Interconnect Guide for Renewable Natural Gas (RNG) In New York State

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Interconnect Guide for Renewable Natural Gas in New York State
Scope & Applicability: A Foreword from the Northeast Gas Association

The objective of this document is to provide the technical framework and guidance necessary for introduction of renewable fuels, such as renewable natural gas (RNG), into the pipeline network. RNG is a product of anaerobic digestion or gasification of a wide variety of waste products. These include dairy/animal residuals (e.g., manure, etc.), landfill biomass material, wastewater treatment produced gases; digestion of agricultural wastes and, in advanced systems, co-digestion of mixed biomass substrates. Digestion or gasification of biomass material results in “raw” biogas production (a gas which contains up to 68% methane); the product suitable for introduction to the natural gas pipeline network is, for the most part, processed biogas (termed “RNG”), where constituents potentially problematic to pipeline integrity and end-use applications are treated to acceptable levels. Over the past decade, significant research has been conducted to better understand the similarities and differences in biogas composition relative to traditional pipeline quality natural gas delivered into the northeast region. In parallel, significant technology advancements have been achieved in processing and treating raw biogas to address trace constituent concerns of end-users making processed biogas, or RNG, compatible with local gas distribution system and end-use requirements. This document is intended to encourage maximizing acceptance of RNG into the pipeline grid by using a “good science & common sense” approach to bridge both policy and technical concerns of project developers and pipeline operators.

Although fundamental interchangeability criteria have been established for alternative gases including biogas/RNG, lack of a consistent approach to evaluating acceptance criteria has proven to be a barrier to wide-scale acceptance of RNG directly into distribution networks. This Guidance Document provides an evaluation process including a list of potential constituents of concern based on biomass feedstock. The approach helps eliminate a “one size fits all” solution to acceptance by focusing on specific, reasonably expected raw gas constituents relative to pipeline natural gas. The process then looks at the proposed clean-up technology to help optimize clean-up solutions relative to reasonably expected constituent levels presently found in flowing pipeline supplies. A user-friendly technical framework is provided to help minimize reduce overall operational risk for both the developer and pipeline operator, thereby minimizing potential impacts to end-use consumers.

This framework includes the following elements:

- Interconnect Agreement Evaluation Process Flow Diagram
- Producer/Developer & Pipeline Operator Assessment Checklists
- Gas Quality & Interchangeability Management Program Matrix
- Raw Biogas & Upgraded RNG Trace Constitutes Measurement Matrix & Sampling Plans

Finally, the document provides a comprehensive list of technical references that support the overall suggested process approach to accepting renewable natural gas supplies into the distribution network. The appendix contains a sample Engineering Service Agreement and Gas Sales Agreement (Interconnect Agreement). These sample agreements serve as a starting place in the evaluation and gas acceptance process and provide essential elements for project/company specific agreements. The ultimate goal of this document is to minimize technical uncertainty and perceived risk by both developers and pipeline operators to the extent the industry can maximize acceptance of this valuable energy resource.
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Renewable Natural Gas Interconnect Agreements
A Guideline for RNG Producers

In his 2016 State of the State speech New York Governor Andrew Cuomo announced an aggressive drive towards incorporating renewable energy into the state’s energy portfolio. Cuomo said clean energy is a business opportunity for the state, as well as an important step to address increasing climate change challenges. He already announced in 2015 that he supports New York getting half of its power from renewable energy within 15 years. New York City already has a goal of powering 100 percent of City government operations from renewable sources of energy.

Renewable natural gas (RNG), or biomethane (another term for RNG), derived from landfills, waste water treatment plants (WWTPs), dairy farms, food waste processors, gasifiers, and other sources can be positioned to become an important part of meeting renewable energy challenges in New York State. This type of gas RNG is already being accepted and used in many parts of the state. Introduction of RNG directly into a gas distribution system has been successfully practiced for over 30 years from that the Fresh Kills landfill on Staten Island landfill and it is being proposed at the Newtown Creek waste water treatment plant (WWTP) in the New York metro area Brooklyn. Many other facilities are using RNG-biogas for electricity generation on site. Today, other companies are considering RNG as a fuel of choice and part of the overall equation in meeting renewable energy needs. This is an opportunity to shape the energy future of New York, recovering a valuable fuel resource while eliminating reducing the release of greenhouse gases to the environment.

Throughout the state, RNG project developers are in discussion with gas distributors (pipeline operators). But the processes, requirements, and agreements are not uniform, resulting in commercial and technical uncertainty for both parties that inhibits maximum enhanced recovery and utilization of this valuable resource. A consistent approach is needed to assess the commercial and technical viability of each project that encourages and maximizes enables introduction of all types of RNG made from a range of waste sources into the pipeline system without compromising pipeline safety or reliability of the pipeline grid. This approach will bring certainty for all parties involved in negotiations with regard to safety, reliability, continuity, and interchangeability. It will define the requirements to keep gas flowing and avoid service interruption. It will help project developers and RNG producers by providing a standardized framework throughout the state that can be used to reduce uncertainty around what is needed from a technical perspective to optimize biogas processing facility design.

This document is intended to outline a structured approach that all parties can use to begin the critical process of technical collaboration processes necessary to understand each other’s requirements and ultimately, to make each biogas development project a success story for all involved parties. It lays out what the distinct roles and responsibilities of the pipeline operator and the project developer/producer should be, and offers a common technical framework describing what each party needs to accomplish. Successful and sustainable introduction of RNG into the natural gas network often depends on multiple variables beyond specific gas quality.
objectives. Defining these variables and their impact on a project will lead to productive dialog between all parties.
Introduction – RNG Gas to Grid

RNG is pipeline quality gas that is fully interchangeable with natural gas. It comes from the product of raw biogas after the biogas has been cleaned-upgraded to pipeline quality of impurities. Raw biogas contains varying amounts of methane and carbon dioxide along with other gases and small amounts of trace constituents that must be removed, most often using one of three common biogas upgrading technologies: pressure swing adsorption (PSA), physical solvent scrubbing (with organic glycols or amines), and gas separation membranes. Raw biogas contains varying amounts of methane with other gases, along with small amounts of trace constituents.

There are two basic types of raw biogas. The first is the more traditional type that comes from anaerobic digestion. The second is derived from biomass gasification.

Anaerobic (oxygen-free) digestion based biogas is produced from a basic two step mechanism independent of the source waste material. Aerobic microorganisms contained in all decaying matter initially react with oxygen from entrapped air. Once the oxygen is depleted, an anaerobic environment is created that allows for the remaining organic material to decompose and be converted into biogas. Potential waste-derived biogas sources are solid waste (landfill/municipal facilities and food waste), WWTPs, and animal manure. The raw biogas from anaerobic digesters is often flared off, or used to generate electricity on-site.

The second source of biogas is from gasification of biomass feedstocks such as wood waste, coal, coke, bagasse, and other biologically-derived sources. Gasification is the process of a high temperature conversion process that transforms organic material into a biogas syngas that can be further methanized and cleaned into RNG.

In contrast to Europe, biogas utilization remains relatively limited in the United States. However, there is heightened interest in upgrading biogas to RNG and more fully utilizing this valuable and versatile renewable resource. In contrast to Europe, biogas utilization remains limited in the United States. Lately, there is heightened interest in fully upgrading biogas to RNG and more fully utilizing this valuable renewable source. The three most common biogas upgrading technologies are: pressure swing adsorption (PSA), physical solvent scrubbing (with organic glycols or amines), and gas separation membranes.

Biogas is recognized as a valuable, relatively untapped resource which, when upgraded to acceptable pipeline quality levels, becomes RNG is an interchangeable low carbon-neutral product with broad sustainability implications/benefits.

Commercial and Contractual Relationships
The two main parties involved in an RNG interconnection project are the project developer/producer (who recovers, processes, and sells the RNG) and the pipeline operator (who receives RNG for purchase, and/or transportation for purchase, by another party for end use).

The developer/producer is responsible for project development, which includes producing and upgrading the gas to meet pipeline specifications. The producer may be the digester owner, or it may be the upgrade process developer, or even a third party who has contracted with one of the above. In some cases, it may be a gas utility.

The pipeline operator owns and operates the pipeline system that would receive the RNG. For the purposes of this document, the pipeline operator may be a Local Distribution Company (LDC) or utility, or it may be an interstate pipeline transmission company who transports gas to the LDC.

In most cases, it is not the intention of the pipeline operator to own or operate the biogas conditioning and/or upgrading facility. The developer/producer is typically the owner of any gas treatment system (prior to gas entering the LDC gas distribution system). While regulatory compliance with New York State Code Title 16, Chapter III 16 NYCRR Part 229 standards for pipeline injection of any gas source for distribution to consumers is the utility or pipeline operators responsibility, the developer/producer is solely responsible for ensuring that upgraded RNG intended for pipeline injection meet these statutory requirements as well as any other requirements of the pipeline operator.

Social and Economic Benefits of RNG Recovery

The social benefits of using RNG are numerous. Depending on the feedstocks used to generate RNG, it can be a ‘net carbon neutral’ or even ‘net carbon-negative’ or low carbon energy source because the carbon released by its combustion comes from carbon already fixed from the natural carbon cycle (i.e. contained in recently living biomass).

Using the methane generated from natural decomposition to make RNG often prevents it from degrading in an open environment and leaking into the atmosphere, especially at dairy farms and other agricultural operations. There is a definite environmental benefit from capturing this gas instead of flaring or venting it, since greenhouse gas (GHG) emissions are reduced, and the final waste stream is cleaner and less polluting. The amount of organic waste disposed in landfills will be reduced because the waste is being diverted into RNG gas projects. Overall air quality is improved.

When the recovered methane is burned to produce heat and energy, the by-products are carbon dioxide (CO₂) and water. While CO₂ is also a greenhouse gas, its impact is considerably less than methane. Combustion of RNG reduces the GHG impact by over 20 times (based on global warming impact calculations for the next 100 years).

Recovering RNG also makes economic sense. Construction, operation, and maintenance of RNG gas production plants create new jobs and stimulate the local economy. Financial payments stay

Commented [MPT8]: While this may be true for a food waste or dairy digester, landfills typically have a 70-85% methane capture rate, which do not include losses during collection or at transfer stations.

Commented [MPT9]: RNG on its own does not drive LF diversion. Landfills are by far the largest source of RNG today, and will continue to produce significant volumes of gas into the future. Regarding air quality, on what basis is this claim being made?
within New York State, to the benefit of municipalities and businesses. Producing, recovering, and using RNG increases the security and diversity of energy supplies in the United States.

**Essential Elements of Getting Connected**

There are a few essential steps in the process for getting an RNG project connected to the pipeline grid. It is recommended that the project developer/producer engage with the pipeline operator 18-24 months in advance of the desired in-service date. Figure 1 shows the basic process. A more detailed flow diagram is found in Appendix A.

![Diagram](image.png)

**Figure 1: Sequence of Events in Getting Connected**

The first step is the Preliminary Evaluation. This is a high-level concept feasibility assessment focused on the ability of a pipeline operator to receive gas into its distribution or transmission system based on the interconnection location and associated system flow capacity. The developer/producer will contact the pipeline operator and describe the project. The more providing as much information that can be provided at this point will make the process go as quickly and smoothly as possible. At a minimum, the preliminary project scope description should include:

- Proposed facility Location,
- Anticipated interconnect pressure,
- Temperature,
- Pipe size,
- The required gas specifications (heating value and specific gravity),
- Production flow rates (net anticipated hourly/daily flow rates),
- Any RNG expected deliverability of gas to the pipeline operator (including daily/seasonal variations if any), and
- Any other key process variables.

The pipeline operator will make a high-level go/no-go appraisal based on the preliminary information provided. If the pipeline operator’s analysis indicates sufficient capacity, determines that the project has potential at the desired interconnect location, and the project developer indicates the pipeline connection cost to workable, estimate the process will move to the next step, which is for the pipeline operator to provide a draft interconnection agreement and for the pipeline operator execution of an Engineering Services Agreement (ESA) to perform a deeper evaluation of the technical aspects of the project, such as pipeline costs, pipeline easement requirements, and seasonal capacity variations, including assessment of biogas feedstock to determine reasonable trace constituents of concern that may impact safety and reliability of the gas pipeline distribution system.

**Commented [SM10]:** The preliminary evaluation should determine pipeline gas capacity and a rough interconnection cost estimate. There should be no “High-level Go/No go”, only an economic evaluation. If the party funding the project wants to proceed, then an engineering feasibility analysis should be conducted by the utility while the Interconnect Agreement is being negotiated. Once the IA is executed, the pipeline is built, tested, then commissioned.

**Commented [SM11]:** RNG specifications should not be case-by-case. The pipeline operator should have an established specification, ideally one proven to be operationally acceptable by long-term RNG receivers such as Atmos Energy, Columbia Gas, Dominion, Duke Energy, DTE, National Grid, Saginaw Bay, etc.

**Commented [MT12]:** My assumption is that the rationale here is to avoid the CA situation where a developer may be required to test for 70+ constituents of concern. The ABC’s RNG quality specification should be used.
Once engineering feasibility is established, a Gas Sales Agreement or Interconnect Agreement should be negotiated, which highlights mutually agreeable commercial aspects of the project (commodity price, facility maintenance cost sharing agreements, initial and on-going gas quality monitoring and sampling requirements, gas odorization and custody transfer measurement, etc.) Following execution of the GSA, the facility is constructed and its product is vetted as acceptable to the pipeline operator through periodic gas analysis and testing protocols identified in the GSA.

**Engineering Services Feasibility Analysis Agreement**

The initial go/no-go decision includes a broad overview of the developer/producer’s project to provide RNG to a pipeline operator. The initial overview evaluation allows the pipeline operator sufficient information to be prepared to move forward with a more detailed engineering evaluation. There are many regulatory, technical and economic details that a pipeline operator must consider before accepting a new source of gas.

As part of the Engineering Feasibility Analysis SA, the pipeline operator will need more detailed information about the project. The developer/producer will provide a detailed RNG Technical Proposal Summary to the pipeline operator, typically conducted under a Non-Disclosure Agreement (NDA).

Included in the RNG Technical Summary proposal is:

- A description of the chosen gas clean-up technology.
- A RNG project schedule with planned pipeline interconnection.
- Expected RNG production rates, including anticipated periods of flow reductions, including expected downtime due to maintenance, etc.
- Supporting data to validate that the clean-up technology is compatible with the upgraded gas feedstock.
- A detailed analysis of the raw biogas for the presence of contaminants detrimental to the proposed clean-up technology solution, pipeline safety, integrity, end users, and consumers.

The gas analysis information is needed to determine what associated process safety mitigation measures should be incorporated into the proposed system. The concern here is what would happen if a gas processing system abnormal operating condition occurred resulting in breakthrough of constituents that ultimately impact gas quality specifications.

The raw gas analysis must include all reasonably expected trace constituents based on the specific feedstock. Each constituent must be addressed by the chosen cleanup technology such that the chemical “fingerprint” of the gas delivered to the pipeline operator is comparable to pipeline quality gas flowing within the pipeline in proximity to the proposed interconnect location.

Commented [SM13]: A NDA is typically not required for this step.

Commented [MT14]: How can a clean-up technology be chosen without knowing the specifications?

Commented [SM15]: It is very rare for a pipeline operator to be comfortable validating upgrading technology. The GSA should cover the pipeline operator’s risk.

Commented [MT16]: Pipeline operators do not ask for unprocessed natural gas analyses, so they should not require biogas analyses. Pipeline operators also typically do not have experience working with different types of unprocessed gas streams, so it is unfair to expect pipeline operators to be able to analyze biogas.

