
Contact Name 3:	Fred Portofe	**Local Hospital:**	*Medical Center*	
Contact Phone	813-917-7534	**Address:**	710 Center St. Columbus, GA	
		Phone:	**(706) 571-1000**	

Southern Research Safety Officer:	John Baker 919-282-1055
Southern Research Office Contact:	Jennifer Lewis 919-282-1050 Ext. 0
Southern Research Backup Contact:	Tim Hansen; 919-282-1052

Work Description: Install and operate field measurement equipment

Expected Hazards, Hazardous Conditions, or Potentially Hazardous Systems:

- ☐ Flying fragments, dust, or dirt
- ☐ Extreme ambient heat or cold
- ☐ Illumination or work lighting
- ☒ Climbing, scaffolding, or access
- ☒ Lifting or material moving
- ☐ Noise
- ☐ Splashes or spills
- ☐ Breathing or atmospheric hazard
- ☐ Radiation (IR) Hazards
- ☒ Electrical wiring
- ☒ Power systems; 480 VAC
- ☒ Falling objects, bumps, pinch points

Engineering, Personal Protective Equipment, or other methods to address each expected hazard checked above:

IMPORTANT: All Southern Research field personnel must wear long sleeve shirts, trousers, and leather or other hard closed-toe shoes (not tennis or running shoes) during testing. Rings and other jewelry should be removed during field activities. Head coverings are recommended at all times.

-- Climbing, scaffolding, or access: Climbing to install and remove test equipment, as well as during testing, will be unavoidable. Southern Research site personnel will exercise extreme caution and will seek assistance from local site personnel. Southern personnel also have a lanyard and harness that they will take with them to use if necessary.

-- Lifting or material moving: Manual handling of the packed boxes is unavoidable, and they will be heavy. Southern Research site personnel will seek local assistance if necessary to move heavy items.

-- Electrical wiring: A qualified electrician will make all connections for power meters involving high voltage. Southern personnel will only be involved in installation of low voltage signal cabling.

All Southern Research personnel and contractors will comply with site standards and requirements regarding personal protective gear and safe operating practices. Southern Research personnel will comply with all Southern Research Standard Operating and Safety procedures. In addition adequate precautions will be taken to protect against insect bites and sunburn. Site incident reporting requirements and procedures will be obtained and attached to this document before work commences.

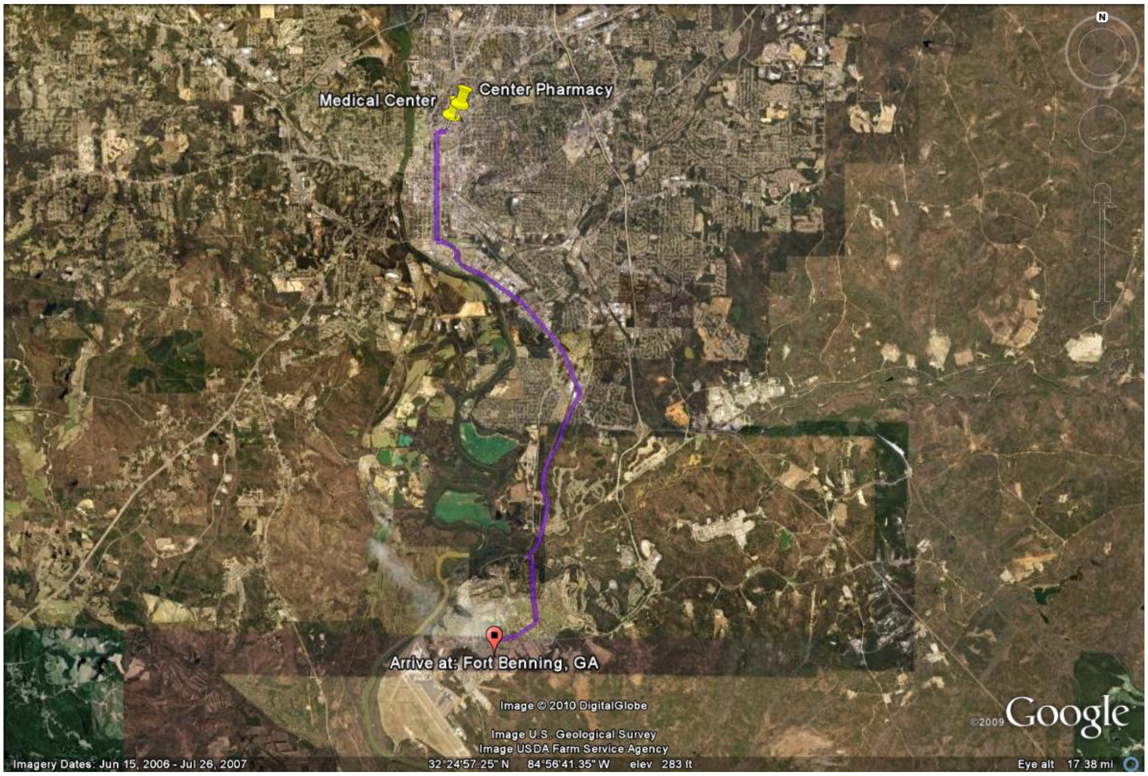

Figure 8: Emergency Services Location

The nearest pharmacy is at the *Center Pharmacy* at 1005 Tallbottom Road Columbus, GA. (Phone: **(706) 327-8967**.) The pharmacy is located 11.2 miles from the host site. *Medical Center*, at 710 Center St. Columbus, GA Phone: **(706) 571-1000** is the nearest hospital emergency ward located 11 miles from the host site. Both are marked on Figure 4.