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

Final Report

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1 The Northeast Gas Association is a regional trade association that focuses on education and training, technology research and development, operations, planning, and increasing public awareness of natural gas in the Northeast U.S. The Northeast Gas Association (NGA) represents natural gas distribution companies, transmission companies, liquefied natural gas suppliers and associate member companies. Its member companies provide natural gas service to over 13 million customers in 9 states (CT, MA, ME, NH, NJ, NY, PA, RI, VT).

Contents

Foreword

The objective of this document is to provide the technical framework and guidance necessary for the introduction of renewable natural gas (RNG) into the natural gas distribution pipeline network.

RNG is a product of anaerobic digestion or gasification of a wide variety of waste products. These include dairy/animal residuals, landfill biomass material, wastewater treatment produced gases, digestion of agricultural wastes and, in advanced systems, co-digestion of mixed biomass substrates. Digestion of biomass material results in "raw" biogas production; gasification of biomass similarly produces a "raw" syngas. To be suitable for introduction to the natural gas pipeline network, these raw gases must be processed in order to increase methane content and remove constituents potentially problematic to pipeline integrity and end-use applications.

Over the past decade, significant research has been conducted to better understand the similarities and differences between the composition of the raw biogas/syngas and traditional pipeline quality natural gas delivered into the gas distribution system pipeline network. In parallel, significant technology advancements have been achieved in processing and treating raw biogas/syngas to address trace constituent concerns of end-users, thus making RNG compatible with the local gas distribution system and end-use requirements.

This document is intended to encourage maximum acceptance of RNG into the natural gas network by using a "*good science and common sense*" approach to establishing composition equivalency and interchangeability with RNG and pipeline supplies - bridging policy and technical concerns of both project developers and pipeline operators. Much of the information contained in this document is based on prior work by GTI and others in assessing the interchangeability and overall compatibility of RNG with traditional pipeline supplies. A list of these resources is included in this document. This manual is a compilation of prior member-sponsored research, publicly available technical literature, Internet information and opinions of researchers, and other experts in the industry.

The industry is still learning about RNG and its effects on pipeline infrastructure and end use. It is in the industry's best interest to continue research, collaboration and dissemination of available history and experience. Even though attempts were made to gather information from reliable sources and correctly interpret it, this information should be used only for educational purposes. More in-depth specific analysis may be required to address project specific situations.

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- Central Hudson Gas & Electric
- Consolidated Edison Company of New York
- National Fuel Gas Distribution
- National Grid
- New York State Electric & Gas (NYSEG)
- Orange & Rockland Utilities
- Rochester Gas & Electric (RGE).

NGA and the participating sponsors would like to thank our consultant for this project, The Gas Technology Institute (GTI), and more specifically Karen Crippen and Kristine Wiley, for their many years of work to help pave a path of mutual understanding for RNG stakeholders based on "good science & common sense."

Individuals making considerable contributions in helping balance both policy and technical concerns of a broad group of stakeholders to encourage broader acceptance of RNG into distribution system pipelines include:

Donald Chahbazpour, National Grid
McKenzie Schwartz, National Grid
Melissa Spinelli, National Grid.

National Grid continues to play a significant role across the industry in developing and promoting RNG acceptance strategies.

NGA and the project sponsors would also like to thank members of The Coalition For Renewable Natural Gas (RNG Coalition) and the American Biogas Council (ABC) for their continued support and willingness to work collaboratively with the pipeline operator community in finding solutions to technical and policy questions that enable our mutual goal of maximizing acceptance of RNG supplies into the pipeline grid.

A. Executive Summary

Throughout North America, RNG project developers are in discussion with gas pipeline operators. However, the processes, requirements, and agreements to enable connecting these valuable supplies are not uniform, resulting in commercial and technical uncertainties for both parties that inhibit maximum recovery and utilization of this valuable resource. A consistent, non-discriminatory approach is needed to assess the commercial and technical viability of each project. Such an approach would encourage and enable introduction of RNG from a range of biomass sources into the pipeline system without compromising safety or reliability of the pipeline grid and end-use applications. Additionally, the approach provides increased certainty for all parties involved in negotiations regarding safety, reliability, continuity, and interchangeability. Development and use of a proper approach can be instrumental in defining the requirements to keep gas flowing from an RNG facility and avoid unnecessary service interruption. Importantly, a project approach will aid project developers and RNG producers by providing a standardized framework that can be applied, as appropriate, to reduce uncertainty about what is needed to optimize biogas/syngas processing facility design.

This document is intended to outline a structured approach that all parties can use to begin the technical collaboration processes necessary to understand each stakeholder's requirements, and ultimately, make each biogas development project a success story for all parties involved. It lays out the distinct roles and responsibilities of the pipeline operator and the project developer/ producer, 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 among all parties.

Although fundamental interchangeability criteria have been established for processed gases, including RNG, the lack of a consistent approach to evaluating acceptance criteria and trace constituent composition equivalency has sometimes been a barrier to broader acceptance of RNG directly into distribution networks. This guidance document provides an example of an evaluation process, including identification of reasonably expected potential constituents of concern (including trace constituents) based on biomass feedstock and conversion processed used, and compares these constituents to those found in typical pipeline supplies. The approach to trace constituent *composition equivalency* helps eliminate a "one size fits all" assessment and gas processing solution by focusing on specific, reasonably expected raw gas constituents relative to biomass feedstock. Project developers can then evaluate, optimize and employ raw biogas/syngas upgrading technologies to produce RNG with comparable reasonably expected trace constituent levels presently found in flowing pipeline supplies (i.e., trace constituent compositional equivalency).

A user-friendly technical framework is provided to help reduce overall operational risk for both the developer and pipeline operator, thereby minimizing potential impacts to end-use consumers. This framework includes the following key elements:

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

Finally, the document provides a comprehensive list of technical references that support the overall suggested process approach to accepting RNG supplies into the distribution network. The appendix contains a sample Interconnect Feasibility Analysis Agreement (IFA) 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.