Commented [MT17]: This is not how conventional natural gas is transferred. As with regular natural gas, RNG should be measured at the transfer point to the pipeline operator to ensure compliance.

Commented [SM18]: The pipeline company should focus on the gas quality of the gas going into their system.
The Engineering Feasibility Analysis should be executed as early as possible after the RNG project developer confirms their wish to proceed after the preliminary evaluation, so that this detailed examination of potential impact on the existing pipeline system and its end-use customers can be quickly determined. Potential impact issues include:

- Examination of pipeline capacity during varying load periods,
- The zone of influence of trace constituent impact (LDCs are advised to be prepared to have a process to evaluate trace constituent impact and resulting potential impact on end-use customers),
- Safety and reliability of the pipeline systems, and
- Impact on therm billing monitoring.

The project developer/producer should be aware that having a pipeline nearby does not guarantee that it can be used for RNG injection. The specific pipeline’s capacity and network configuration must be taken into account. Not all pipelines can handle gas receipt on a routine basis. Making contact with the pipeline operator and agreeing to move forward with an Engineering Feasibility Analysis does not guarantee acceptance of the project.

The ESA may provide reimbursement to the pipeline operator for their engineering services expenses incurred while fully evaluating the Technical Proposal to make an interconnect. Whether or not reimbursement is included will be negotiated by the involved parties. This is a legal contract between the pipeline operator and the project developer/producer.

The pipeline operator commits to a full technical and economic feasibility evaluation of the Technical Proposal. The producer/developer commits to providing complete information and transparency of their RNG upgrade process. The Engineering Feasibility Analysis ESA will include a schedule of communication between the two parties and will designate the technical contacts for the review process.

The next step, after essential elements of the Engineering Feasibility Analysis ESA are satisfied complete and the resulting gas quality proven acceptable, would be finalization establishment of a mutually agreeable Gas Sales Agreement between the producer/developer and the pipeline operator. This should be executed prior to commencing facility construction.

NOTE: While successful completion of the Engineering Feasibility Analysis ESA is key for project success, its completion does not guarantee project acceptance and is non-binding pending successful execution of the Gas Sales Agreement (GSA).

Appendices B, C, and D offer guidance for the assessment process. Appendix E contains an example ESA.

Interconnect Contract or Gas Sales Agreement

Commented [SM19]: The RNG specification should assume some customers receive 100% RNG. Once the 100% RNG case is covered, then all blending cases are covered as well.

Commented [SM20]: Again, the RNG specification should ensure full gas interchangeability, so this is not required.

Commented [SM21]: Pipeline operators do not change conventional natural gas suppliers a fee to assess their system, so this is an unfair burden on RNG developers. If a pipeline operator has a problem charging these costs to their rate base, they should take this up with their regulator.

Commented [MT22]: Again, the ambiguity around this process is concerning. While no two projects are the same, why not create a fillable template associated with the ESA process, and provide transparency around fees associated with each step?

Commented [SM23]: The project developer does not typically have complete information on their upgrading process. Again, the pipeline operator should only be concerned that the RNG meets specification.

Commented [SM24]: This is obvious and does not need to be highlighted.
Once the technical feasibility evaluation is complete and the interconnect is found acceptable, commercial aspects of accepting gas from the proposed facility are negotiated and an Interconnect Contract or Gas Sales Agreement (GSA) is executed. Some pipeline operators may separate the GSA into a Supply Agreement and a Tap Agreement. Occasionally it is recommended that the GSA can be negotiated in parallel with the Engineering Feasibility Analysis (ESA), but in most cases, this phase of project acceptance occurs following successful completion of the ESA. The ESA provides a common platform of technical certainty which facilitates optimization of a commercial agreement.

Essential elements of a GSA include:

- **Pipeline Interconnection cost**
- **Commodity and receipt point O&M (Operations and Maintenance) compensation**,  
- **Delivery obligations** (RNG specification, expected volume, energy content, pressure, temperature, flow rate, etc.),
- **Gas pairing agreements** (contractual blending if applicable),
- **Gas measurement requirements** (schedule and periodicity, equipment, sharing of monitoring information and electronic signals etc.),
- **Operation and maintenance requirements** (monitoring and measurement equipment maintenance, odorization and metering equipment maintenance etc.),
- **Facility access**,  
- **Gas quality monitoring requirements**,  
- **Conditions that impact acceptance of upgraded gas and facility isolation**,  
- **Billing and payment terms**, and
- **Tariff or a special contract for transporting the gas**, this will enable the pipeline operator to facilitate the desired transaction for the producer/developer if the RNG will be sold to a third party.

Appendix F contains an example GSA.

**Project Evaluation and Connection Assessment Process**

Several steps are necessary for a proper project evaluation and connection assessment, and are described in the following sections.

**Producer Preliminary Technical Assessment and Connection Evaluation Request**

The first step in the project assessment process is for the developer/producer to directly contact the pipeline operator. A brief description of the proposed project is needed including:

- Source of biogas (WWTP, landfill, agriculture, food, gasification, etc.),
- Precise site location and who owns the land,
- How much gas will be produced,
- What flow rates are anticipated,
- What pressure will be available.

Commented [SM25]: Typically a single price is provided for the interconnection and line extension.

Commented [SM26]: Conventional natural gas suppliers do not guarantee delivery flow rates and RNG projects do not either.

Commented [SM27]: This is not typically a required of RNG interconnection agreements.

Commented [SM28]: This is not required and typically is part of a separate agreement.

Commented [SM29]: RNG pressure is based on the pipeline requirements only.
• Any seasonality changes to the gas stream, both in composition and availability,
• What cleanup technology is planned to will be used and how efficient it will be, and
• Prior experience with the proposed cleanup technology relative to the biogas feedstock.

The pipeline operator contact person will engage a technical team to perform a high-level technical review of the preliminary proposal. This process may take several weeks. The pipeline operator contact person will then contact the developer/producer to discuss results of the preliminary assessment, which include a pipeline capacity assessment and interconnection cost estimate, typically a "go / no-go" response to proceed to the next phase of evaluation. If the project developer wishes to proceed, proposal is selected for further assessment, the pipeline operator contact can choose to will set up a preliminary review meeting with the developer/producer. The developer/producer may withdraw the proposal at any time.

During this preliminary review meeting, the pipeline operator will go over the next steps including a review of the Engineering Feasibility Analysis ESA, the GSA requirements, pipeline operator specific needs, and any local, state and/or federal regulatory requirements including New York State Code 16 NYCRR Part 229 gas quality standards for pipeline injection. Relevant gas quality information and rationale will be included based on the anticipated biomass feedstock material (see Appendix G for Feedstock/Upgraded Gas Constituent Guidance Matrix).

If the developer/producer decides to continue the process, the Engineering Feasibility Analysis ESA will be executed and the pipeline operator will begin the comprehensive system engineering feasibility study. A schedule for further meetings will be determined along with a timeline for Engineering Feasibility Analysis ESA completion, and discussion of the financial commitment needed from the developer/producer.

**System Engineering Feasibility Study**

The pipeline operator has many variables to assess to ensure a reliable and safe interconnect agreement, including:

1. A pipeline capacity study, including seasonality
2. A pipeline routing, easement, and necessary approvals assessment
3. A pipeline construction schedule
4. A pipeline interconnected detailed cost analysis

1. Will the RNG be aggregated (contractual blending/pairing or in-situ system aggregation) with pipeline gas or will the gas be introduced from a sole source with limited pipeline blending capability?

*Commented [SM30]:* The RNG specification should ensure 100% interchangeability. The capacity study includes existing agreements, existing infrastructure, etc. There have been several studies confirming full interchangeability of 970 BTU/ft³ gas with 1100 BTU/ft³, for example, so the point on Wobbe and Heating Value is not valid.
2. What is the zone of influence? A zone of influence is the geographical area that could be significantly affected by changes in the gas supply, properties, and constituents. It is determined through engineering modeling of the gas flows and pressures. It includes an evaluation of pipeline integrity issues as well as end-use considerations. This approach is similar to how a utility would look at any change in gas quality such as Wobbe or Heating Value.

3. Who would receive the RNG? How will the gas be utilized by potentially sensitive receptors of the gas? An end-user such as a bakery or food processor may not be able to tolerate even a slight change in heat content of the gas or the presence of trace constituents. A customer impact survey may be needed.

4. Can the end-user handle it better if the RNG is blended with pipeline gas? Depending on the interconnect location, this may or may not be feasible.

5. Will accepting the RNG have any impact on other local pipeline interconnects? The project cannot compromise any existing interconnect agreements.

6. Does the proposed connection have sufficient capacity (is the pipeline main large enough)? It is very costly to install new pipelines in the public right of way.

7. Can the pipeline operator accept the proposed quantity of gas? Varying load periods must be considered to ensure sustainable acceptance into the pipeline grid and avoid injection interruptions.

8. Evaluation of the raw gas analysis. If any Constituents of Concern (COC) are found in the raw gas, at what levels should specific actions take place if it breaks through to the RNG?

Feedstock, Pipeline Gas Quality and Safety Assessment

It is important for the engineering staff making the evaluation to understand the RNG feedstock. RNG gas quality concerns will vary depending on the source. Gas from a landfill operation can be different than gas from a biomass gasifier or a dairy. There will be significantly different COCs depending on the source of the biogas (see Appendix G for Feedstock/Upgraded Gas Constituent Guidance Matrix).

As part of the ESA evaluation, the developer/producer will need to provide a comprehensive gas analysis of the raw biogas. This analysis will go beyond the routine determination of major and minor constituents as found in typical natural gas tariffs. The purpose of the thorough analysis is to reasonably define what the COCs are so that impact on the zone of influence can be made and to assess if the proposed treatment is adequate to ensure effective removal of these constituents to reasonable levels, typically defined as comparable to flowing pipeline supplies at the interconnect point. These levels will be up to the developer/producer to maintain.

NOTE: It is the developer/producer’s responsibility to affirm and demonstrate through comparative analysis that reasonably expected COC concentrations (based on feedstock analysis

Commented [SM31]: Compliance to the RNG specification should be the pipeline operator’s concern. Pipeline operators are not experts in raw biogas and biogas upgrading technologies and should not be expected to become experts.

Commented [MT32]: Once again, how is this possible if a project is only at the design phase?
and/or-prior-processing-experience) are removed and/or limited to concentrations typically found in flowing pipeline supplies in the vicinity of the interconnect location.

The comprehensive raw gas analysis needs to include the following constituent classes. It is also important to test the natural gas supply at or near the proposed interconnect point to provide an equal basis for comparison. Testing should be done by a mutually agreed-upon third-party analytical laboratory service provider and paid for by the developer.

- Major/minor constituents, including hydrogen, with properties calculation (heating-value, Wobbe Number, relative density, hydrocarbon dewpoint temperature),
- Sulfur, both major/minor and trace constituents, especially dimethyl sulfide, hydrogen sulfide and naturally occurring mercaptans including methyl and ethyl mercaptan,
- Ammonia (possible carry-over from gas treatment or breakthrough from raw biogas),
- Reasonably suspected volatile and semi-volatile organics,
- Siloxanes (typically found in raw biogas from landfills and WWTPs).
- Halogenated compounds (for example vinyl chloride and Freon compounds may be found in landfill-derived raw biogas)
- PCBs and pesticides (if necessary, depending on type of biogas)
- Corrosion-causing bacteria and spores (Sulfate-reducing Bacteria (SRB), Acid-producing Bacteria (APB), and Iron-oxidizing bacteria (IOB) are widely considered the most aggressive corrosion-causing bacteria)
- Aldehydes and ketones (commonly associated with biogas odor)
- Volatile metals and mercury
- Temperature
- Moisture content

Each of these COCs has a differing impact on gas quality, interchangeability, public safety, and pipeline integrity. In some cases, the individual constituent may not appear to present a problem. However, the synergistic effect of that constituent in the presence of others could result in an unacceptable condition. Full transparency and disclosure by the developer/producer of the potential for these COCs to be present and the demonstrated compatibility of the proposed treatment system to adequately treat these constituents to levels commonly found in pipeline quality natural gas is essential for any project. The pipeline operator must have a consistent and predictable RNG supply.

One example of a gas quality specification table is shown in Table 1. The specific details of the gas quality specification will be defined by each pipeline operator. Not Detectable, for purposes of this table, is defined as a value less than a mutually agreeable specification concentration, or the lowest detectable level for a standard industry analytical test method.

Commented [MT33]: Using the “lowest detectable level” is fraught with problems, such as test repeatability and lab capability. Using this method is not recommended.

1 For purposes of this document, treated biogas that results in a biomethane product that is interchangeable from a end-use perspective and similar in constituents (both qualitative and quantitative) to pipeline natural gas shall considered commercially free of objectionable materials per AGA Report 4A.
Table 1: Gas Quality Specification Example

<table>
<thead>
<tr>
<th>Gas Quality Specification</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTU Content (Heat Content) [BTU/scf]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wobbe Number</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative Density</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Vapor Content [lb/MMscf]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mercaptans (as Odorant) [lb/MMscf]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrocarbon Dew Point, [°F] CHDP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrogen Sulfide (H₂S)</td>
<td></td>
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<td>Total Diluent Gases</td>
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<td>— Carbon Dioxide (CO₂)</td>
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<tr>
<td>— Nitrogen (N₂)</td>
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<tr>
<td>— Oxygen (O₂)</td>
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<tr>
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<tr>
<td>Aldehyde/Ketones</td>
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</tbody>
</table>

Clean-up Technology Evaluation Summary

The engineering feasibility study will also include an evaluation of the clean-up technology. It is in both party’s best interest to use effective, efficient, and commercial and state-of-the-art methods to produce acceptable RNG from the raw biogas.

The developer/producer will need to provide information about the cleanup technology and plant operations to the pipeline operator, along with the raw biogas analysis, to ensure the proposed cleanup technology is compatible with processing requirements of the raw biogas to the extent that COCs are sufficiently removed. The proposed technology review should include specifications on the efficiency of the clean-up technology. As soon as possible, results of a gas quality analysis on the cleaned RNG should be provided to the pipeline operator. This analysis may be from similar completed projects so long as the raw biogas analysis and feedstock are comparable and the cleanup technology is the same.

Pre-Construction, Construction and Facility Start-up

The pipeline operator must be kept informed on the progress of the biogas clean-up plant construction and specifications. All proper regulatory requirements, construction codes, and
standards for design and installation of safety systems (including gas and fire detection systems, electrical, and instrumentation facilities) must be followed. The pipeline operator should be granted access for periodic progress inspection(s) and compliance with any applicable company engineering standards and practices, and apprised of any changes in the project timeline. Standards and practices may include personnel and process safety procedures and assessments, detection, and security policies, etc. It is suggested that interim meetings be held to discuss the project’s progress at the 50% and 90% completion points, and possibly at other mutually agreed upon points.

Prior to construction, several pre-construction questions need to be addressed and should be included in the GSA. These questions include:

- Facility start-up procedures and plans,
- O&M and safety plans and procedures,
- Discussion of odorization needs and responsibility,
- Final gas quality tariff specifications,
- On-line instrumentation needs,
- Determination of schedule for monitoring of gas quality,
- Identification of necessary sampling points,
- Identification of target COCs for periodic monitoring,
- Initial sampling requirements,
- Follow-up sampling requirements,
- Steady state sampling requirements,
- Trigger levels for specific COCs, and
- Response actions for out-of-compliance supply

Some pipeline operators may separate the GSA into a Supply Agreement and a Tap Agreement and address the questions in those documents.

Facility Operation and Maintenance

Once the project is underway, the developer/producer should be aware of some items that would contribute to successful injection of RNG. These are described in the following sections.