B. Introduction - RNG Gas to Pipeline Grid

Biogas, Syngas and RNG

RNG is a pipeline-compatible, gaseous fuel derived from biomass or other renewable sources. It has lower lifecycle CO_2e emissions than geological natural gas and is compositionally equivalent and fully interchangeable with natural gas. It is the product of raw biogas (from anaerobic digestion) or syngas (from biomass gasification) that has been upgraded to pipeline quality.

Anaerobic digestion (AD) produces biogas through the biological decomposition of organic matter in the absence of oxygen. The digestion process begins with bacterial hydrolysis of the input materials in order to break down insoluble organic polymers such as carbohydrates and make them available for other bacteria. Acidogenic bacteria then convert the sugars and amino acids into carbon dioxide, hydrogen, ammonia, and organic acids. Acetogenic bacteria then convert these resulting organic acids into acetic acid, along with additional ammonia, hydrogen, and carbon dioxide. Finally, methanogens convert these products to methane and carbon dioxide. Potential waste-derived biogas sources include landfills, source separated organics anaerobic digestion (AD) facilities, wastewater treatment plants (WWTPs), and animal farms. Gasification produces syngas from biomass feedstocks such as wood waste, the organic fraction of municipal solid waste, bagasse, and other biologically derived materials. Gasification is a high temperature conversion process with very low oxygen present that transforms organic material into syngas that can be further processed to reform the predominantly hydrogen and carbon monoxide syngas to methane, and ultimately into RNG.

Regardless of the biomass source or conversion technology, when the raw gas is appropriately upgraded to meet trace constituent compositional equivalency and interchangeability requirements, RNG is an overall low carbon product that facilitates meeting long-term decarbonization goals. In addition, in certain areas RNG recovery can be a viable option for meeting localized demand for pipeline natural gas and reducing the need for pipeline expansion.

RNG is already being accepted and used in many parts of the country. As an example, introduction of RNG directly into a gas distribution system has been successfully practiced for over 30 years at the Fresh Kills landfill in Staten Island, New York, and one of the largest sewage treatment plant digester gas to RNG projects is planned at the Newtown Creek wastewater treatment plant (WWTP) in New York City. Today, more companies are considering RNG as a fuel of choice and part of their overall equation in meeting renewable energy needs. This is an opportunity to further shape the energy future of the gas network by recovering a valuable fuel resource while reducing the release of greenhouse gases to the environment. Indeed, much like the "great conversion" from manufactured gas to pipeline supplies in the 1960's, a comprehensive energy strategy regarding recovery and introduction of RNG directly into the pipeline grid may be the industry's second great conversion.

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 or the local natural gas utility (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 requirements. 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 select, 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). Pipeline operator gas quality and interchangeability requirements are driven by pipeline safety, integrity and end-use requirements in addition to local regulatory requirements. For example, in New York State, 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 operator's 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 to ensure trace constituent compositional equivalency and interchangeability.

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-negative or low carbon energy source because the carbon released by its combustion is already fixed from the natural carbon cycle and may originally derive from the collection of potent greenhouse gas emission-related carbon gases. Consequently, recovery of biogas and subsequent processing to RNG represents a holistic view of the energy system by capturing gaseous by-products of local waste stream decomposition to address climate change. Furthermore, an existing gas network is delivering a new source of renewable energy.

Recovering RNG also makes economic sense. Construction, operation, and maintenance of RNG gas production plants create new jobs and stimulates the local economy. Producing, recovering, and using RNG increases the security and diversity of energy supplies in the United States. For local distribution system operators, RNG introduction can significantly help meet growing local demand for natural gas, and in some cases, do so without the need for construction of additional pipeline capacity. Where pipeline interconnects are not economical due to the proximity of the RNG supply relative to the pipeline network, virtual pipelines are providing valuable options to transport the RNG product to local distribution systems.

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 connection process, with each step discussed in detail in ensuing sections.

Figure 1: Sequence of Events in Getting Connected

C. Preliminary Evaluation

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 describe the project to the pipeline operator. Providing as much information at this point will make the process go as quickly and smoothly as possible. At a minimum, the preliminary evaluation should cover:

- Proposed facility location and land ownership,
- Source of raw gas (WWTP, landfill, agriculture, food, gasification, etc.),
- Anticipated interconnect pressure,
- Temperature,
- Interconnect pipe size,

- Anticipated gas quality at the interconnect point,
- Information about proposed upgrading/cleanup technology (including commercial track-record if available),
- Production flow rates (net anticipated hourly/daily flow rates),
- Any RNG expected daily/seasonal variations, and
- Any other key process variables such as the ability to aggregate supply, if needed.

The pipeline operator's 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's contact person will then contact the developer/producer to discuss results of the preliminary assessment, which includes a pipeline capacity assessment and an order-of-magnitude interconnection cost estimate. If the project developer wishes to proceed, the pipeline operator contact can choose to set up a preliminary review meeting with the developer/producer.

During a preliminary review meeting, the pipeline operator will go over the required next steps based on pipeline operator-specific needs, and any local, state and/or federal regulatory requirements related to the interconnection. Relevant gas quality requirements will be included based on the anticipated biomass feedstock material (see Appendix H for Feedstock/Upgraded Gas Constituent Guidance Matrix)[2]. A schedule for further meetings will be determined, if appropriate. A sample preliminary assessment form is included in Appendix A. A nominal application fee may be appropriate to enable the pipeline operator to recover its costs to perform the preliminary evaluation.

D. Interconnect Feasibility Analysis Agreement (IFA)

If the pipeline operator's analysis indicates enough capacity at the desired interconnect location, and the project developer indicates the preliminary estimate for pipeline connection cost is within their feasibility range, the process will move to the next step, which is the execution of Interconnect Feasibility Analysis Agreement (IFA).

The IFA is required for a pipeline operator to conduct more detailed engineering assessments, interconnection design and design review and cost analysis for making the connection to the pipeline system. Reasonable cost recovery for the IFA may be required to ensure ratepayers are not subsidizing a project developer's work. In this case, pipeline operators will provide an IFA cost estimate for the project developer to consider. The IFA provides the framework for the detailed evaluation of the technical aspects of the project, such as pipeline materials; pipeline easement requirements; equipment, facilities and layout of the interconnection; flow and seasonal capacity system modeling impacts on the pipeline network as a result of a new source of supply (RNG); impacts on potential sensitive end-use customers; and potential impact of RNG supply influence on therm billing zones. The assessment also includes a comparative

2 The goal is to ensure that the RNG is equivalent, from a compositional and interchangeability perspective, to pipeline supplies flowing at the proposed interconnect point.

evaluation of existing gas supply composition to establish baseline RNG interchangeability and quality requirements for the project.

The detailed IFA includes the pipeline operator consulting internally within their organizations (gas supply, gas control, engineering, legal, etc.) to ensure a complete interconnection estimate is provided to the developer to formally assess project feasibility. The IFA will include a schedule of communication and required deliverables between the two parties and will designate the technical contacts for the review process.

As part of the IFA, the pipeline operator will need more detailed information about the project. The developer/producer will provide a detailed *RNG Technical Summary* to the pipeline operator, conducted under a Non-Disclosure Agreement (NDA) if required by the developer.

Included in the RNG Technical Summary is:

- A description of the biomass source, conversion technology and raw gas upgrading technologies under consideration.
- A projected RNG project schedule with planned pipeline interconnection.
- Expected RNG production rates, including anticipated periods of reduced flow due to expected downtime for maintenance, etc.
- Supporting data from reference projects that demonstrates the proposed upgrading technology is sufficient to meet the pipeline gas compositional and interchangeability equivalency requirements.

The IFA should be executed as soon as possible after the RNG project developer confirms their wish to proceed based on 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. Executing the IFA and completing the FA does not guarantee acceptance of the project. 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 and end-use customer needs must be considered. Not all pipelines have capacity to receive gas on a routine basis.

Appendices A-D offer guidance and highlight technical considerations that should be included in the IFA. Appendix E contains an *example* of an IFA. In addition to successful completion of the IFA, a Gas Sales Agreement (GSA) must be executed before the project is considered binding and construction can proceed. In some cases, the IFA/GSA is negotiated as a *single* agreement. The GSA is discussed in more detail in the next section.

E. Gas Sales Agreement (GSA) or Interconnect Agreement

Once the IFA is complete and the interconnect is found acceptable to all parties, 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 (commercial terms of gas purchase) and a Tap Agreement (commercial terms of the interconnect / custody transfer facility). It is recommended that the GSA be negotiated in parallel with the IFA. Elements of a GSA include but are not limited to:

- Payment for pipeline interconnection cost(s) and any other ongoing charges,
- Delivery obligations (mutually agreeable RNG gas quality specification, expected flow rates),
- Gas pairing agreements (contractual blending net metering and compensation agreements if applicable)[3],
- 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, heating value adjustment, if needed, 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.

The GSA will include the many variables assessed by the pipeline operator during the IFA in order to complete a reliable and safe interconnection including:

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?
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 constituents of concern (COC). A customer impact survey may be needed.

3 Gas pairing agreements allow for contractual blending, where the pipeline operator provides the developer with the option for "pairing" RNG that cannot otherwise meet pipeline requirements, typically for heating value, for a negotiated fee.

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 enough 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. Consideration of the raw gas source. If any Constituents of Concern (COC) are reasonably expected in the raw gas, the developer will work with the operator to provide assurance that the proposed cleanup technologies can control COCs to meet pipeline composition equivalency and interchangeability requirements.

After completion of the GSA or Interconnect Agreement, the project can then commence facility construction, ultimately leading to Commissioning. Appendix F contains an example GSA. Appendix G provides a more detailed Gas-to-Grid process flow diagram.

F. Feedstock, Pipeline Gas Quality and Safety Assessment Considerations

It is important for the engineering staff undertaking the preliminary evaluation and IFA to understand the RNG feedstock (biomass/typical raw gas composition), since raw gas quality will vary depending on the source. Raw gas from a landfill operation, for example, is different than gas from a biomass gasifier or a dairy digester. Constituents of concern (COC typically include trace constituents which may vary significantly by feedstock and conversion technology (see Appendix H for Feedstock/Upgraded Gas Constituent Guidance Matrix) and aligning testing requirements with expected COC will help optimize testing requirements***. If a COC is not reasonably expected to be found above background levels in flowing gas supplies at the point of interconnect, then testing may not be required.***

It is the developer/producer's responsibility to affirm and demonstrate through comparative analysis that reasonably expected COC concentrations in the raw gas (based on raw gas analysis and/or similar prior processing experience or prior applicable engineering studies) will be removed and/or limited to concentrations typically found in flowing pipeline supplies at the interconnect location. It is not the pipeline operator's intent to approve the selected technology, merely to review and ensure the technology selected is appropriate to meet the gas composition and interchangeability requirements of the interconnect point.

The biomass source / raw gas evaluation needs to consider, as appropriate, the constituent classes identified below.[4] It is also important to evaluate the natural gas supply at or near the

4 See Appendix H for reasonable guidance on potential constituents of concern based on biomass / raw gas.

proposed interconnect point to provide a basis for comparison. COC testing, when required, should be done by a mutually agreed upon third party analytical laboratory service provider using mutually agreeable standard sampling and testing methods.

Technical considerations include:

- *Major/minor constituents*—Including hydrogen, with properties calculation (heating value, Wobbe Number, relative density, hydrocarbon dew point 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*—May be found in raw biogas from landfills and WWTPs
- *Halogenated compounds*—For example vinyl chloride, cloroethane and Freon™ compounds may be found in landfill-derived raw biogas
- *PCBs and pesticides*--If necessary, depending on type of biogas and any reasonable indication of historical presence (such as a landfill that may have received PCB containing hazardous waste)
- *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*

Each of these COCs has a differing impact on gas quality, interchangeability, end-use safety/reliability 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[5] is essential for any project. The pipeline operator must have a consistent and predictable RNG supply.

Table 1 highlights reasonably attainable gas quality parameter boundary limits to ensure a reliable, interchangeable RNG supply into the pipeline grid. These limits have been demonstrated to be achievable utilizing currently available raw gas upgrading/clean-up technologies. It should be noted that this table serves as a *starting place* for discussions

5 For purposes of this document, treated biogas that results in a biomethane product that is interchangeable from an end-use perspective and similar in constituents (both qualitative and quantitative compositional equivalency) to pipeline natural gas at the point of interconnect shall be considered commercially free of objectionable materials consistent with the intent of the definition in AGA Report 4A.

between the pipeline operator and the developer. Individual interconnect points, operating procedures or tariffs may require different limits based on system operations as determined by the pipeline operator.