Monitoring, Communication and Notification Requirements

As with all pipeline interconnects, the gas quality and flow rates must be monitored to ensure the gas is meeting the agreed-upon specifications. In cases where the quality has a potential to vary, monitoring is usually performed by on-line instrumentation for essential parameters such as hydrocarbon composition, Wobbe Number, specific gravity and heat content, non-hydrocarbons (inerts and diluents), sulfur compounds (total and speciated), temperature, pressure, and moisture.

Commented [MT34]: Shouldn’t they be aware of any/all “items” associated with a successful project?

Commented [SM35]: All natural gas sources vary. RNG should be held to the same gas testing standards as conventional natural gas.
This information must be made available to the pipeline operator and is usually connected to a Supervisory Control and Data Acquisition system (SCADA). A SCADA process control system gathers data in real time from remote locations in order to control equipment and conditions. A central Gas Control facility continuously monitors gas quality and pipeline conditions through computerized data input and visual inspection.

The pipeline operator must also be notified as soon as possible or within 24 hours of any change in the biogas upgrade process, feedstock change or disruptions, expected system shut downs, and scheduled servicing.

Facility O&M Procedures

A comprehensive, well documented Operations and Maintenance Plan (O&M) of the biogas processing facility is key to ensure sustainable uninterrupted operations. In addition to increasing operating revenue, an effective O&M Plan also extends to the productive lifetime of the assets, resulting in a reduction in the overall capital expenditure as well as environmental risks.

The interface between the upgrading plant and the pipeline interconnect is known as the gas metering station or custody transfer point. It is the “roles and responsibility demarcation point” between the pipeline operator and cleanup facility owner/operator.

O&M plans should include:

- Operating specifications, plans and procedures,
- Point of ownership/demarcation at the metering facility, with a process schematic that denotes major process equipment, critical isolation valves, pressure and flow monitoring equipment, measurement equipment and sample points, odorization equipment,
- Location and control of overpressure protection, critical isolation valves and check valves to prevent backflow,
- Isolation procedures,
- Organization charts, key contact information, phone numbers, and
- Daily facility check-in protocols and communication requirements.

Emergency Plan and Facility Isolation

Should the RNG gas quality fall out of specification, based on established trigger levels that both parties have agreed upon in the GSA, the pipeline operator will have authority to isolate the interconnect to protect their system. Communications with the facility operator will determine the extent of the expected anomaly and how long the plant requires isolation until the internal facility issue related to the anomaly is resolved.

Commented [SM36]: This is not practical. The RNG system operator should inform the pipeline operator of expected outages, but the RNG system operator cannot anticipate all downtime.

Commented [SM37]: Again, the biogas processing facility operation is not the pipeline operator’s concern. The RNG quality and quantity is.
NOTE: All reasonable efforts will be made to keep the facility operational. For short duration low impact anomalies that have limited impact on gas system operations, the pipeline operator may be able to accommodate these types of events occasionally through rerouting of gas supplies and/or pipeline blending. Applying this mitigation measure is at the sole discretion of the pipeline operator and is considered an exception, not the “rule”.

If facility isolation from the pipeline system is necessary, the pipeline operator will notify the facility operator as soon as reasonably possible. The facility operator will need to provide assurance that all gas quality requirements of the GSA are satisfied before gas flow is resumed through the interconnect system.

Gas Measurement Protocols and Instrumentation

The GSA (or Tap and Supply Agreements) will specify which party is responsible for operating and maintaining the measurement facilities. In most cases this will be the facility operator or producer, with SCADA connections to a Gas Control facility. The GSA will also specify the gas measurement basis, i.e. the pressure and temperature that all data will be corrected to and reported as, and whether the gas is to be considered dry or saturated with water vapor. Typical temperature is 60°F and either 14.696 or 14.73 psia.

The required instrumentation for gas analysis consists of basic equipment that is found at all custody transfer points.

- 10-component gas chromatograph
- Odorant/sulfur chromatograph
- Moisture analyzer
- Temperature thermocouple
- Pressure transducer
- Flow rate measurement

Good practice for analytical instrumentation involves writing a Standard Operating Procedure (SOP), training of operators, determination of specific accuracy limits, calibration frequency, performance verification, periodicity of measurements, calculation methods, equipment maintenance procedures, and reporting protocols.

Gas Quality Analysis and Management

The GSA will also specify any gas quality specifications that cannot be reliably measured on-line. These tests involve periodic gas sampling and tests at a specialized laboratory. Delineate additional monitoring requirements for specific COCs that will verify the consistent operation of the upgrading facility. The particular COCs selected for periodic analysis will be based upon their presence in the raw biogas, likelihood for breakthrough from the upgrading technology used, potential pipeline integrity impact, potential human health concerns, interchangeability impact, and any regulatory requirements.
Trigger levels for out-of-compliance test results from specialized laboratories will result in two possible scenarios:

- Additional monitoring requirements if the concentration level of a COC rises above the first action limit. Gas will be accepted, but additional monitoring will be required until periodic testing proves the issue is resolved.
- A secondary gas test to confirm the first reading was not erroneous.
- The gas will be shut-in and the facility isolated if the concentration level is validated to be out of specification for the second test, rises above a second, higher action level, until periodic testing proves the out of compliance issue is resolved.

Monitoring is aimed at confirming that RNG from a discrete system, given a discrete biomass input and gas cleanup technology, can consistently achieve required value ranges for specific compounds in the treated gas.

Usually there will be an accelerated phase of compliance monitoring (3-6 months) for specialized laboratory testing COCs at the beginning of an RNG interconnect project. This is designed to look at potential variation in the gas cleanup system. Maintenance sampling and analysis will be less frequent as the upgrading process and biogas source are shown to be in control. The maintenance schedule should consider expected seasonal variation of gas quality.

This compliance monitoring achieves three goals:

1. The pipeline operator is able to monitor and assure the quality of the new fuel product within the pipeline system based on routine production of the product over a trial period of time,
2. The producer is able to verify that the product is consistent and safe for pipeline interchange, and,
3. Both parties may better understand the nature of specific gas quality parameters and constituents necessary to optimize the cleanup process prior to introduction to the pipeline network.

Samples shall be taken in accordance with mutually agreeable industry accepted practices. Inerted sample containers and specific sorbent materials will be used as necessary for particular constituents as specified in the GSA. Guidance documents for sampling and testing on the exact required trace gases COCs can be found in the Technical References section of this document.

It is recommended that all on-line measurements be available for independent viewing by qualified personnel for verification of quality during the test period. This period of testing and system analysis is for the protection of the receiving pipeline system and it will provide data which assures routine and rigorous gas quality.

Odorization

Commented [SM38]: The concept of 'lower action level' is unfair to RNG. Either the RNG meets specification and it is accepted, or it verified to be out of compliance and is not accepted. If gas utilities decide to impose a 'lower action level' on conventional natural gas, RNG suppliers will do the same.

Commented [MT39]: Routine and rigorous testing? Or consistent gas quality?
It is a federal code requirement (49 CFR 192.625) that all gas that is transported through specified populated areas be odorized as a warning agent so that the gas can be readily detected by a person with a normal sense of smell at a minimum of one-fifth of the Lower Explosive Limit. New York State code (16 CRR-NY 255.625) is even more stringent, requiring odorization at one-tenth of the Lower Explosive Limit for distribution pipeline systems.

The RNG gas being considered for pipeline injection must also be odorized. The pipeline operator will specify the type of odorizer, which odorant to use, and what the odorant level should be. In most cases, the pipeline operator will design, specify, construct and operate the odorization facility as part of the gas metering and monitoring station with cost recovery as noted in the GSA, however, alternative arrangements may be agreed upon and specified in the GSA.

According to 16 CRR-NY 255.625, odorization equipment must be designed and maintained so as to ensure the required odorant level in the gas under varying conditions. The equipment must be installed so that it does not cause a release of fumes to nearby residents. These can be eliminated through engineering controls. The pipeline operator will be responsible for odorizer operation and maintenance. It is recommended that the developer/producer have a high-level familiarity with odorant safety practices in case of an odorant issue onsite.

It is important to keep the biogas upgrading process in control as trace constituents such as lower molecular weight mercaptans, aldehydes, ketones, and semi-volatile organic species can interfere with or mask the odorant smell. Treatment chemicals and solvents from the upgrading process can also be carried over and interfere with odorization.

Commented [SM40]: There is no research to support GTI’s claim here. Until some research or field experience indicates there is a problem, this claim is unsubstantiated.
Technical References


Definitions

The definitions provided here are intentionally limited in scope and are offered for general information only.

**Aerobic Digestion** – Decay of organic matter in the presence of oxygen. It is the first step in microbiological conversion of organic materials to biogas. Aerobic microorganisms contained in all decaying matter initially react with oxygen from entrapped air.

**Aggregation** – Another term for gas blending.

**Aldehyde** – An organic compound which incorporates a carbonyl functional group, C=O, bonded on one side to a hydrogen atom and on the other side to a hydrocarbon group. Aldehydes and ketones are chemically similar. They can be found in waste streams containing building materials such as OSB (oriented strand board), MDF (medium-density fiberboard), carpet and linoleum/vinyl flooring, other pressed wood products, hardwood and plywood paneling, upholstery fabrics, latex-backed fabrics, fiberglass, and urea formaldehyde foam insulation.

**Ammonia** – Ammonia is a colorless inorganic compound of nitrogen and hydrogen with the formula NH$_3$, usually in gaseous form with a characteristic pungent odor. Ammonia is potentially encountered in anaerobic digestion of organic waste.

**Anaerobic Digestion** – Decay of organic matter in the absence of oxygen. It is the second step in microbiological conversion of organic materials to biogas. Once the oxygen is depleted, an anaerobic environment is created that allows for the remaining organic material to decompose and be converted into biogas.

**ASTM** – American Society for Testing and Materials

**Biogas** – The gas resulting from the anaerobic digestion or gasification of biomass. Depending upon the process used and possible conditions of digestion, biogas consists of 40 – 65% methane. The remaining 35 – 60% of the biogas consists of “other” gases, with carbon dioxide being the major other gas along with trace gases including nitrogen compounds (ammonia, etc.), water vapor, sulfur compounds (hydrogen sulfide, etc.) and other constituents, depending upon the biomass used. Biogas is considered “raw” unless cleaned or “conditioned” to meet the requirements of end use or inclusion within natural pipeline systems. “Raw” biogas is not considered suitable for interchange within natural gas pipeline networks.

**Biomass** – Organic materials that may be converted to gaseous fuel through digestion (breakdown) or high temperature conversion (gasification). These materials may include all organic substances, but some biomass materials possess more caloric value than others, thereby producing more energy. Biomass sources vary widely and include domestic wastes, animal wastes, livestock operation residues, forest and mill residues, agricultural crops and wastes, wood and wood wastes, aquatic plants, fast-growing trees and plants, and municipal and industrial wastes.
Biomethane – Another term for RNG. The portion of biogas which consists primarily of methane. Biomethane is generally extracted from raw biogas through cleanup or conditioning, to remove those constituents which impact gas quality. Using effective biogas cleanup (removal of gases which effect overall gas quality), biomethane can be up to 99% methane. Biomethane is considered suitable for many end-use applications and may be considered suitable for inclusion in general pipeline systems, depending upon other characteristics of the gas and specific tariff requirements.

Chromatograph – An analytical instrument that separates a gas sample into its components for measuring and is used to determine gas quality data such as heating value, relative density (specific gravity), and compressibility.

Commercially Free – As defined in AGA 4A, commercially free is a contract term used to qualify objectionable material to the extent the gas is reasonably free of contaminants or constituents that otherwise would interfere or cause harm to the pipeline or would preclude utilization of a gas supply in the ordinary course of business.

Constituents of Concern (COC) – Chemicals that could reasonably be expected to be associated with specific waste streams and be volatilized into the raw biogas, with potential for breakthrough into RNG.

Corrosion-causing Bacteria – See Microbial Induced Corrosion (MIC).

Detection Limit – If a concentration is reported as “below detection limit” (BDL), the analyte was not detected at a concentration greater than the specified detection limit concentration.

Digester (Anaerobic) – A tank, covered lagoon or other covered vessel designed to convert biomass to biogas. Digesters are common to the wastewater treatment industry as well as in farming operations for manure management. Conversion of the biomass in the digester depends upon bacterial degradation or transformation of compounds, both carbon-based and other, to gaseous products, which are then present in the resulting biogas. Digesters vary in complexity and design. The maximum quantity of biogas generated from digestion of biomass is dependent upon the design of the digester (temperature and hydraulic retention time), biologically degradable fraction of the raw material and other factors. Biogas generated through anaerobic digestion of biomass in digesters requires further cleanup prior to use (interchange) within natural gas pipeline systems.

Distributor – The distributor owns and operates the pipeline system. The distributor may be a Local Distribution Company (LDC) or utility, or it may be a pipeline transmission company who sells gas to the LDC.

Engineering Services Agreement (ESA) – An agreement where the distributor or pipeline operator performs a detailed evaluation of the technical aspects of an RNG pipeline introduction project. During this step the producer will provide a detailed Technical Proposal.
EPA – Environmental Protection Agency

Gas Cleanup – Used in reference to cleaning raw biogas resulting from biomass conversion. The goal of the gas cleanup unit is to remove constituents within the raw biogas in order to produce a clean RNG product, suitable for further end use or potential inclusion within gas pipeline networks. Cleanup efficiencies for particular constituents of concern vary between cleanup or “conditioning” units.

Gas Sales Agreement (GSA) – An agreement between the producer and the distributor or pipeline operator for gas purchase. Also known as an interconnect agreement. The GSA will establish the conditions in which supplies will be accepted into the pipeline operator’s pipeline. It will contain the details of the purchasing process including delivery obligations, pricing, gas measurement requirements (schedule and periodicity), operation and maintenance requirements, access, and billing and payment terms.

Gas Separation Membranes – Gas separation membranes use selective permeation, driven by partial pressure differences across the membrane, to separate gas components. Other species are removed by pre- and post-treatment as necessary.

Gasification – An alternate way to produce RNG. Gasification is the process of high temperature conversion of organic material into a biogas that can be further methanized and cleaned into a clean product ready for pipeline injection.

Grab sample – A single sample taken at a specific time or over a short period of time.

Grain – A measurement of weight. 7,000 grains = 1 lb.

GPA – Gas Processors Association

Halocarbons – Organic compounds containing the elements fluorine (F), chlorine (Cl), bromine (Br), and iodine (I), which make up the seventh period in the periodic table of the elements. Compounds which consist of these elements are often used in disinfectant solutions, or as refrigerant gases in air conditioning and other cooling equipment. Upon degradation, the elements may be released as gases.

Heating Value – Gross heating value, also known as Higher Heating Value (HHV), is defined as the amount of energy transferred as heat from the complete, ideal combustion of the gas with air, at a standard temperature, in which all the water formed by the reaction condenses to liquid. Another commonly seen heating value parameter is net heating value, or Lower Heating Value (LHV). The difference between HHV and LHV is that the water produced by combustion remains in the vapor state when determining the LHV. The energy gained by the condensation of the water vapor is not realized so the heating value is lower. Heating values are also often reported as wet or dry. Wet gas refers to gas that is completely saturated with water vapor. A wet gas has a lower heating value per volume than a dry gas because some of the gas volume is occupied by the water vapor,
so the absolute amount of combustible gas is less. The North American Energy Standards Board recommends utilizing the HHV expressed on a dry basis.

**Hydrocarbon Dewpoint Temperature** – The hydrocarbon dew point temperature (HDP) is the temperature of the corresponding state condition at which the non-methane hydrocarbon components of natural gas begin to condense into the liquid phase.