Nonetheless, this table is a useful tool to enable reasonable determination of gas quality interconnect requirements and constituent limits that ensures trace constituent compositional equivalency and interchangeability at the interconnect.

Table 1: Gas Quality Minimum Considerations[6]

Gas Quality Specification	Low	High
Heat Content (BTU/scf) 7	970	1110
Wobbe Number (+/- 4% from historical supply)8	1270	1400
Water Vapor Content (lbs./MM scf)9		<7
Product Gas Mercaptans (ppmv, does not include gas odorants)		<1
Hydrocarbon Dew Point, (°F) CHDP		15
Hydrogen Sulfide (grain/100 scf)		0.25
Total Sulfur (grain/100 scf)		1
Total Diluent Gases including the following individual constituent limits:		4%

[6] For purposes of this document "Commercially Free" is defined as "Not Detectable" relative to typical pipeline gas flowing at the interconnect location that results in RNG being compositionally equivalent to flowing supplies. The analytical method and associated detection threshold are based on a mutually agreeable analytical method and laboratory. Testing should be considered where potential COC's are reasonably expected and should not be presumed to be required for all projects or in all cases. Typically detection thresholds / reasonable concentration limits relative to pipeline gas are provided for context.

7 HHV is dry, @ 14.73 psia 60°F

8 Wobbe +/- 4% from adjustment gas (historical supply), provided that the lower limit will not be below 1270, and upper limit will not be above 1,400, with HHV capped at 1,110.

9 Water vapor content specified in tariffs from interstate pipelines serving the Northeast typically ranges from <4 to <7 lbs/MMscf, and as a practical matter, actual measured values are typically below 4lbs/MMscf.

Carbon Dioxide 2% max Nitrogen 2% max Oxygen (O_2) 0.1%-0.4%[10] max		
Hydrogen[11]		0.1-0.3%
Total Bacteria[12]	Comm Free (≤0.2 microns)	
Mercury	Comm Free (<0.06 µg/m³)	
Other Volatile Metals	Comm Free(<213 µg/m³)	
Siloxanes as (D4)[13]	Comm Free(-<0.5 mg Si/m³)	
Ammonia	Comm Free(<10 ppmv)	
Non-Halogenated Semi-Volatile and Volatile Compounds	Comm Free(<500 ppmv)	
Halocarbons (total measured halocarbons)	Comm Free(<0.1 ppmv)	
Aldehyde/Ketones	Comm Free(<100 ppbv)	
PCB's/Pesticides[14]	Comm Free(<1 ppbv)	

The minimum heating value requirement is based on utilization by atmospheric burners typically associated with end-use appliances and is parallel to recently issued guidance in California. Factors that may ultimately influence this value include the ability of the pipeline operator to manage system flows to ensure safe, reliable supply conditions in the event there is an RNG supply interruption or processing anomaly. The pipeline operator will typically assess this value based on the zone of influence analysis and system modeling conducted in the system interconnect feasibility analysis, and discuss injection/interconnect options with the developer. This may be a specific concern for interconnect points involving a single feed, or isolated sections of a local gas distribution system due to the lack of aggregation capability.

G. Pre-Construction, Construction and Facility Start-up

Transparency during project development is key and the pipeline operator must be kept informed on the progress of the biogas upgrading/clean-up plant construction. All applicable 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. For any equipment directly interfacing with the pipeline operator such as the metering and custody transfer point, the pipeline operator must be granted access for

10 Oxygen content specified in tariffs from interstate pipelines serving the Northeast typically range from <0.1% to <0.4% max.

11 Hydrogen content can range from 0.1% to 0.3% with typical measured values <0.1%

12 An acceptable alternative to Total Bacteria testing would be to include installation of a 0.2 micron particulate filter, coupled with appropriate filter maintenance practices. Initial start-up testing may include filter effectiveness analysis.

13 Historical testing and data presented in this document include a siloxane detection threshold of < 0.5mg Si/m³. Analytical methods have recently been improved resulting in a reduced detection threshold of < 0.1mgSi/m³. Due to specific limitations of certain identified applications within an affected zone of influence, an operator and developer may consider the reduced threshold.

14 PCB/Pesticide testing is typically not required as the maximum equilibrium concentration in recovered gas at atmospheric temperature is typically below detection thresholds.

periodic progress inspection and to ensure compliance with any applicable company engineering standards and practices. 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 as they affect the pipeline,
- O&M and safety plans and procedures as they affect the pipeline,
- Discussion of odorization needs and responsibility,
- Final gas quality tariff specifications,
- On-line instrumentation needs and sharing of data/signals
- 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.

H. Facility Operation and Maintenance

Once the project is operational the developer/producer and pipeline operator should work together in the spirit of transparency to ensure on-going success of the facility. Specific areas of focus are summarized below.

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 (inert and diluents including oxygen, nitrogen and carbon dioxide), sulfur compounds (total and specified), temperature, pressure, and moisture.

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 of any substantive expected change to the raw gas quality or upgrading process that have the potential to impact RNG quality, so that the pipeline operator can review whether any action is required. In some cases, for example, if the feedstock changes a supplemental technology review, additional sampling, or shut down of the interconnection may be required..

Facility O&M Procedures

A comprehensive, well documented Operations and Maintenance Plan (O&M) of the raw gas processing facility is the key to ensure sustainable, uninterrupted operations. Operational reliability is a key consideration for both the developer and the pipeline operator. In addition to increasing operating revenue, an effective O&M Plan also extends 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, Btu adjustment spiking equipment
- Location and control of overpressure protection, critical isolation valves and check valves to prevent backflow,
- Gas quality monitoring alarm or "trigger levels" that require response actions and a description of required actions,
- 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.