**Inerted Gas Sample Collection Cylinder** – Sample collection cylinders containing an inert coating or otherwise passivated so that the cylinder exhibits very low reactivity to compounds such as sulfur odorants or H₂S.

**Interchangeability** – The ability to substitute one gas for another, in the context of natural gas replacement, without materially changing or influencing environmental health and safety, end use performance, or pipeline integrity.

**Interconnection Agreement** – Another term for the GSA. A business contract between the gas supplier (producer) and utility, pipeline operator, or gas distributor.

**Ketone** – An organic compound which incorporates a carbonyl functional group, C=O, bonded on both sides to a hydrocarbon group. Aldehydes and ketones are chemically similar. They can be found in waste streams containing building materials such as OSB (oriented strand board), MDF (medium-density fiberboard), carpet and linoleum/vinyl flooring, other pressed wood products, hardwood and plywood paneling, upholstery fabrics, latex-backed fabrics, fiberglass, and urea formaldehyde foam insulation.

**Landfill Gas** – Gas which is emitted from the breakdown of materials in a landfill. This gas is considered “raw” and requires upgrade for introduction to the pipeline network.

**Local Distribution Company (LDC)** – A pipeline operator of a distribution system or utility company that typically transports natural gas from delivery points located on interstate and intrastate pipelines to residential households and commercial businesses through smaller diameter and lower pressure distribution pipe.

**Microbial Induced Corrosion (MIC)** – Corrosion caused by bacteria present in a pipeline network. Specific groups of bacteria can produce acids that deteriorate pipes through pitting and oxidation. MIC bacteria groupings include, but are not limited to: sulfate reducing bacteria (SRB), acetic-acid producing bacteria (Acidophiles), including acetic-acid producing bacteria (total group) and butyric-acid producing bacteria (total group), iron oxidizing bacteria (IOB), denitrifying bacteria (DNB), and methanogens—microbes which produce methane (in the Archaea domain). MIC can be very deleterious to pipeline integrity and has been associated with pipeline failure.

**O&M** – Operations and Maintenance
Pipeline Operator – For purposes of this document, the pipeline operator owns and operates the pipeline system. The pipeline operator may be a Local Distribution Company (LDC) or utility, or it may be a pipeline transmission company who sells gas to the LDC.

PCBs – Polychlorinated Biphenyls are synthetic chlorinated chemicals that were produced for approximately 50 years between the 1920s and the 1970s. The mixtures were sold under the registered trade mark of “Aroclor” followed by a 4 digit code. PCB oils used to be used as compressor lubricants for natural gas pipeline transmission lines. In 1976 Congress passed the Toxic Substances Control Act (TSCA) which banned their use.

Physical Solvent Scrubbing – Physical solvents preferentially absorb acid gases (over methane), unlike chemical solvents that react with acid gases. One popular solvent is based on a mixture of the dimethyl ethers of polyethylene glycol (DEPG). Amine solvents can also be used, such as monoethanolamine (MEA), diethanolamine (DEA) and methyl diethanolamine (MDEA).

Pressure Swing Adsorption (PSA) – A process that separates mixtures of gases according to the species' molecular characteristics, affinity for, and attraction to the surface of an adsorbent material. These materials can be molecular sieves (zeolites), activated carbon, silica gel, and/or alumina. In gas cleanup applications, the physical adsorption of CO₂ occurs at high pressure. The process then swings to a lower pressure to desorb the adsorbed gas. In most applications pre- or post-treatment is required to reduce other contaminants such as non-methane organics (NMOCs) and hydrogen sulfide.

Producer – The producer is responsible for producing and upgrading biogas to RNG. The producer may be the digester owner, or it may be the upgrade process developer, or even a third party who has contracted with one of the above.

Relative Density – The relative density of a gas is defined as the ratio of the mass density of the gas to the mass density of air (where the molecular weight of air is defined as 28.9625 grams per mole), both at a defined pressure and temperature. This property, along with the higher heating value, is used to determine the Wobbe Number, an interchangeability parameter that takes both HHV and the relative density of the gas into consideration and accounts for both heat content and gas flow through a fixed orifice.

RNG or Renewable Natural Gas – Another term for biomethane. The portion of biogas which consists primarily of methane. RNG is generally extracted from raw biogas through cleanup or conditioning, to remove those constituents which impact gas quality. Using effective biogas cleanup (removal of gases which effect overall gas quality), RNG can be up to 99% methane. RNG is considered suitable for many end-use applications and may be considered suitable for inclusion in general pipeline systems, depending upon other characteristics of the gas and specific tariff requirements.

RNG Verification Testing Program – A period of time in which the gas resulting from an RNG production process is subject to analytical testing and review, to confirm RNG quality.
program is advised, as the quality of biogas and RNG varies with process design, biomass input, choice of cleanup unit and other parameters. The verification program should be executed prior to introduction of the RNG product to the natural gas system, so that analytical compliance may be demonstrated over a period of time.

Supervisory Control And Data Acquisition (SCADA) – A SCADA process control system gathers data in real time from remote locations in order to control equipment and conditions. A central Gas Control facility continuously monitors gas quality and pipeline conditions through computerized data input and visual inspection.

Siloxane - Any chemical compound composed of units of the form R₂SiO₂, where R is a hydrogen atom or a hydrocarbon group. A siloxane has a branched or unbranched backbone of alternating silicon and oxygen atoms, -Si-O-Si-O-Si, with side chain R groups attached to the silicon atoms. The word siloxane is derived from the words silicon, oxygen and alkane. Siloxanes can be found in products such as cosmetics, deodorants, water repelling windshield coatings, food additives and soaps. When combusted, the siloxane molecules are reduced to silica dust; this is extremely abrasive and damaging to internal engine components. The combustion process can cause a build up around burner tips and on the tubes of heat exchangers. Silica dust may also pose health risks to humans and other receptors.

Transmission Company – The company that owns the interstate and/or intrastate natural gas pipeline network which transports processed natural gas from processing plants in producing regions to areas with high natural gas requirements. A transmission company can also own an LDC or utility.

Volatile and Semi-volatile Compounds – Biogas produced from landfill biomass sources typically consists of methane and other major components but can also contain hundreds of other chemicals - most of which are known as "non-methane organic compounds" or volatile or semi-volatile organic compounds (VOCs and SVOCs). These are typically compounds containing carbon, hydrogen, and sometimes oxygen. Many non-halogenated VOCs and SVOCs are present in natural gas as well, originating from the geological basin from which the gas was extracted.

Volatile Metals – Volatile metals refers to a group of mostly toxic metals that have high atomic weights. Some are always toxic (e.g. lead, mercury, cadmium, arsenic, chromium) and others are toxic at high concentrations (e.g. zinc, copper). They are found everywhere in the environment because they are naturally part of the earth’s crust or are concentrated in waste streams due to the use of a compound that incorporates a heavy metal element. When a compound that contains a heavy metal is degraded, the element can be released as a toxic gas.

Wobbe Number – An interchangeability parameter that takes both the higher heating value and the relative density of the gas into consideration and accounts for both heat content and gas flow through a fixed orifice. The Wobbe Number is calculated by dividing the HHV by the square root of the relative density. Differences in the relative density, and by extrapolation the Wobbe
Number, generally come from the presence of other hydrocarbons or diluent and inert gases such as carbon dioxide or air (nitrogen plus oxygen).

**WWTP** – Wastewater Treatment Plant. A WWTP facility treats household water waste (sewage) and can be an effective biogas source through an anaerobic digester. This gas is considered “raw” and requires upgrade for introduction to the pipeline network.

**Zone of Influence** – The geographical area that could be significantly affected by changes in the gas supply. It is determined through engineering modeling of the gas flows and pressures. It is an evaluation of pipeline integrity issues as well as potential gas storage and End Users.

*Commented [SM49]: This concept is irrelevant if the RNG is specified to be interchangeable.*
Commented [SM50]: This process needs to be redone to reflect the same process a conventional natural gas interconnection would follow.
Appendix B – Producer and Pipeline Operator Assessment Process Checklists

The purpose of this checklist is to provide a worksheet of items to consider when assessing the producer’s technical proposal.

A. Who are the parties who are entering into the contract
B. Assignment of a project manager (technical contact) from the producer
C. Assignment of a project manager (technical contact) from the pipeline operator
D. Physical location of the receipt/delivery point
E. Agreement of producer to allow access to site where applicable
F. Description of the process
   i. Anaerobic digester gas type (dairy, WWTP, food waste, landfill) or gasification feedstock
G. Definition of any technical terms
H. Regulatory requirements, as necessary
I. Discussion of New York State Code NYCRR Chapter 03 Gas Standards Part 229 standards for pipeline injection
J. Liabilities
K. Agreement to forward any new information regarding the project and amend the ESA when appropriate
L. Periodic meeting schedule
M. Description of requirements that the pipeline operator needs to provide to the producer
   i. Company standards for the developer to follow (electrical, instrumentation)
   ii. Company specifications for metering
   iii. Technical assistance as needed for analytical instrumentation
   iv. Odorant design and specifications (utility will operate odorizer but developer is responsible for installation and costs)
   v. Any other engineering and technical assistance
N. Description of requirements for the producer (equipment and facilities required for the project that is provided by producer and specified by the pipeline operator)
   i. Gas service and associated metering equipment
   ii. System tie-in equipment
   iii. System to remotely transmit gas quality and flow data to utility
   iv. On-line gas analysis equipment and associated necessities
   v. Commitment as to reading, cleaning, repairing, inspecting, testing, calibrating, adjusting the equipment
   vi. Remote shut-in capability
   vii. Odorizer and associated necessities
O. Estimation of the cost to be paid by the producer to the pipeline operator
   P. IP agreement
   Q-P. Agreement to follow “Good Utility Practice”
   R.Q. Insurance agreement
   S.R. Expiration date and termination terms

Commented [SMS1]: This is not required
Appendix C – Gas Quality and Interchangeability Management Program Matrix

The purpose of this matrix is to provide a checklist of items to consider when developing the gas quality and interchangeability management program. The goal is to optimize gas quality, maximize gas supply, and to avoid problems with the pipeline infrastructure, end-use applications, and consumer health and safety. Information was extracted from AGA’s Natural Gas Quality Management Manual. It is recommended to consult this manual for more detailed information.

The management plan will look at the raw biogas composition and make science-based decisions on potential breakthrough of COCs from the gas cleanup process, and any detrimental impact that such breakthrough may incur. Constituent and parameter limits are established that will strike a balance between all of the stakeholders involved.

A gas quality management plan should:

- Identify requirements
- Determine procedures to ensure compliance
- Identify response actions and/or corrective actions for anomalies/noncompliance
- Establish data retention schedules to support compliance

It is advised to conduct an overall interchangeability assessment for each project to determine what the range of acceptability should be. This assessment should include at a minimum an assessment of:

- Historically delivered supplies into the market area with respect to gas quality constituents and parameters that define interchangeability,
- Historical effects of anomalies or upsets in gas processing and system aggregation of the market area,
- Records of pipeline infrastructure, end user complaints, and storage operation problems potentially linked to gas quality issues into the market area,
- the proposed biogas cleanup technology and maximum constituent concentrations that may be present in the proposed substitute gas,
- The cleanup system and balancing of concerns of potentially sensitive end users
- The history of end users requirements, equipment upgrades, and appliance re-adjustment in the market area,
- A comprehensive review of federal, state, and local regulatory requirements; internal operating procedures; and tariff requirements,
- A model of the zone of influence of the proposed substitute gas and determination if the aggregated supply profile meets tariff and/or contract requirements, and
- Any sensitive receptors within the zone of influence.

Prior to introduction to the natural gas pipeline network, it is suggested that the RNG be monitored for quality for a discrete test period. Depending upon the specific tariff requirements pertaining to any individual company receiving the gas, this test period may vary in length. It is
recommended that the test period be executed prior to introduction to the natural gas pipeline network. Any product flaring should be done in compliance with federal, state and local codes.

This Verification Program achieves three goals:
- The pipeline operator is able to monitor and assure the quality of the new fuel product and the routine production of the product over a trial period of time,
- The producer is able to verify that the product is consistent and safe for pipeline interchange, and,
- Both parties may better understand the nature of specific gas quality parameters and constituents necessary to optimize the cleanup process prior to introduction to the pipeline network.

Modern on-line instruments provide continuous real-time or near-real time monitoring, and readings should be performed as frequently as can be done reliably and with quality results possible. The natural gas industry measures BTU content at custody transfer points because gas is sold on an energy basis, not a volume basis. Since the on-line BTU analyzer is commonly a gas chromatograph, its use will also provide data on methane and other hydrocarbons present, as well as nitrogen, oxygen, and carbon dioxide.

An on-line temperature probe, pressure transducer, and moisture analyzer must be installed, as well as a sulfur analyzer with capability to measure both H2S and total sulfur at a minimum. Testing for MIC bacteria, and total bacteria and spores is also advised on a monthly basis throughout the test/verification period for anaerobic digester-derived RNG.

Other COCs traced in Appendix D should be tested on a spot sample retrieved when the verification period begins. Samples should be collected monthly during the verification period for at least three months.

Once verification of minimum gas quality has been determined, a “maintenance” testing schedule can be established. The maintenance schedule should cover seasonal variation of the gas quality and should be a minimum of three months. Trigger levels for COCs trace gases will be established during the maintenance period.