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 and appropriate sampling points that are typically found at custody transfer locations:

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

Good practice for utilization of 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 additional monitoring requirements for specific COCs that will verify the consistent operation of the upgrading facility. The 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 testing will result in two possible scenarios:

1. 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.[15]

[15] The purpose of establishing "action levels" is to provide transparency and visibility of potential trends in gas quality that could result in reaching a trigger level requiring a shut down. Ultimately, both the developer and pipeline operator need to work together to keep the facility on-line.

2. The gas will be shut-in and the facility isolated if the concentration level 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. Again, the goal is to optimize any gas clean-up process to make the RNG consistently compositionally equivalent and interchangeable with the pipeline gas at the interconnect point.

Usually there will be an accelerated phase of compliance monitoring (3-6 months) for COCs at the beginning of an RNG interconnect project while the facility is on-line. This monitoring plan is designed to look at potential variation in gas quality resulting from the gas cleanup system. It is reasonable to *reduce* the frequency of maintenance sampling as the upgrading process and biogas source are shown to be in control and meeting design specifications. The maintenance sampling schedule and mutually agreeable acceptable compositional ranges should consider potential seasonal variation of gas quality. This compliance monitoring achieves three goals:

1. The pipeline operator can monitor and assure the quality of the gas product within the pipeline system based on routine production of the product over a trial period,
2. The producer can verify that the product is consistent and safe for pipeline interchange,
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. Inert sample containers and specific sorbent materials will be used as necessary for constituents as specified in the GSA. Guidance documents for sampling and testing on the exact required 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 will provide data which assures consistent gas quality. Once the pipeline operator and producer are mutually satisfied that the facility is operating as expected and in control, maintenance monitoring may commence. Maintenance monitoring includes use of on-line monitoring equipment such as the 10-component gas chromatograph, odorant/sulfur chromatograph, moisture analyzer, and pressure and temperature monitors, to ensure the gas upgrading facility remains in control thereby allowing these parameters to act as surrogate monitoring parameters for COCs. This surrogate monitoring strategy will allow for optimization of future COC verification monitoring[16].

16 When applying a surrogate parameter maintenance monitoring strategy, trace constituents are first measured and confirmed to be within specification in parallel with major constituent and other on-line monitoring requirements. During routine “maintenance monitoring”, the facility and process are presumed to be in control,

Odorization

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. Other local jurisdictional limits may apply; for example, New York State code (16 NYCRR 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 odorizing agent, which odorant to use, and what the odorant level should be. In some 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 NYCRR 255.625, odorization equipment must be designed and maintained 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. Regardless of ultimate responsibility for odorization equipment operation, 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 chemically interfere with or mask the odorant smell. Treatment chemicals and solvents from the upgrading process can also be carried over into the pipeline and “pool” within the pipeline facility providing a sponge-like effect, absorbing injected odorant, and subsequently interfering with the odorization process.

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provided primary monitoring parameters stay in control avoiding routine, on-line monitoring of trace constituents. If any physical changes occur within the gas clean-up process, or operational anomalies occur that cannot be immediately corrected, additional COC monitoring may need to be repeated to establish the facility can meet gas quality control requirements.

I. Technical References

1. Natural Gas Quality Management Manual. Prepared by the AGA Transmission Measurement Committee. August 2013. Catalog # XQ1303.

2. Report No. 4A AGA Natural Gas Contract Measurement and Quality Clauses. AGA Transmission Measurement Committee. 2009. Catalog #XQ0904.

3. White Paper on Natural Gas Interchangeability and Non-Combustion End Use. NGC+ Interchangeability Work Group. February 28, 2005.

4. White Paper on Liquid Hydrocarbon Drop Out in Natural Gas Infrastructure. NGC+ Liquid Hydrocarbon Drop Out Task Group. February 28, 2005.

5. Pipeline Quality Biogas – Guidance Document for Dairy Waste, Waste Water Treatment and Landfill Conversion. USDOT/PHMSA Agreement: DTPH56-08-T-000018, Project 250. GTI Project 20736. 2009.

6. Pipeline Quality Biomethane: North American Guidance Document for Introduction of Dairy Waste Derived Biomethane into Existing Natural Gas Networks. GTI Collaborative Project 20614. GTI Report # 09/0011. September 2009.

7. Guidance Document for the Introduction of Landfill-Derived Renewable Gas into Natural Gas Pipelines. GTI Collaborative Project 20792. GTI Report # 12/0007. May 2012.

8. Guidance on Biogas Quality and RIN Generation when Biogas is Injected into a Commercial Pipeline for use in Producing Renewable CNG or LNG under the Renewable Fuel Standard Program. EPA-420-B-16-075. September 2016.

9. Renewable Gas — Vision for a Sustainable Gas Network. National Grid position paper. https://www9.nationalgridus.com/non_html/NG_renewable_WP.pdf Accessed Oct. 14, 2010.

10. The Production, Treatment, And Utilization of Biogas, Lee Enterprises Consulting Inc, July 2018

11. Biomethane in California Common Carrier Pipelines: Assessing Heating Value and Maximum Siloxane Specifications, CCST 2018, ISBN Number 978-1-930117-59-4

J. 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. In landfills, it is the first step in microbiological conversion of organic materials to volatile fatty acids, carbon dioxide and ammonia. Aerobic microorganisms contained in all decaying matter initially react with oxygen from entrapped air.

Aggregation – Another term for gas blending.

Agricultural / Clean Organics – include organic waste derived from agriculture by-products or waste streams such manure, crop waste, etc.

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 of biomass. Depending upon the feedstocks used and conditions of digestion, biogas typically 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 "conditioned" or "upgraded" to meet the

requirements of the intended end use, including pipeline injection. "Raw" biogas is not interchangeable with 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 have higher energy potential than others, and some are more suited for anaerobic digestion while others with high lignin content are more suitable for gasification. 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.

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.

Compositionally Equivalent – Relative comparison of the composition of two gas streams' trace constituents to establish supply equivalency and interchangeability from an individual constituent perspective.

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, typically includes trace constituents (see Trace Constituents).

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

Digester (Anaerobic) – A tank, covered lagoon or another 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.

Interconnect Feasibility Analysis Agreement (IFA) – An agreement where the distributor or pipeline operator performs a detailed evaluation of the technical aspects of an RNG pipeline interconnection point and overall RNG project proposal impacts on the pipeline system. During this step the producer will provide a detailed Technical Proposal.