Trigger levels for out-of-compliance testing will result in two possible scenarios:
- Extra monitoring will be required if the concentration level of a COC rises above the first action limit. Gas will be accepted, but additional monitoring will be required until periodic testing proves the issue is resolved.
- The gas will be shut out if the concentration level rises above a second, higher action level, until periodic testing proves the out of compliance issue is resolved. A secondary gas test to confirm the first reading was not erroneous.
- The gas is shut-in if the concentration level is validated to be out of specification for the second test.
Once the maintenance testing schedule is complete, on-line verification of BTU content, moisture, temperature, and sulfur content should be maintained to provide continuous confirmation of gas quality to the receiving pipeline system.
### Appendix D – Raw Biogas and Upgraded RNG Trace Constituents Measurement Matrix

The table below lists some recommended parameters and their testing frequency for the initial RNG Verification Program. The following table details some on-line and off-line analysis methods.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating Value</td>
<td>Continuous real-time or near-real time monitoring and periodic field samples for independent confirmation.</td>
</tr>
<tr>
<td>Temperature</td>
<td>Continuously measured on-line</td>
</tr>
<tr>
<td>Pressure</td>
<td>Continuously measured on-line</td>
</tr>
<tr>
<td>Water Content</td>
<td>Continuously measured on-line</td>
</tr>
<tr>
<td>Sulfur, including Hydrogen Sulfide</td>
<td>Continuous real-time or near-real time monitoring and periodic field samples for independent confirmation</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>Continuous real-time or near-real time monitoring and periodic field samples for independent confirmation</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>Continuous real-time or near-real time monitoring and periodic field samples for independent confirmation</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>Continuous real-time or near-real time monitoring and periodic field samples for independent confirmation</td>
</tr>
<tr>
<td>Oxygen</td>
<td>Continuous real-time or near-real time monitoring and periodic field samples for independent confirmation</td>
</tr>
<tr>
<td>Biologicals</td>
<td>Monthly testing for MIC bacteria, and live and dead bacteria and spores is advised through the test period for anaerobic digester-derived RNG</td>
</tr>
<tr>
<td>Mercury</td>
<td>Minimum of three samples over a three month period, with increased frequency, depending upon concentration at first sample point</td>
</tr>
<tr>
<td>Siloxanes</td>
<td>Minimum of three samples over a three month period, with increased frequency, depending upon concentration at first sample point</td>
</tr>
<tr>
<td>Semi-volatile and Volatile Compounds</td>
<td>Minimum of three samples over a three month period, with increased frequency, depending upon concentration at first sample point</td>
</tr>
<tr>
<td>Halocarbons</td>
<td>Minimum of three samples over a three month period, with increased frequency, depending upon concentration at first sample point</td>
</tr>
<tr>
<td>Aldehydes and Ketones</td>
<td>Minimum of three samples over a three month period, with increased frequency, depending upon concentration at first sample point</td>
</tr>
</tbody>
</table>

Commented [SMS4]: These tests do not line up with the ABC’s recommendation for pipeline quality RNG.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating Value</td>
<td>ASTM D3588 (on-line, or off-line canister collection*)</td>
</tr>
<tr>
<td>Water Content</td>
<td>ASTM D5454 (on-line only)</td>
</tr>
<tr>
<td>Sulfur, including Hydrogen Sulfide</td>
<td>ASTM D6228, D5504 (off-line canister collection)</td>
</tr>
<tr>
<td></td>
<td>ASTM D4084 (H$_2$S on-line) and D4468 (total S on-line)</td>
</tr>
<tr>
<td></td>
<td>ASTM D7493 (on-line sulfur speciation)</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>ASTM D1945, D1946 (usually only off-line gas chromatographs can measure hydrogen, canister collection)</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>ASTM D1945, D1946 (on-line, or off-line canister collection)</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>ASTM D1945, D1946 (on-line, or off-line canister collection)</td>
</tr>
<tr>
<td>Oxygen</td>
<td>ASTM D1945, D1946 (on-line, or off-line canister collection)</td>
</tr>
<tr>
<td>Biologicals</td>
<td>NACE qPCR (off-line with gas filter collection)</td>
</tr>
<tr>
<td></td>
<td>NASA NHB 5340.1D (off-line with gas filter collection)</td>
</tr>
<tr>
<td>Mercury</td>
<td>ASTM D5954, D6350 (gold sorbent, on-line and off-line)</td>
</tr>
<tr>
<td>Siloxanes</td>
<td>Gas chromatography (off-line canister collection) with atomic emission detection (GC-AED), mass spectral detection (GC-MS), or vacuum ultraviolet absorption detection (GC-VUV)**</td>
</tr>
<tr>
<td>Semi-volatile and Volatile Compounds</td>
<td>EPA TO-14, TO-15 (off-line)</td>
</tr>
<tr>
<td></td>
<td>Canister collection (volatiles)</td>
</tr>
<tr>
<td></td>
<td>XAD sorbent media (semi-volatiles)</td>
</tr>
<tr>
<td>Halocarbons</td>
<td>EPA TO-14, TO-15 (off-line canister collection)</td>
</tr>
<tr>
<td>Aldehydes and Ketones</td>
<td>EPA TO-11 (off-line DNPH sorbent)</td>
</tr>
</tbody>
</table>

* Canister collection refers to a sample collected in a sample cylinder, Summa canister, or other device.

** ASTM standard expected to be balloted for these three techniques in late 2017 or early 2018.
Appendix E – Example of Engineering Services Agreement (ESA)

This Engineering Services Reimbursement Agreement ("Agreement"), effective as of this _____ day of __________ ("Effective Date"), is by and between ___________________ ("Customer"), a ____________________ organized and existing under the laws of ____________________ and __________________________ ("Company"), a corporation organized and existing under the laws of the State of New York.

WHEREAS, Customer is proposing to build an anaerobic digester within a ____________ located in ________________________, New York that will recover digester methane gas from ___________________ , with excess gas to be sent to Company’s natural gas distribution system (the "Project"); and

WHEREAS, Customer desires to have Company perform certain engineering services (as specified below) in connection with the Project, and Company has agreed to perform such services upon the terms and conditions set forth below;

NOW, THEREFORE, in consideration of the mutual promises and covenants contained herein, and other good and valuable consideration, the receipt and sufficiency of which are hereby acknowledged, the parties entering into this Agreement (each a "Party", and collectively, the "Parties"), with the intent to be bound, agree as follows:

ARTICLE I – SERVICES

Section 1 – Scope of Services

Company will perform those services specified in Exhibit A attached hereto and hereby incorporated herein ("Services"). No goods, equipment, or materials will be provided under this Agreement.

This Agreement does not provide for generation interconnection service, procurement of equipment, installation or construction, or transmission service.

Section 2 – Customer’s Responsibilities

Customer shall provide:

1. Complete and accurate information regarding requirements for Services, including, without limitation, constraints, space requirements and relationships, special equipment, systems, site requirements, underground or hidden facilities and structures, and all applicable drawings and specifications;

2. If and to the extent applicable, Company access to the site where Services will be performed;
2. A project manager who will be given the authority to coordinate all aspects of the Project between Customer and Company;

4. If and to the extent applicable, adequate parking for the vehicles of Company personnel performing the Services; and

5. Other responsibilities and access deemed necessary by, and in the sole discretion of, Company to facilitate performance of the Services.

Customer shall reasonably cooperate with Company as required to facilitate Company’s performance of the Services. Other express Customer responsibilities, if any, shall be as specified in Exhibit A attached hereto.

Anything in this Agreement to the contrary notwithstanding, Company shall have no responsibility or liability under this Agreement for any defective performance or nonperformance to the extent such defective performance or nonperformance is caused by the inability or failure of (i) Customer to cooperate or to perform any of the tasks or responsibilities contemplated to be performed or undertaken by Customer in Exhibit A or elsewhere in this Agreement, or (ii) Customer and Company to reach agreement on any matter requiring their mutual agreement as contemplated in Exhibit A or elsewhere in this Agreement.

Section 3—Unknown Conditions

Customer represents, warrants and covenants that all information provided by Customer is accurate and complete and acknowledges and agrees that Company may and will rely on this representation, warranty and covenant in performing under this Agreement. If, as a result of additional, different, or previously unknown information, any changes in Services are required that will result in an increase or decrease in the cost or time of performance under the Agreement, the Price, schedule and other affected provisions of this Agreement shall be equitably adjusted and this Agreement shall be amended in writing to memorialize such changes.

Section 4—Changes and Extras

Customer may request changes in Services in writing. If any such changes will result in an increase or decrease in the cost or time of performance under this Agreement, the Price, schedule and other affected provisions of the Agreement shall be equitably adjusted and this Agreement shall be amended in writing to memorialize such changes. Company may make changes in Services with the prior written approval of Customer (which approval shall not be unreasonably withheld, conditioned, or delayed).
Section 5—Governmental Requirements

Changes in Services may be necessary in order to meet the requirements of governmental authorities, laws, regulations, ordinances, Good Utility Practice (as such term is defined in Article V, Section 1, below) and/or codes. After Customer’s approval (which shall not be unreasonably withheld, conditioned, or delayed), Company will make changes in Services as it deems necessary, in its sole discretion, to conform to such requirements. If any such changes will result in an increase or decrease in the cost or time of performance under this Agreement, the Price, schedule and other affected provisions of this Agreement shall be equitably adjusted and this Agreement shall be amended in writing to memorialize such changes. If Customer withholds its approval, and in Company’s sole and exclusive judgment the withholding of approval by Customer is not reasonable, then, at Company’s election, this Agreement may be immediately terminated upon written notice to Customer. Nothing in this Agreement shall relieve Customer of the responsibility to comply with requirements of ISO-NE or other utilities with regard to the Project and the Services.

ARTICLE II—PRICE, TAXES, AND PAYMENT

Section 1—Price

The price for the Services to be paid by Customer shall be the actual costs and expenses incurred by the Company and its affiliates in connection with performance of the Services or otherwise incurred by Company in connection with this Agreement, and shall include, without limitation, any such costs that may have been incurred by Company prior to the Effective Date (the “Price”).

The Price shall include, without limitation, the actual costs and expenses for the following to the extent incurred in connection with performance of the Services: labor (including, without limitation, internal labor); materials; subcontracts; equipment; travel, lodging, and per diem paid in accordance with Company policy; copying and reproduction of materials; overnight delivery charges; certified mailing charges; first class mailing charges; and similar types of incidental charges; transportation; carrying charges and surcharges; all applicable overheads including an Administrative and General (A&G) expense charge at Company’s current rate at the time of invoicing; all federal, state and local taxes incurred; all costs and fees of outside experts, consultants, counsel and contractors; all other third-party fees and costs; and all costs of obtaining any required consents, releases, approvals, or authorizations. All invoiced sums will include applicable expenses, surcharges, and federal, state and local taxes.

If Customer claims exemption from sales tax, Customer agrees to provide Company with an appropriate, current and valid tax exemption certificate, in form and substance satisfactory to Company, relieving Company from any obligation to collect sales taxes from Customer (“Sales Tax Exemption Certificate”). During the term of this Agreement, Customer shall promptly provide Company with any modifications, revisions or updates to the Sales Tax Exemption Certificate or to Customer’s exemption status. If Customer fails to provide an acceptable Sales Tax Exemption...
Certificate for a particular transaction, Company shall add the sales tax to the applicable invoice to be paid by Customer.

Section 2 – Payment

Customer shall provide Company with an initial prepayment in the amount of ________ US dollars ($______00) (“Initial Prepayment”). Company shall not be obligated to commence performance of Services until it has received the Initial Prepayment. If, during the performance of the Services, Company determines that one or more additional prepayments are required before completing the Services, Company may, but is not required to, request additional prepayment from Customer; any such requests will be in writing. If an additional prepayment is requested and is not received from Customer on or before the date specified in each such request, or if no date is specified, within 30 days of receipt of the written request, Company may cease work upon the depletion of the Initial Prepayment and any other prepayments made by Customer to date, as applicable. Upon Company’s receipt of the additional requested prepayment from Customer (such prepayment to be additional to the Initial Prepayment and any other prepayments made by Customer to date), Company will continue to perform the Services. The Initial Prepayment and the additional prepayments (if any) represent estimates only.

Company is not required to request additional prepayments from Customer and may, in its sole discretion, to continue performing Services hereunder after the depletion of the Initial Prepayment, or any other prepayments made by Customer to date, as applicable, without additional prepayments and invoice Customer for such Services at a later date. Customer shall be responsible to pay Company the total Price for completing the Services actually performed by Company whether or not any additional prepayments were made at Company’s request. Any election by Company to seek or defer additional prepayments in one instance shall not obligate the Company to seek or defer additional prepayments in any other instance.

Company will invoice Customer for all sums owed under this Agreement. With the exception of additional prepayments required under the first paragraph of this Section 2 of Article II, in which case the due date provided in such paragraph shall apply, payment shall be due in full within thirty (30) days of Company’s submittal of an invoice, without regard to claims or offsets. Payment shall be made in immediately available funds transmitted by the method specified in the invoice. A continuing late payment charge of 1.5% per month will be applied on any late payments.

If Company’s Price for completing the Services is less than the Initial Prepayment plus any such additional prepayments paid by Customer under this Article (“Total Prepayment”), Company will refund the remaining unused portion of the Total Prepayment to Customer.
ARTICLE III—SCHEDULE, DELAYS, AND FORCE MAJEURE

Company will use reasonable efforts to commence the Services promptly following its receipt of all of the following: a fully executed Agreement, the Initial Prepayment, and all information required by this Agreement to be supplied by Customer prior to commencement of the Services.

If Company’s performance of the Agreement is delayed by Customer, an equitable adjustment shall be made for any increase in the cost and/or time of performance caused by the delay.

Any delays in, or failure of, performance by Customer or Company, other than payment of monies, shall not constitute default and shall be excused hereunder, if and to the extent such delays or failures of performance are caused by occurrences beyond the reasonable control of Customer or Company, as applicable, including, but not limited to, acts of God, Federal and/or state law or regulation, sabotage, explosions, acts of terrorism, unavailability of personnel, equipment, supplies, or other resources for utility-related duties, delays by governmental authorities in granting licenses, permits or other approvals necessary in connection with Services, compliance with any order or request of any governmental or judicial authority, compliance with Company’s public service obligations, storms, fires, inclement or adverse weather, floods, riots or strikes or other concerted acts of workers, and accidents.

ARTICLE IV—INTELLECTUAL PROPERTY

Any drawings, specifications or other documents (i) prepared or used by Company, or (ii) prepared by Customer for Company in connection with this Agreement, shall be the proprietary, confidential information and sole property of Company at no cost to Company (collectively “Materials”).

Excluding third-party owned documents and software, Customer is granted an irrevocable, nontransferable, and non-assignable license to use such Materials solely in connection with the Project. No commercialization of such Materials by Customer is authorized. Customer shall not disclose any of the Materials to any third party, in whole or in part, without the prior written consent of Company.

The obligations imposed by this Article IV shall survive the completion, cancellation, or termination of this Agreement.

ARTICLE V—PERFORMANCE

Section 1—Performance.

Company shall perform the Services in a manner consistent with “Good Utility Practice” (as such term is defined below); provided, however, that Company shall have no responsibility or liability in connection with (i) any items or services provided by Customer or its third party contractors or
representatives whether or not such items or services are incorporated in the Services, (ii) any items or services provided, manufactured or licensed by third parties whether or not such items or services are incorporated in the Services, or (iii) any defects in Services that result from the acts or omissions of persons other than Company or accidents not caused by Company.

“Good Utility Practice” shall mean the practices, methods and acts engaged in or approved by a significant portion of the electric utility industry during the relevant time period, or any practices, methods and acts which, in the exercise of good judgment in light of the facts known at the time the decision was made, would have been reasonably expected to accomplish the desired result consistent with good business practices, safety, and law. Good Utility Practice is not intended to require or contemplate the optimum practice, method or act, to the exclusion of all others, but rather to be reasonably acceptable practices, methods, or acts generally accepted in the region in which the Services are to be performed.

Prior to the expiration of one (1) year following the date of completion of a Service, Customer shall have the right to give Company written notice that some or all of such Service was not performed in compliance with the first paragraph of this Section 1, and the Company shall, at the option of Company, either (i) re-perform or repair the defective portion of such Service, or (ii) refund the amount of money paid by the Customer to Company attributable to the defective portion of such Service. The remedy set forth in this Section 1 of Article V is the sole and exclusive remedy granted to Customer for any failure of Company to meet the performance standards or requirements set forth in this Agreement.

ARTICLE VI – INSURANCE

From the commencement of the Agreement through its expiration, each Party shall provide and maintain, at its own expense, insurance policies issued by reputable insurance companies with an A. M. Best rating of at least B+ (collectively, the “Required Insurance Policies”). The Required Insurance Policies shall, at a minimum, include the following coverages and limitations:

Workers’ Compensation and Employers’ Liability Insurance, as required by the State in which the work activities under this Agreement will be performed. If applicable, coverage will include the U.S. Longshoremen’s & Harbor Workers’ Compensation Act, and the Jones Act. If a Party is a qualified self-insurer by the State, Excess Workers’ Compensation coverage shall be maintained in lieu of the Workers’ Compensation coverage.

Public Liability, including Contractual Liability and Products/Completed Operations coverage, covering all operations to be performed under this Agreement, with minimum limits of:

Bodily Injury $1,000,000 per occurrence
Property Damage $1,000,000 per occurrence

Automobile Liability, covering all owned, non-owned and hired vehicles used under or in connection with this Agreement, with minimum limits of:
Bodily Injury——$500,000 per occurrence
Property Damage——$500,000 per occurrence OR
Combined Single Limit——$1,000,000 per occurrence

If requested, each Party will provide evidence to the other Party that it maintains the Required Insurance Policies required under this Article.