EPA – U.S. Environmental Protection Agency

Gas Cleanup and Gas Upgrading – Used somewhat interchangeably in reference to the unit operations for treating raw gas resulting from biomass conversion. The goal of the gas cleanup unit is to remove constituents within the raw gas that could cause pipeline or end-user health or safety issues. Cleanup efficiencies for constituents of concern vary between cleanup or "conditioning" units. An upgrading unit for biogas will isolate the methane from the carbon dioxide in order to increase heating value of the RNG, while an upgrading unit for syngas will reform the hydrogen and carbon monoxide to form methane in order to produce RNG.

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 a raw gas which can be used to produce RNG. Gasification is a high-temperature, low oxygen conversion process of organic material into a syngas that can be reformed into methane and cleaned of trace constituents into RNG for pipeline injection.

Gasifier/Syngas – See Gasification

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. For example, these constituents include Freons, chloroethane and vinyl chloride.

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.

Inert 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 H_2S.

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 upgrading 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.

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.

Producer – The producer is responsible for producing and upgrading biogas/syngas to RNG. The producer may be the digester owner, or it may be the upgrading 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 – Pipeline compatible gaseous fuel derived from biomass or other renewable sources that has lower lifecycle CO2e emissions than geological natural gas. It is 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 during which the gas resulting from an RNG production process is subject to analytical testing and review, to confirm RNG quality. The verification program includes certain verification steps prior to introduction of the RNG product to the natural gas system, so that analytical compliance may be demonstrated, and then continued with the RNG system fully on-line.

Sensitive Receptor – An end-use customer, process or equipment that is affected, to an unusual degree, by compositional change or rate of change of gas properties.

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 R_2SiO_2, 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 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.

Source / Facility Separated Organics – organic materials separated at the source for separate collection.

Trace Constituents – A very small quantity of an element or compound in a given substance, especially when so small that the amount is not quantitatively determined above a method detection limit based on a mutually agreeable industry approved analytical method.

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

Volatile and Semi-volatile Organic 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 upgrading 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.

Appendix A – Preliminary Scope Details Sample Project Assessment Form

Applicant Information					
Company Name	Awesome RNG			Today's Date	10/10/18
RNG Facility	Leftovers, Inc.				
RNG Facility Address	1234 6th Street, Brooklyn	State	NY	ZIP	11111
PROCESS INFORMATION					
Cleanup System Interconnect Pressure	Process outlet is 100#, will adjust to meet pipeline needs				
Cleanup System Interconnect Temperature	Process outlet is 80F, will adjust to meet pipeline needs				
Expected Heating Value Range (BTU) of Cleaned Biomethane[17]	970-990 BTU/ft3				
Amount and Flow of Gas (in dth/hr, scf/hr or BTU/hr)	1MMCF/hr				
Daily/Seasonal Variations in Deliverability of Gas Composition	Expected to run 24/7/365 with no variation in product flow or specifications				
ADDITIONAL INFORMATION					
Please provide more detailed information about expected composition of RNG					
• __% methane • __% nitrogen • __% CO_2 • __% O_2 • Etc.					
Please provide any other key process variables and any additional information if available below					

17 Specify HHV as real, dry @ 14.73 psia 60°F

- Chosen gas cleanup technology
- Data providing technology is compatible with gas feedstock
- Etc.

Pressure Swing Adsorption system. Can provide data from project X that has similar feedstock and uses a PSA system on their gas to inject into the local distribution system. Cleanup vendor TBD.

Expect to begin commissioning in August 2021 and full commercial operations in January 2022.

Appendix B – Producer and Pipeline Operator Assessment Process Checklists

- ☐ Who are the parties who are entering into the contract?
- ☐ Assignment of a project manager (technical contact) from the producer
- ☐ Assignment of a project manager (technical contact) from the pipeline operator
- ☐ Physical location of the receipt/delivery point
- ☐ Agreement of producer to allow access to site where applicable
- ☐ Description of the process: Anaerobic digester gas type (dairy, WWTP, food waste, landfill) or gasification feedstock
- ☐ Definition of any technical terms
- ☐ Regulatory requirements, as necessary
- ☐ Discussion of New York State Code NYCRR Chapter 03 Gas Standards Part 229 standards for pipeline injection and pipeline operator specifications
- ☐ Specified party responsibilities and accountability aspects of O&M of the interconnect facilities
- ☐ Agreement to forward any new information regarding the project and amend the IFA / GSA when appropriate
- ☐ Periodic meeting schedule
- ☐ Description of requirements that the pipeline operator needs to provide to the producer
    i. Company standards for the developer to follow (electrical, instrumentation, safety etc.)
    ii. Company specifications for metering
    iii. Technical assistance as needed for analytical instrumentation
    iv. Odorant design and specifications (utility may operate odor equipment, but developer is responsible for installation and costs)
    v. Any other engineering and technical assistance
- ☐ 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. Odor equipment and associated necessities
- ☐ Estimation of the cost to be paid by the producer to the pipeline operator
- ☐ Agreement to follow “Good Utility Practice”
- ☐ Insurance requirements
- ☐ Expiration date and termination terms

Appendix C – Gas Quality and Interchangeability Management Program Considerations

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 monitoring requirements, 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 and other historical references/reports. It is recommended to consult this manual for more detailed information.

The gas quality management plan should consider reasonable expectations for the presence of constituents of concern (COC) before making decisions regarding testing and monitoring plans. Project Developers typically have historical information regarding gas clean-up technologies as well as additional information regarding reasonably expected constituents that may be present in the raw gas stream. The pipeline operator and developer should work together to develop a plan that considers will look at the raw biogas composition and make technically based 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 should be established are established that will strike a balance between all the stakeholders concerns involved. A gas quality management plan should:

- Identify monitoring requirements
- Establish sampling, analytical and monitoring procedures, test methods and method detection thresholds to ensure conformance.
- Identify response actions and/or corrective actions for anomalies/noncompliance
- Establish data retention schedules to support compliance

The completion of an overall interchangeability assessment is advised for each project to determine what the range of acceptability should be. This assessment should include:

- 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 history of end-user 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 of up to 72 hours after successful start-up, where process equilibrium has been reached. The initial start-up test period should include two on/off cycles of the upgrading unit and verification that the system shuts- in and diverts potential non-conforming gas. Depending upon the specific requirements pertaining to any individual company receiving the gas and, the complexity of the upgrading process, 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 start-up product gas generated during the test period should be handled (thermal oxidation, ground flares etc.) in accordance with federal, state and local requirements. Additional monitoring is then conducted as the RNG is initially introduced into the natural gas pipeline network.

This initial Verification Program achieves three goals:

- The pipeline operator can monitor and assure the quality of the new fuel product and the routine production of the product over a trial period,
- The developer/producer can verify that the product is consistent, in conformance with facility performance expectations and safe for pipeline interchange,
- 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 ("system adjustments").

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. 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 H_2S, DMS, methyl mercaptan, ethyl mercaptan and total sulfur at a minimum.

Other COC trace constituents listed in Appendix D should be considered for follow-up testing on a spot sample basis as defined in the GSA, starting when the verification period begins. Samples should be collected every 30 days over a 90 day period. Composite samplers are encouraged as opposed to discrete "grab samples" however both methods used in combination are not unusual.

Once verification of gas quality conformance as specified in the GSA has been determined, a "maintenance" testing schedule can be established. The maintenance testing schedule should

cover seasonal variation (if applicable) of the gas quality and should be a minimum of three sample event periods over the subsequent 12 months following commissioning.
Trigger levels for COC's should be established in the monitoring plan for the maintenance period similar to the start-up analysis period.

Trigger levels for out- of- conformance testing will result in two possible scenarios:

- Additional 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 RNG product gas will be shut-in if the concentration level rises above a second, higher action level, until periodic testing proves the out of compliance issue is resolved.

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. Once the processing system is confirmed operating as designed, these parameters can be used as "surrogate" parameters to ensure the RNG process is in control thereby minimizing on-going testing of trace constituent COC's as described below.

Following initial start-up testing and maintenance monitoring programs, routine monitoring parameters highlighted above using on-line monitoring equipment with data signals remotely monitored by the pipeline operator, shared with the facility operator, allow both parties to ensure the facility is operating in control with similar expected outcomes for COC concentrations during start-up. As a result, unless there is reasonable cause to sample and analyze for COC's (as defined in the GSA), these routine monitoring parameters can be used as COC surrogate monitoring. If any of the routine monitoring parameters trend or spike beyond conformance expectations, and cannot be immediately explained and corrected, additional COC monitoring may be required. These anomalies and conditions should be defined and mutually agreed to as part of the GSA. An example of a routine monitoring program control limits and action levels is included in the Table below:

SAMPLE XYZ Gas Quality Monitoring - Alarm Settings and Shutdown Limits

BTU's		CO2		Oxygen		Nitrogen		Sp. Gravity		Total Sulfur	
Alarm	ESD	Alarm	MSD	Alarm	ESD	Alarm	MSD	Alarm	ESD	Alarm	MSD
971	965	1.78%	2.00%	0.40%	0.50%	1.40%	1.8%	H- .589 L- .560	0.594	0.6 PPM	1 PPM
Contract Limit 972		Contract Limit 1.80%		Contract Limit 0.45%		Contract Limit 1.60%		Contract Limit 0.590		Contract Limit 1 PPM	

Notes:	ESD - Emergency Shut Down - Automatic valve closure
	MSD - Manual Shut Down - Pipeline Operator / Facility Operator initiates remote valve closure
	The total of nonhydrocarbon gases (CO 2 + O2 + N2) is not to exceed 4%
	Total Sulfur is measured at Plant output before Odorant is added

Appendix D –Upgraded RNG Trace Constituents Measurement Matrix

The tables below highlight gas quality monitoring/testing considerations for RNG projects including examples of testing frequencies, test methods and common laboratory detection limits.

Parameter and Sample Frequency Considerations

Parameter	Frequency
Heating Value	Continuous real-time or near-real time GC monitoring and periodic field samples for independent confirmation.
Temperature	Continuously measured on-line
Pressure	Continuously measured on-line
Water Content	Continuously measured on-line
Sulfur, including Hydrogen Sulfide, Ethyl & Methyl Mercaptan, Dimethylsulfide	Continuous real-time or near-real time GC monitoring and periodic field samples for independent confirmation
Hydrogen	Continuous real-time or near-real time monitoring and periodic field samples for independent confirmation
Carbon dioxide	Continuous real-time or near-real time monitoring and periodic field samples for independent confirmation
Nitrogen	Continuous real-time or near-real time monitoring and periodic field samples for independent confirmation
Oxygen	Continuous real-time or near-real time monitoring and periodic field samples for independent confirmation
Biologicals (If reasonably expected)	Incorporation of a 0.2 micron filter would mitigate need for testing if bacteria/spores are reasonably expected
Mercury (if reasonably expected)	Minimum of three samples over a three-month period, with increased frequency, depending upon concentration at first sample point
Siloxanes	Minimum of three samples over a three-month period, with increased frequency, depending upon concentration at first sample point
Semi-volatile and Volatile Compounds (if reasonably expected)	Minimum of three samples over a three-month period, with increased frequency, depending upon concentration at first sample point
Halocarbons (if reasonably expected,	Minimum of three samples over a three-month period, with increased frequency, depending upon concentration at first

Parameter	Frequency
Examples are Freons, chloroethane and vinyl chloride))	sample point
Aldehydes and Ketones (if reasonably expected)	Minimum of three samples over a three-month period, with increased frequency, depending upon concentration at first sample point
PCBs/Pesticides (if reasonably expected)	Minimum of three samples over a three-month period, with increased frequency, depending upon concentration at first sample point]