Either Party may elect to self-insure to the extent authorized or licensed to do so under the applicable laws of the State of New York, provided, that, the electing Party provides written notice of any such election to the other Party. Company hereby notifies Customer that it is a qualified self-insurer under the applicable laws of the State of New York and that it elects to self-insure to satisfy its obligations under this Article.

ARTICLE VII—TERM AND TERMINATION

The term of this Agreement shall expire one (1) year from the Effective Date. As of the expiration of this Agreement or, if earlier, its termination, the Parties shall no longer be bound by the terms and provisions hereof, except (a) to the extent necessary to enforce the rights and obligations of the Parties arising under this Agreement before such expiration or termination (including, without limitation, with respect to payment of all amounts due and payable hereunder), and (b) such terms and provisions that expressly or by their operation survive the termination or expiration of this Agreement.

Either Party may terminate this Agreement for convenience by delivery of written notice to the other Party, such termination to be effective on the tenth (10th) day following delivery of such written notice, or upon payment in full of all amounts due and payable hereunder, whichever is later. On or before the effective termination date of this Agreement, Customer shall pay Company all amounts due and payable as the Price for that portion of the Services performed to the effective date of termination ("Amount Outstanding"), including, without limitation, all costs and expenses incurred, less the Total Prepayment. In the event that the Total Prepayment exceeds the Amount Outstanding, Company shall remit the balance to Customer.

ARTICLE VIII—MISCELLANEOUS PROVISIONS

Section 1—Assignment and Subcontracting

Customer agrees that Company has the right, but not the obligation, to (i) use the services of its affiliated companies in connection with the performance of Services, and (ii) issue contracts to third parties for, or in connection with, the performance of Services hereunder, without the prior consent of Customer, and that the costs and expenses of such affiliated companies or third parties charged or chargeable to Company shall be paid by Customer as part of the Price.
Section 2—No Third-Party Beneficiary

Nothing in this Agreement is intended to confer on any person, other than the Parties, any rights or remedies under or by reason of this Agreement.

Section 3—Amendment; Equitable Adjustments

This Agreement shall not be amended, superseded or modified, except in a writing signed by both Parties. In any circumstance in which this Agreement contemplates an equitable adjustment to Price, schedule or any other term of this Agreement, Company shall have no obligation to continue performance hereunder until and unless such equitable adjustment has been mutually agreed to by both Parties in writing.

Section 4—Notices

Any notice given under this Agreement shall be in writing and shall be hand delivered, sent by registered or certified mail, delivered by a reputable overnight courier, or sent by facsimile (fax) with electronic confirmation of receipt, to the party's representatives as follows:

Customer:

[__________________________]

ATTN: [___________________]

[__________________________]

[__________________________]

Phone: [____________________]

Fax: [______________________]

Email: [____________________]

Company:

[__________________________]

ATTN: [___________________]

[__________________________]

[__________________________]

Phone: [____________________]

Fax: [______________________]

Email: [____________________]

Section 5—Waiver

No term of this Agreement may be waived except in a writing signed by an authorized representative of the Party against whom the amendment, modification, or waiver is sought to be enforced. Waiver of any provision herein shall not be deemed a waiver of any other provision herein, nor shall waiver of any breach of this Agreement be construed as a continuing waiver of other breaches of the same or other provisions of this Agreement.
Section 6—Approvals

It is understood that Company may be required to obtain, regulatory, and other third-party approvals and releases in connection with the provision of the Services. If so, this Agreement shall be effective subject to the receipt of any such approvals and releases, in form and substance satisfactory to Company in its sole discretion, and to the terms thereof.

Section 7—Laws

This Agreement shall be interpreted and enforced according to the laws of the State of New York and not those laws determined by application of the State of New York’s conflicts of law principles. Venue in any action with respect to this Agreement shall be in the State of New York; each Party agrees to submit to the personal jurisdiction of courts in the State of New York with respect to any such actions.

Section 8—Severability

To the extent that any provision of this Agreement shall be held to be invalid, illegal or unenforceable, it shall be modified so as to give as much effect to the original intent of such provision as is consistent with applicable law and without affecting the validity, legality or enforceability of the remaining provisions of the Agreement.

Section 9—Integration and Merger; Entire Agreement

Customer and Company each agree that there are no understandings, agreements, or representations, expressed or implied, with respect to the subject matter hereof other than those expressed herein. This Agreement supersedes and merges all prior discussions and understandings with respect to the subject matter hereof, and constitutes the entire agreement between the Parties with respect to such subject matter.

Section 10—Authority

Each Party represents to the other that the signatory identified beneath its name below has full authority to execute this Agreement on its behalf.

Section 11—Information and Coordination Contact

[____ Name, contact information ______________________] or such other representative as Company may designate, will be the point of contact for Customer to submit the information required for Company to perform the Services stated in this Agreement.
Section 12—Counterparts

This Agreement may be executed in multiple counterparts, each of which shall be considered an original, and all of which together shall constitute one and the same agreement. The exchange of copies of this Agreement and of signature pages by facsimile or other electronic transmission (including, without limitation, by e-mailed PDF) shall constitute effective execution and delivery of this Agreement as to the Parties and may be used in lieu of the original Agreement for all purposes. Signatures of the Parties transmitted by facsimile or other electronic means (including, without limitation, by e-mailed PDF) shall be deemed to be their original signatures for all purposes.

IN WITNESS WHEREOF, the Parties hereto have caused this Agreement to be executed by their duly authorized representatives as of the Effective Date.

[____ Customer Name ____________]
By: ____________________________
Name:
Title:

[____ Company Name ____________]
By: ____________________________
Name:
Title:

EXHIBIT A—Scope of Services

Company’s scope of Services shall be:

- Assign a Project Engineer and Project Manager to provide technical support for the Project;
- Arrange and schedule periodic Project meetings;
- Provide standards for Customer to follow in order to design metering equipment in accordance with Company specifications;
- Provide the specifications for the meters to be installed and determine the size and quantity of meters required;
- Provide technical assistance as needed by Customer in reviewing the design and layout for analytical equipment to be installed by Customer in accordance with manufacturer’s recommendations;
- Provide technical assistance as needed by Customer in reviewing the design and layout for odorant equipment to be installed by Customer in accordance with applicable health and safety regulations.

[____ Name, contact information ____________] or such other representative as Customer may designate, will be the point of contact for Company to request additional information from Customer, if required.
safety codes for the storage of odorant, including DEC, DEP, and Suffolk County Department of Health;

- Review drawings and specifications created by Customer for the equipment set forth below. Company reserves the right to make changes to the design in order to meet National Grid standards; and
- Provide engineering services to assist Customer in design and development of specifications for the work to purchase and install the equipment and facilities set forth below.

Equipment and Facilities Required for Project (to be provided by Customer):

- Gas service and associated metering equipment for backup supply from Company
- Gas outlet system tie-in and associated metering equipment for gas produced on site
- Remote Terminal Unit (RTU) to transmit gas quality and flow data to Company’s Gas Control Room
- Gas Chromatograph (10 component) to measure BTU, inert (CO2, N2), Oxygen of digester gas
- Odorant Chromatograph to measure mercaptans, total sulfur, and H2S in the digester gas
- Moisture Meter to measure amount of H2O in the digester gas
- Remote control valve to enable remote shut-in of Customer’s outlet in cases where gas from the plant is out of specification as listed in Table below.
- Odorant injection system with sight glass diffusion probe, storage tank(s) with dike
- Gas filters with differential gages on plant outlet line
- Analyzer Building — prefabricated concrete building to house RTU and all analytical equipment with electric service and Power Conditioning, and Battery Back Up system
- Odorant Building — negative pressure concrete building to house odorant equipment with electric service and gas detector(s), charcoal filter, blower, fire suppression and monitoring equipment (as required by __________ Fire Marshall).

Assumptions and Conditions:

Any dates, schedules or cost estimates resulting from the Services are preliminary projections/estimates only and shall not become or give rise to any binding commitment.

The Services contemplated by this Exhibit and this Agreement do not include any construction, relocations, alterations, modifications, or upgrades with respect to any facilities (“Construction”), nor does Company make any commitment to undertake such Construction. If the Parties elect, in their respective sole discretion, to proceed with any Construction: (i) such Construction would be performed pursuant to a separate, detailed, written, and mutually acceptable Cost Reimbursement Agreement to be entered into by the Parties prior to the commencement of any such Construction, and (ii) payment of all actual costs incurred by Company or its Affiliates in connection with or related to such Construction shall be the responsibility of Customer and Customer shall reimburse Company for all such costs.

For the avoidance of doubt: This Agreement does not provide for generation interconnection service, procurement of equipment, installation or construction. The Company shall not have any
responsibility for seeking or acquiring any real property rights in connection with the Services or the Project including, without limitation, licences, consents, permissions, certificates, approvals, or authorizations, or fee, easement or right of way interests. Neither this Agreement nor the Services include securing or arranging for Customer or any third party to have access rights in, through, over or under any real property owned or controlled by the Company.
Appendix F – Example of Gas Sales Agreement (aka Interconnect Agreement)

This Digester Gas Sales Agreement (“Agreement”), effective as of this _______ day of ___________ (“Effective Date”), is by and between ___________________ (“Buyer”), a corporation organized and existing under the laws of the State of New York, and ________________________ (“Seller”), a _____________________ organized and existing under the laws of ________________.

WHEREAS, Seller owns an anaerobic digester within a ________________ located in _________________, New York that recovers digester methane gas from ______________; and

WHEREAS, Buyer is a regulated natural gas distribution company which owns and operates a natural gas distribution system in ___________________ counties; and

WHEREAS, Seller desires to sell and deliver Renewable Natural Gas ("RNG" or Biomethane) to Buyer, and Buyer desires to purchase and accept such RNG from Seller; and

WHEREAS, Buyer has agreed to operate and maintain certain of the facilities required in connection with the delivery of RNG, and Seller has agreed to reimburse Buyer for performing such operation and maintenance services; and

NOW, THEREFORE, in consideration of the mutual promises and covenants contained herein, and other good and valuable consideration, the receipt and sufficiency of which are hereby acknowledged, the parties entering into this Agreement (each a “Party”, and collectively, the “Parties”), with the intent to be bound, agree as follows:

ARTICLE 1: DEFINITIONS

1.1 The term “Btu” means British Thermal Unit, and shall be the quantity of heat required to raise the temperature of one (1) pound of water one (1) degree Fahrenheit at sixty (60) degrees Fahrenheit at a pressure of 14.73 psia.

1.2 The term “dekatherm” means a unit of heat energy equal to 1,000,000 BTUs.

1.3 The term “Day” means a period of twenty-four (24) consecutive hours beginning and ending at 9:00 AM Central Standard Time.

1.4 The term “Delivery Point” shall mean the point of interconnection between the facilities of Seller and Buyer at or near the facility where RNG will be sold and delivered by Seller to Buyer under this Agreement, as shown on Exhibit “A” hereto.

[Insert Schematic drawing]
1.5 Facilities” means those facilities that will be maintained by the Buyer pursuant to this Agreement and other facilities utilized in connection with the delivery of RNG.

1.6 The term “Maximum Daily Quantity” (or “MDQ”) is the maximum amount of RNG that Buyer is obligated to purchase on any Day during the term of this Agreement.

1.7 The term “MMbtu” means one million Btu.

1.8 The term “mdth” means one thousand dekatherms.

1.9 The term “Month” means a period beginning at 9:00 AM Central Standard Time on the first Day of any calendar month and ending at 9:00 AM Central Time on the first Day of the next succeeding calendar month (per NAESB and FERC).

1.10 The term “Plant” means the digester and processing facilities operated by Seller.

1.11 The term ”RNG” means the gas produced by Seller at the Plant.

1.12 “Services” has the meaning set forth in Article 8 of this Agreement.

1.13 “Pipeline Quality” has the meaning defined in latest version of AGA Report 4A.

ARTICLE 2: EFFECTIVE DATE AND TERM

2.1 The term of the Agreement shall commence as of the date first written above and shall remain in effect through _________________, and from month to month thereafter unless terminated by either Party on no less than thirty (30) days prior written notice to the other.

2.2 Upon the termination of this Agreement for any reason, any monies due and owing Seller or Buyer shall be paid pursuant to the terms hereof, and any corrections or adjustments to payments previously made shall be determined and made at the earliest possible time. The provisions of this Agreement shall remain in effect until the obligations under this paragraph have been fulfilled.

ARTICLE 3: SALE AND PURCHASE OBLIGATIONS

3.1 Subject to the terms and conditions of this Agreement, Seller agrees to sell and deliver, and Buyer agrees to purchase and receive, each Day during the term of this Agreement, at the Delivery Point, a quantity of RNG equal to the lesser of (a) the quantity of RNG produced by the Plant on such Day or (b) the MDQ for such Day.

3.2 As of the effective date of this Agreement, the MDQ shall be ___ MMBtu.
3.3. Seller shall tender RNG for delivery at a substantially uniform rate of flow throughout each Day, at a minimum of 0 mdth/day and a maximum of ________ mdth/day. If Seller becomes aware that the rate of delivery or the total quantity of RNG that Seller will deliver for any Day will differ by more than twenty-five percent (25%) (positive or negative) from that achieved the previous Day, Seller shall so notify Buyer’s Gas Control Center at the contact set forth in Section 13.10 below. Seller also shall notify Buyer’s Gas Control Center at least twenty-four (24) hours in advance of any suspension of RNG deliveries under this Agreement necessitated by Seller’s maintenance of its Plant.

ARTICLE 4: PRICE OF GAS

4.1. The price paid for each MMBtu of RNG sold and purchased under this Agreement in any Month shall be equal to the New York Mercantile Exchange (NYMEX) natural gas futures contract last day settle price for such Month.

ARTICLE 5: TITLE TO GAS

5.1. Seller hereby warrants good and merchantable title to all RNG delivered hereunder, free and clear of all liens, encumbrances and claims whatsoever. Seller will indemnify Buyer and hold it harmless from any and all suits, actions, debts, accounts, damages, costs, losses, and expenses arising from or out of adverse title claims of any and all persons to said RNG.

5.2. Title to all RNG received by Buyer shall pass to Buyer at the Delivery Point. As between the Parties hereto, Seller shall be deemed to be in exclusive control and possession of the RNG deliverable hereunder and responsible for any damage or injury caused thereby until the same shall have been delivered to Buyer at the Delivery Point; thereafter Buyer shall be deemed to be in exclusive control and possession of such gas and responsible for any damage or injury caused thereby.

ARTICLE 6: GAS PRESSURE, TEMPERATURE AND QUALITY

6.1. Seller shall tender RNG for delivery to Buyer under this Agreement at the Delivery Point at pressures sufficient for such RNG to enter Buyer’s facilities at such point, but in no event in excess of the maximum allowable operating pressure on Buyer’s system which, at the time of execution of this Agreement, is ______ psig. Buyer shall promptly notify Seller of any changes in the maximum operating pressure of the Buyer’s system.

6.2. Seller shall tender RNG for delivery to Buyer under this Agreement at the Delivery Point at a temperature no less than _____ degrees Fahrenheit and no greater than _____ degrees Fahrenheit. Should Seller tender RNG to Buyer at the Delivery Point at a temperature colder or warmer than such range and Buyer’s meter is damaged as a result, then in addition to and without limitation of any other remedy Buyer may have, Buyer shall be entitled to receive from Seller an amount equal to Buyer’s cost to repair or replace such RNG.
meter and any other related equipment affected.

6.3 Seller agrees that it will exercise reasonable care and diligence in tendering RNG for delivery to Buyer under this Agreement, and warrants that all RNG when tendered for delivery to Buyer hereunder at the Delivery Point shall:

a. be compatible and interchangeable with pipeline gas as defined in 16 NYCRR 229;
b. be within the limits set forth in Table 1
c. be monitored as to conformity with all of the foregoing criteria by manual test or by mutually acceptable continuous monitoring equipment; and Buyer will require quarterly random grab sampling to ensure gas is free of objectionable materials with analytical costs to be reimbursed by the Seller.

Table 1: Gas Quality Specifications

<table>
<thead>
<tr>
<th>Gas Quality Specification</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTU Content (Heat Content) [BTU/scf]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wobbe Number</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative Density</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Vapor Content [lb/MMscf]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mercaptans (as Odorant) [lb/MMscf]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrocarbon Dew Point, [°F] CHDP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrogen Sulfide (H₂S)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Sulfur</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Diluent Gases</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon Dioxide (CO₂)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen (N₂)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygen (O₂)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrogen</td>
<td>-</td>
<td>Not Detectable Commercially Free</td>
</tr>
<tr>
<td>Total Bacteria Biologicals</td>
<td>-</td>
<td>Not Detectable Commercially Free</td>
</tr>
<tr>
<td>Mercury Heavy Metals</td>
<td>-</td>
<td>Not Detectable Commercially Free</td>
</tr>
<tr>
<td>Other Volatile Metals (including arsenic)</td>
<td>-</td>
<td>Not Detectable</td>
</tr>
<tr>
<td>Siloxanes</td>
<td>-</td>
<td>Not Detectable</td>
</tr>
<tr>
<td>Ammonia</td>
<td>-</td>
<td>Not Detectable</td>
</tr>
<tr>
<td>Non-Halogenated Semi-Volatile and Volatile Compounds</td>
<td>-</td>
<td>Not Detectable</td>
</tr>
<tr>
<td>Halocarbons</td>
<td>-</td>
<td>Not Detectable</td>
</tr>
</tbody>
</table>
NOTES:

1. Not-detectable for purposes of this specification is defined as a value less than the lowest detectable level for a mutually agreeable standard industry analytical test method.

2. BTU = commonly referred to as Higher Heating Value (HHV)

3. Wobbe = Interchangeability parameter; ratio of BTU content to specific gravity

4. In addition to the specified limits above, gas received into Buyer’s pipeline system shall be pipeline quality and as such remain commercially free of objectionable materials and merchantable as defined in latest edition of AGA Report 4A “Natural Gas Contract Measurement and Quality Clauses”

6.4 Seller shall maintain in good working order its facilities at the Plant that enable it to ensure that the pressure, temperature and quality of the RNG it tenders for delivery under this Agreement fully conform with the criteria set forth in this Agreement.

6.5 In addition to any and all other remedies that it may have, Buyer shall have the right to reject as non-conforming any RNG Seller tenders for delivery under this Agreement that fails to comply with the pressure, temperature or quality specifications set forth in this Agreement, and will maintain suitable equipment at Seller’s premise in order to remotely monitor and shut off Seller’s supply should it not meet such specifications.

6.6 The Parties shall develop a facility start-up gas quality sampling and testing plan (the “Plan”) to ensure all equipment is functioning as and intended in order to provide RNG conforming to the quality specifications set forth in Table 1 above. The Plan shall include provisions regarding frequency of initial testing.

ARTICLE 7: GAS MEASUREMENT

7.1 The quantity of RNG delivered hereunder shall be measured according, to Boyle’s and Charles’ Laws for the measurement of gas under varying temperatures and pressures and shall be determined as follows:

a. the sales unit of the RNG delivered shall be one (1) MMBtu of gas measured as HHV on a real, dry, basis at standard temperature and pressure;

b. the unit of weight for the purpose of measurement shall be one (1) pound mass of gas;

c. the average absolute atmospheric pressure shall be assumed to be 14.73 pounds per square inch; and

d. the temperature of gas passing through the meter shall be determined by the continuous use of a temperature measuring device; the arithmetic averages of the temperature recorded each twenty-four (24) hour Day shall be used in computing gas
volumes or continuous instantaneous temperature measurements may be applied to metering instruments to provide the volume computation.

7.2 The metering equipment shall be sealed and the seals shall be broken only upon occasions when the meters are to be inspected, tested or adjusted, and representatives of Seller shall be afforded at least twenty-four (24) hour notice and reasonable opportunity to be present upon such occasions. Buyer shall use reasonable efforts to give Seller more than twenty-four (24) hour notice of such inspections, tests or adjustments.

7.3 Periodic tests of such metering equipment, at intervals not to exceed two times per year, will be made at any reasonable time upon request there for by Seller. If, as a result of any such additional test, the metering equipment is found to be defective or inaccurate, it will be restored to a condition of accuracy or replaced. If an additional test of the metering equipment is made at the request of Seller with the result that said metering equipment is found to be registering correctly or within two percent (2%) plus or minus of one hundred percent (100%) accuracy, Seller shall bear the expense of such additional test. If such additional test shows an error greater than two percent (2%) plus or minus of one hundred percent (100%) accuracy, then Buyer shall bear the expense of such additional test and any necessary repair or replacement.

7.4 All meters shall be adjusted as close as practical to one hundred percent (100%) accuracy at time of installation and testing. If any of the metering equipment tests provided for herein disclose that the error for such equipment exceeds two percent (2%) plus or minus of one hundred percent (100%) accuracy, and the period of inaccuracy cannot be reasonably ascertained, then the period of inaccuracy will be assumed to have begun at the midpoint in time between the discovery of the inaccuracy and the previous meter test.

7.5 Any correction in billing resulting from such correction in meter records shall be made in the next monthly invoice rendered by Buyer after the inaccuracy is discovered. Should any metering equipment fail to register the gas delivered or received during any period of time, the amount of RNG delivered or received during such period will be estimated by the Parties according to the amounts previously delivered or received during similar periods under substantially similar conditions, and upon mutual agreement of the Parties shall be used as the basis for billing for that period.

ARTICLE 8: OPERATION and MAINTENANCE SERVICES, EQUIPMENT REPLACEMENT COSTS

8.1 SCOPE – During the term of this Agreement the Buyer will perform, or cause to be performed, in a prudent and workman like manner the Services set forth in Section 8.2 below. Upon the mutual agreement of the Parties, the Buyer may perform additional Services (the "Unscheduled Services") in connection with the Facilities. In the case of emergencies that render the Facilities unsafe, the Buyer may perform emergency services that it deems necessary to make the Facilities safe (the "Emergency Services"), including shutting off gas supply and the gas delivery. The Buyer shall attempt to notify Seller prior to
commencing any such Emergency Services, however if prior notification is impractical, the Buyer shall have the right to commence the Emergency Services immediately and to notify Seller within 24 hours thereafter.

8.2 SERVICES – During the term of this Agreement, the Buyer shall provide the labor and materials necessary to operate and maintain the gas meters, gas regulators, odorant system, gas chromatographs, telephone lines and other ancillary equipment required by the Company in connection with the delivery of RNG pursuant to this Agreement (the “Services”). The Services do not include repairs for damages, malfunctions or failures caused by or occurring as the result of: (a) repairs, adjustments or any other actions performed by persons other than the Buyer’s authorized representatives; (b) failure of components not serviced by the Buyer’s authorized representatives; (c) abuse, misuse or negligent acts of Seller or others; or (d) an event of force majeure as defined in Article 11 hereof. Installation of the equipment described above is the Seller’s responsibility.

8.3 COST OF SERVICES – Seller shall reimburse the Company for the fully loaded cost incurred by the Company in performing the Services, Unscheduled Services and/or Emergency Services.

8.4 EQUIPMENT REPLACEMENT AT END OF LIFE – Seller shall reimburse the Company for the fully loaded cost to replace gas meters, gas regulators, odorant system, gas chromatographs, telephone lines and other ancillary equipment when such equipment reaches the end of its service life.

ARTICLE 9: BILLING AND PAYMENT

9.1 On or before the fifth (5th) day of each Month, Buyer shall notify Seller of the quantity of RNG delivered by Seller to Buyer during the preceding Month. Seller shall render a written statement to Buyer on or before the fifteenth (15th) day of such succeeding Month which, upon verification by Buyer, shall be paid by Buyer by the twenty-fifth (25th) day of such Month. If the twenty-fifth (25th) day of any Month falls on a weekend or bank holiday, payment by Buyer shall be due on the next succeeding business day.

9.2 The fully loaded costs incurred by the Buyer in performing any Services, Unscheduled Services, and/or Emergency Services will be applied as an offset to the amount invoiced by Seller pursuant to Section 9.1 above.

9.3 AUDITS – Each Party shall have the right at its own expense to examine and audit at a reasonable time and upon reasonable prior notice the books, records and charts of the other Party relevant to this Agreement. Each Party shall use reasonable efforts to make available such records as may be necessary to verify the accuracy of any statements or charges made under or pursuant to any of the provisions of this Agreement. A formal audit of accounts shall not be made more than once each calendar year.
ARTICLE 10: ACCESS TO PREMISES

10.1 Seller agrees during the term of this Agreement that it will provide access as may be required by the Buyer's authorized representatives for the performance of its obligations hereunder. Upon 24 hours' notice, Seller shall grant access to, or obtain access for, the Buyer's authorized representatives for performance of the Services and the Unscheduled Services. Furthermore, Seller shall grant or obtain immediate access for the Buyer's authorized representatives for the performance of Emergency Services.

ARTICLE 11: FORCE MAJEURE

11.1 The term force majeure as employed herein shall mean acts of God, strikes, lockouts or other industrial disturbances, acts of the public enemy, wars, blockades, insurrections, riots, epidemics, landslides, lightning earthquakes, fires, storms, floods, washouts, arrests, the order of any court of governmental authority having jurisdiction while the same is in force and effect, civil disturbances, explosions, breakage, accidents to machinery or lines or pipe, freezing of or damage to facilities, inability to obtain or unavoidable delay in obtaining material, equipment, and any other cause whether of the kind herein enumerated or otherwise, not reasonably within the control of the Party claiming suspension and which by the exercise of due diligence such Party is unable to prevent or overcome.

11.2 In the event of either Party being rendered unable, wholly or in part, by force majeure to carry out its obligations (other than the continuing obligation set forth herein below), it is agreed that on such Party's giving notice and full particulars of such force majeure in writing or by telegraph or telecopy to the other Party within a reasonable time (not to exceed five (5) days) after occurrence of the cause relied on, the obligations of both Parties, so far as they are affected by such force majeure, shall be suspended during such period of force majeure, but for no longer period, and such cause shall so far as possible be remedied with all reasonable dispatch.

11.3 Neither Party shall be liable in damages to the other for any act, omission or circumstance occasioned by, or in consequence of, force majeure, as herein defined. Such causes or contingencies affecting the performance by either Party, however, shall not relieve it of liability unless such Party shall give notice and full particulars of such cause or contingency in writing, to the other Party at the address set forth in Section 13.10 within a reasonable time after the occurrence relied upon, nor shall such causes or contingencies affecting the performance by either Party relieve it of liability in the event of its failure to use due diligence to remedy the situation and remove the cause with all reasonable dispatch, nor shall such causes or contingencies affecting the performance relieve Buyer from its obligation to make payments of amounts in respect of RNG delivered.

11.4 To the extent that, in Buyer's sole judgment. Buyer's ability to receive, measure monitor
and/or odorize RNG is impaired by conditions on its system including, but not limited to, the performance of routine maintenance or repairs, then Buyer's obligation to purchase and receive such RNG shall be suspended for the duration of such condition.

ARTICLE 12: EVENTS OF DEFAULT

12.1 EVENTS OF DEFAULT – The occurrence of anyone or more of the following shall be an "Event of Default" under this Agreement:

a. Failure by a party to pay/reimburse any amount when due and payable that is required to be paid by the terms of this Agreement.

b. Failure by a party to perform any covenant, condition or agreement required to be performed by it by the terms of this Agreement that continues for a period of ten (10) days after the required date of performance.

12.2 REMEDIES ON DEFAULT

a. The non-defaulting party shall have the right, upon written notice to the defaulting party, to terminate this Agreement upon any Event of Default.

b. Upon any Event of Default by the Buyer, Seller, or a designee of Seller, may cure any breach or default of the Company under this Agreement that resulted in an Event of Default (including the failure to perform Services), in which case the full cost thereof shall be reimbursed to Seller by the Buyer.

ARTICLE 13: MISCELLANEOUS

13.1 Except as provided hereinafter, neither this Agreement nor any rights or obligations hereunder may be assigned or transferred, by operation of law or otherwise by either Party without the prior written consent of the other Party, which consent shall not be unreasonably withheld. Notwithstanding the foregoing, Buyer may assign this Agreement and all of its rights and obligations to an affiliate of Buyer at any time upon 30 days prior written notice to Seller.

13.2 Seller shall provide, at no cost to Buyer, all of the electricity and compressed air required for Buyer to operate the facilities that will measure, regulate and odorize the RNG gas delivered by Buyer to Seller under this Agreement at Buyer's facilities for such purposes located at or near the Delivery Point.

13.3 The sale and delivery of RNG by Seller and the purchase and receipt thereof by Buyer are subject to all valid legislation with respect to the subject matter hereof and to all valid present and future orders, rules and regulations of duly constituted authorities having jurisdiction. Neither Buyer nor Seller shall be liable to the other for failure to perform any
obligation hereunder where such failure is due to compliance with such valid laws, orders, rules or regulations. If any statute, order, rule, or regulation of a duly constituted authority having jurisdiction over a Party or the performance of this Agreement prevents Seller from charging or collecting the price or prices payable hereunder or prevents Buyer from recovering costs representing the price or prices payable hereunder, the following shall apply notwithstanding any other provision of this Agreement:

a. If Buyer is prevented from recovering any costs representing all or a portion of the price or prices payable hereunder, or Buyer’s recovery of such costs is made subject to refund, Buyer may, at its option, terminate this Agreement by written notice to Seller, effective not less than sixty (60) days after delivery thereof;

b. If Seller is prevented from charging or collecting all or any part of the price or prices payable hereunder, or Seller’s collection of such prices is made subject to refund, Seller may, at its option, terminate this Agreement by written notice to Buyer, effective not less than sixty (60) days after delivery thereof.

13.4 This Agreement sets forth all understandings between the Parties respecting the terms and conditions of this transaction. All other agreements, understandings and representations by and between the Parties hereto prior to this Agreement, whether consistent or inconsistent, oral or written, concerning this transaction are merged into and superseded by this written Agreement.

13.5 All headings appearing herein are for convenience only and shall not be considered a part of this Agreement for any purpose.

13.6 The Parties may, by mutual agreement, waive any provision herein; however, a waiver shall not be construed to constitute a continuing waiver hereunder and furthermore, a waiver by either Party of any one or more defaults by the other Party in performance of any provision of this Agreement shall not operate or be construed as a waiver of future default or defaults, whether of a like or different character.

13.7 Seller hereby agrees to indemnify and hold harmless Buyer from damage to Buyer’s or third parties’ property or injury to persons (including death) to the extent resulting from the negligence of Seller, its servants, agents or employees, while engaged in activities under this Agreement. Buyer shall indemnify and hold harmless Seller from damage to Seller’s or third parties’ property or injury to persons (including death) to the extent resulting from the negligence of Buyer, its servants, agents or employees while engaged in activities under this Agreement except to the extent Buyer’s Schedule for Gas Service (as filed with and approved by the Public Service Commission of the State of New York), limits Buyer’s liability. The obligations under this Section shall survive termination of this Agreement.

13.8 This agreement shall be governed by and construed in accordance with the laws of the state of New York, without regard to any rules governing conflicts of laws that would require application of the laws of another jurisdiction.
13.9 This Agreement may be executed in several counterparts, each of which is an original and all of which constitute one and the same instrument.

13.10 Unless otherwise specified, any notice, request, demand, statement, bill or other payment provided for in this Agreement, or any notice which a Party may desire to give to the other, shall be considered duly delivered as of the earlier of the date of the receipt by the addressee or three (3) business days after the postmark date when mailed by ordinary mail or given to the addressee at the addresses listed below:

ARTICLE 14: Facilities and Estimated Costs

<table>
<thead>
<tr>
<th>Cost Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials</td>
</tr>
<tr>
<td>Freight</td>
</tr>
<tr>
<td>Taxes</td>
</tr>
<tr>
<td>Environmental</td>
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<td>Construction Support</td>
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<td>Labor and Equipment</td>
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<td>Engineering</td>
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<tr>
<td>Overheads</td>
</tr>
<tr>
<td>O&amp;M</td>
</tr>
<tr>
<td>Subtotal</td>
</tr>
</tbody>
</table>

Total Estimated Cost

CONTACT INFORMATION

Buyer Notices:

[______________________]
ATTN: [______________________]

Fax: [______________________]
Email: [______________________]

Buyer Billings:

[______________________]
ATTN: [______________________]

Phone: [______________________]
IN WITNESS WHEREOF, the Parties hereto have caused this Agreement to be executed by their duly authorized representatives as of the Effective Date.

[____ Buyer ____________________________]
By: ________________________________
Name: ______________________________
Title: ______________________________

[____ Seller ____________________________]
By: ________________________________
Name: ______________________________
Title: ______________________________

Appendix G: Feedstock/Upgraded Gas Constituent Guidance Matrix

The following table lists some potential COCs that may be found in raw gas from specific feedstocks for RNG production. Each biogas to RNG project will be different, and the final list of constituents of concern will depend on many unique criteria. The tables that follow list typical ranges found in fully upgraded RNG from several of these feedstocks.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Landfill</th>
<th>Dairy, Swine</th>
<th>WWTP</th>
<th>Food Waste</th>
<th>Gasifier, Syngas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water-Content</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfur, including Hydrogen Sulfide</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Hydrogen</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Carbon-dioxide</td>
<td></td>
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<tr>
<td>Nitrogen</td>
<td></td>
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</tr>
</tbody>
</table>

Commented [SM62]: Pipeline operators typically do not test shale gas derived NG, LNG sourced NG, etc. RNG should be equivalent or better than the range of NG sources used currently in the US and this is reflected in the ABC RNG purity specification. Requiring pipeline operators to understand biogas source differences is also overly burdensome.
## Observed Ranges Found in Fully Upgraded RNG from Landfills

The following data on upgraded RNG from landfills is from GTI lab analyses from 2006-2016.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>AGA-4A Reported Range</th>
<th>Range Found in Upgraded Landfill-Derived RNG</th>
<th>Range Found in Natural-Gas-Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sulfur</td>
<td>maximum 0.5 to 20 grains per 100 SCF</td>
<td>BDL (0.003) to 0.32 grains per 100 SCF</td>
<td>BDL (0.003) to 1.3 grains per 100 SCF</td>
</tr>
<tr>
<td>Hydrogen Sulfide</td>
<td>maximum 0.25 to 1.0 grains per 100 SCF</td>
<td>BDL (0.003) to 0.03 grains per 100 SCF</td>
<td>BDL (0.003) to 0.36 grains per 100 SCF</td>
</tr>
</tbody>
</table>

Commented [SM63]: It is not appropriate to include this level of information in a gas sales agreement.

Commented [MT64]: Returning to my comment before about “raw biogas sampling”: The fact that all of this data already exists suggests it is unnecessary and even burdensome to require each new project/developer to provide samples during the ESA/GSA process.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>AGA 4A Reported Range</th>
<th>Range Found in Upgraded Landfill-Derived RNG</th>
<th>Range Found in Natural Gas Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>max. 0.04 to 0.1 vol%</td>
<td>BDL (0.1) to 1.0 vol%</td>
<td>BDL (0.1) to 0.3 vol%</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>maximum 1 to 3 vol%</td>
<td>BDL (0.03) to 2.2 vol%</td>
<td>BDL (0.03) to 2.6 vol%</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>maximum 1 to 4 vol%</td>
<td>0.5 to 9.5 vol%</td>
<td>BDL (0.03) to 12.7 vol%</td>
</tr>
<tr>
<td>Oxygen</td>
<td>max. 0.001 to 1 vol%</td>
<td>BDL (0.03) to 1.3 vol%</td>
<td>BDL (0.03) to 1.2 vol%</td>
</tr>
<tr>
<td>Diluents + Inerts</td>
<td>maximum 3 to 6 vol%</td>
<td>0.6 to 10.0 vol%</td>
<td>0.3 to 12.7 vol%</td>
</tr>
<tr>
<td>Ammonia</td>
<td>none</td>
<td>BDL (10 ppmv)</td>
<td>BDL (10 ppmv)</td>
</tr>
<tr>
<td>Total Bacteria</td>
<td>none</td>
<td>2.46x10^4 to 3.29x10^7 # per 100 SCF</td>
<td>3.47x10^4 to 6.39x10^7 # per 100 SCF</td>
</tr>
<tr>
<td>Mercury</td>
<td>none</td>
<td>BDL (0.01) to 0.3 µg/m³</td>
<td>BDL (0.01) to 0.06 µg/m³</td>
</tr>
<tr>
<td>Other Volatile Metals</td>
<td>none</td>
<td>BDL (30) to 250 µg/m³ (Cr, Cu, Mn, Pb, Sb, Zn)</td>
<td>BDL (30) to 213 µg/m³ (As, Cu, Pb, Zn)</td>
</tr>
<tr>
<td>Siloxanes (D4)</td>
<td>none</td>
<td>BDL² to 6.0 mg Si/m³</td>
<td>BDL²</td>
</tr>
<tr>
<td>Non-Halogenated Semi-Volatile and Volatile Compounds</td>
<td>none</td>
<td>BDL² to 1.4 ppmv (BTEX, phthalates)</td>
<td>BDL² to 47.1 ppmv (1,3-butadiene, acrylonitrile, BTEX)</td>
</tr>
<tr>
<td>Halocarbons</td>
<td>none</td>
<td>BDL (0.1) to 3.6 ppmv (Freons, chloroethane, vinyl chloride)</td>
<td>BDL (0.1 ppmv)</td>
</tr>
<tr>
<td>Aldehyde/Ketones</td>
<td>none</td>
<td>BDL (10) to 522 ppbv</td>
<td>BDL (10) to 103 ppbv</td>
</tr>
<tr>
<td>Polychlorinated Biphenyls (PCBs)</td>
<td>none</td>
<td>BDL (0.01 ppbv)</td>
<td>BDL (0.01 ppbv)</td>
</tr>
<tr>
<td>Pesticides</td>
<td>none</td>
<td>BDL (0.0005) to 0.003 ppbv (4,4'-DDT)</td>
<td>BDL (0.0005 ppbv)</td>
</tr>
</tbody>
</table>

¹Detection limits for siloxane ranged from 0.5 mg Si/m³ to 0.1 as analysis methods improved.
²Detection limits vary from 1 ppmv (volatiles) to 5 ppbv (semi-volatiles).
³Field blanks contained copper, zinc and acetone.
Observed Ranges Found in Fully Upgraded RNG from Dairies

The following data on upgraded RNG from dairies is from GTI lab analyses from 2006-2016.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>AGA 4A Reported Range</th>
<th>Range Found in Upgraded Dairy-Derived RNG</th>
<th>Range Found in Natural Gas Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sulfur</td>
<td>maximum 0.5 to 20 grains per 100 SCF</td>
<td>BDL (0.003) to 0.31 grains per 100 SCF</td>
<td>BDL (0.003) to 1.1 grains per 100 SCF</td>
</tr>
<tr>
<td>Hydrogen-Sulfide</td>
<td>maximum 0.25 to 1.0 grains per 100 SCF</td>
<td>BDL (0.003) ppmv</td>
<td>BDL (0.003) to 0.36 grains per 100 SCF</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>max. 0.04 to 0.1 vol%</td>
<td>BDL (0.1 vol%)</td>
<td>BDL (0.1) to 0.3 vol%</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>maximum 1 to 3 vol%</td>
<td>0.06 to 0.95 vol%</td>
<td>BDL (0.03) to 2.6 vol%</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>maximum 1 to 4 vol%</td>
<td>0.20 to 7.81 vol%</td>
<td>BDL (0.03) to 12.7 vol%</td>
</tr>
<tr>
<td>Oxygen</td>
<td>max. 0.001 to 1 vol% majority: 0.1 to 0.2 vol%</td>
<td>BDL (0.03) to 1.99 vol%</td>
<td>BDL (0.03) to 1.2 vol%</td>
</tr>
<tr>
<td>Diluents + Inerts</td>
<td>maximum 3 to 6 vol%</td>
<td>0.37 to 10.65 vol%</td>
<td>0.3 to 12.7 vol%</td>
</tr>
<tr>
<td>Ammonia</td>
<td>none</td>
<td>BDL (0.1 ppmv)</td>
<td>BDL (0.1 ppmv)</td>
</tr>
<tr>
<td>Total Bacteria</td>
<td>none</td>
<td>3.28x10^4 to 1.02x10^6 # per 100 SCF</td>
<td>3.47x10^4 to 6.30x10^6 # per 100 SCF</td>
</tr>
<tr>
<td>Mercury</td>
<td>none</td>
<td>BDL (0.01 µg/m³)</td>
<td>BDL (0.01) to 0.06 µg/m³</td>
</tr>
<tr>
<td>Other Volatile Metals(^2)</td>
<td>none</td>
<td>BDL (20 µg/m³)</td>
<td>BDL (30) to 213 µg/m³ (As, Cu, Pb, Zn)</td>
</tr>
<tr>
<td>Siloxanes (D4)</td>
<td>none</td>
<td>BDL(^3)</td>
<td>BDL(^3)</td>
</tr>
<tr>
<td>Non-Halogenated Semi-Volatile and Volatile Compounds</td>
<td>none</td>
<td>BDL to 0.1 ppmv (BTEX, N-nitroso-di-n-propylamine, benzyl alcohol)</td>
<td>BDL to 471 ppmv (1,3-butadiene, acrylonitrile, BTEX)</td>
</tr>
<tr>
<td>Halocarbons</td>
<td>none</td>
<td>BDL (0.1 ppmv)</td>
<td>BDL (0.1 ppmv)</td>
</tr>
<tr>
<td>Aldehyde/Ketones(^3)</td>
<td>none</td>
<td>not tested</td>
<td>BDL (10) to 103 ppbv</td>
</tr>
<tr>
<td>Polychlorinated biphenyls (PCBs)</td>
<td>none</td>
<td>BDL (0.01 ppbv)</td>
<td>BDL (0.01 ppbv)</td>
</tr>
<tr>
<td>Pesticides</td>
<td>none</td>
<td>BDL (0.0004) to 0.5 ppbv (gamma-chlordane)</td>
<td>BDL (0.0006 ppbv)</td>
</tr>
</tbody>
</table>

\(^2\) Detection limits for siloxane ranged from 0.5 mg Si/m³ to 0.1 as analysis methods improved.
\(^3\) Detection limits vary from 1 ppmv (volatiles) to 5 ppbv (semi-volatiles).
\(^4\) Field blanks contained copper, zinc and acetone.
**Observed Ranges Found in Fully Upgraded RNG from WWTPs**

The following data on upgraded RNG from WWTPs is from GTI lab analyses from 2006-2016. Only one fully upgraded site was analyzed.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>AGA-4A Reported Range</th>
<th>Range Found in Upgraded WWTPs-Derived RNG</th>
<th>Range Found in Natural-Gas Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sulfur</td>
<td>maximum 0.5 to 20 grains per 100 SCF</td>
<td>BDL (0.003) to 0.01 grains per 100 SCF</td>
<td>BDL (0.003) to 1.4 grains per 100 SCF</td>
</tr>
<tr>
<td>Hydrogen Sulfide</td>
<td>maximum 0.25 to 1.0 grains per 100 SCF</td>
<td>BDL (0.003) to 0.01 grains per 100 SCF</td>
<td>BDL (0.003) to 0.36 grains per 100 SCF</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>max. 0.04 to 0.1 vol%</td>
<td>BDL (0.1 vol%)</td>
<td>BDL (0.1) to 0.3 vol%</td>
</tr>
<tr>
<td>Carbon-dioxide</td>
<td>maximum 1 to 3 vol%</td>
<td>0.49 to 0.66 vol%</td>
<td>BDL (0.03) to 2.6 vol%</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>maximum 1 to 4 vol%</td>
<td>BDL (0.03 vol%)</td>
<td>BDL (0.03) to 12.7 vol%</td>
</tr>
<tr>
<td>Oxygen</td>
<td>max. 0.001 to 1 vol% majority: 0.1 to 0.2 vol%</td>
<td>0.49 to 0.66 vol%</td>
<td>BDL (0.03) to 12.7 vol%</td>
</tr>
<tr>
<td>Diluents + Inerts</td>
<td>maximum 3 to 6 vol%</td>
<td>BDL (0.03 vol%)</td>
<td>BDL (0.03) to 12.7 vol%</td>
</tr>
<tr>
<td>Ammonia</td>
<td>none</td>
<td>BDL (10 ppmv)</td>
<td>BDL (10 ppmv)</td>
</tr>
<tr>
<td>Total Bacteria</td>
<td>none</td>
<td>9.85x10^4 to 2.14x10^6 # per 100 SCF</td>
<td>3.47x10^4 to 6.39x10^4 # per 100 SCF</td>
</tr>
<tr>
<td>Mercury</td>
<td>none</td>
<td>BDL (0.01 µg/m³)</td>
<td>BDL (0.01) to 0.06 µg/m³</td>
</tr>
<tr>
<td>Other Volatile Metals¹</td>
<td>none</td>
<td>BDL to 329 µg/m³ (Zn)</td>
<td>BDL (30) to 213 µg/m³ (As, Cu, Pb, Zn)</td>
</tr>
<tr>
<td>Siloxanes (D4)</td>
<td>none</td>
<td>BDL (0.1 mg/m³)</td>
<td>BDL²</td>
</tr>
<tr>
<td>Non-Halogenated Semi-Volatile and Volatile Compounds</td>
<td>none</td>
<td>BDL² to 6 ppbv (phthalate)</td>
<td>BDL² to 471 ppbv (1,3-butadiene, acrylonitrile, BTEX)</td>
</tr>
<tr>
<td>Halocarbons</td>
<td>none</td>
<td>BDL (0.1 ppmv)</td>
<td>BDL (0.1 ppmv)</td>
</tr>
<tr>
<td>Aldehyde/Ketones²</td>
<td>none</td>
<td>BDL (10 ppbv)</td>
<td>BDL (10) to 103 ppbv</td>
</tr>
<tr>
<td>Polychlorinated biphenyls (PCBs)</td>
<td>none</td>
<td>BDL (0.01 ppbv)</td>
<td>BDL (0.01 ppbv)</td>
</tr>
<tr>
<td>Pesticides</td>
<td>none</td>
<td>BDL (0.0006) to 0.006 ppbv (4,4'-DDT)</td>
<td>BDL (0.0006 ppbv)</td>
</tr>
</tbody>
</table>

¹ Detection limits for siloxane ranged from 0.5 mg Si/m³ to 0.1 as analysis methods improved.
² Detection limits vary from 1 ppmv (volatiles) to 5 ppbv (semi-volatiles).
³ Field blanks contained copper, zinc and acetone.