Parameter, Analytical Methods and Method Detection Limits

Parameter	Method	Common Laboratory Detection Limit
Heating Value	ASTM D3588 (on-line, or off-line canister collection*)	N.A.
Water Content	ASTM D5454 (on-line only)	N.A.
Sulfur, including Hydrogen Sulfide	ASTM D6228, D5504 (off-line canister collection) ASTM D4084 (H_2S on-line) and D4468 (total S on-line) ASTM D7493 (on-line sulfur speciation)	0.05 ppmv
Hydrogen	ASTM D1945, D1946 (usually only off-line gas chromatographs can measure hydrogen, canister collection)	0.1 vol% (0.001 vol% with special techniques)
Carbon dioxide	ASTM D1945, D1946 (on-line, or off-line canister collection)	0.03 vol%
Nitrogen	ASTM D1945, D1946 (on-line, or off-line canister collection)	0.03 vol%
Oxygen	ASTM D1945, D1946 (on-line, or off-line canister collection)	0.03 vol%
Biologicals[18]	Use of a ≤0.2 micron filter to assess the presence of total bacteria/spores	0.2 microns

[18] Biological constituent testing may be precluded by incorporating a filter 0.2 micron filter or as an alternative total bacteria/spores *monitoring* using a 0.2 micron filter incorporated into a appropriate in-line sampling device. Additional detailed analytical methods are available including NACE qPCR, NASA NHB 5340.1D however as a practical operational approach, monitoring to ensure total particulate matter does not exceed 0.2 microns would address the biological COC's.

Parameter	Method	Common Laboratory Detection Limit
Mercury	ASTM D5954, D6350 (gold sorbent, on-line and off-line)	0.01 µg/m^3
Siloxanes	ASTM D8230, gas chromatography (off-line canister collection) with atomic emission detection (GC-AED) or mass spectral detection (GC-MS)**	0.1 mg Si/m^3 (0.01 mg Si/m^3 with pre-concentration)
Semi-volatile and Volatile Compounds	EPA TO-14, TO-15 (off-line) Canister collection (volatiles) XAD sorbent media (semi-volatiles)	0.1 ppmv or lower, depending on technique and/or volume of gas sampled
Halocarbons	EPA TO-14, TO-15 (off-line canister collection)	0.1 ppmv or lower, depending on technique and/or volume of gas sampled
Aldehydes and Ketones	EPA TO-11 (off-line DNPH sorbent)	10 ppbv or lower, depending on volume of gas sampled
PCBs/Pesticides?	PUF/XAD sorbent tube sampling followed by EPA Method 8082 or EPA TO-10A	<1 ppbv depending on technique

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

**The prior detection threshold of 0.5 mg Si/$m^3$was considered “commercially free”. The Operator and Developer should consider end use implications in defining an appropriate detection threshold.

N.A. = Not Applicable

[

Appendix E – Example of Interconnect Feasibility Analysis Agreement[19] (IFA)

This Interconnect Feasibility Analysis Agreement (Engineering Services Reimbursement Agreement0 ("*Agreement*"), effective as of this _____ day of _____ ("*Effective Date"),* is by and between _____ ("*Customer*"), an _____ 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 raw biogas from _____ and upgrade the raw biogas to renewable natural gas (RNG), with excess gas RNG to be sent to Company's natural gas distribution system (the "*Project*"); and

WHEREAS, Customer desires to have Company perform certain 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 gas interconnection service, procurement of equipment, installation or construction, or electric transmission and distribution service.

Section 2 - Customer's Responsibilities

Customer shall provide:

[19] This sample agreement is for illustrative purposes only. Each Operator will have a company specific/project specific agreement which considers/incorporates Articles and content contained within the sample provided.

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 the Project will be developed;

3. A project manager who will be given the authority to coordinate all aspects of the Services 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 cannot 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 the Services are required, in the sole discretion of the Company, that will result in an increase or decrease in the cost and/or time of performance under the Agreement, the Price, schedule and other affected provisions of this Agreement shall be amended in writing to memorialize such changes and to recognize the increase or decrease in costs and/or time required to perform the Services.

Section 4 - Changes and Extras

Customer may request changes in Services in writing. If the Company, in its sole discretion, accepts such changes, and such changes will result in an increase or decrease in the cost or time

of performance under this Agreement, the Price, schedule this Agreement shall be amended in writing to memorialize such changes and to recognize any increases or decreases in the cost and/or time required to perform the Services. 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 amended in writing to memorialize such changes and will recognize any increases or decreases in the cost and/or time required to perform the services. 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 an ISO- or other utilities about 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 equal to the estimated cost of the Services (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 elect, 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 later. Customer shall be responsible to pay Company the total Price for completing the Services performed by Company whether 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. Except for 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 off-sets. 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 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, this Agreement shall be amended to recognize the increase in cost and/or time to perform the Services 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*"). Proprietary information provided by the Customer in connection with this Agreement will remain the sole property of the Customer.

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 gas 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. If Company concurs, 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. If 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 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 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.

[____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.

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.

Section 13 – Limitation of Liability

In no event shall any Party or its subcontractors be liable for indirect, special, incidental, punitive, or consequential damages of any kind including loss of profits, arising under or in connection with this Agreement or performance of the Services, or from reliance on the studies, designs and analyses performed hereunder. Nor shall any Party or its subcontractors be liable for any delay in delivery or for the non-performance or delay in performance of its obligations under this Agreement.

Section 14 – Disclaimer of Warranty

In performing the Services, the Company and any subcontractors employed by it shall have to rely on information provided by the other Party, and possibly by third parties, and may not have control over the accuracy of such information. Accordingly, neither the Company nor any subcontractor employed by the Company makes any warranties, express or implied, whether arising by operation of law, course of performance or dealing, custom, usage in the trade or profession, or otherwise, including without limitation implied warranties of merchantability and fitness for a particular purpose, with regard to the accuracy, content, or conclusions of the analyses, studies, and designs prepared in accordance with this Agreement. Customer acknowledges that it has not relied on any representations or warranties not specifically set forth herein and that no such representations or warranties have formed the basis of its bargain hereunder.

Section 15 – Indemnification

Company/Project specific mutually agreeable indemnification language.

Section 16 - Confidentiality

Company/Project specific mutually agreeable non-disclosure agreement.

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 may include:

- Assign a Project Engineer and Project Manager to provide technical support for the services;
- Arrange and schedule periodic meetings, as appropriate, to review the status and results of the Services;
- Provide standards for Customer to follow in order to design metering equipment in accordance with Company specifications and requirements;
- Provide the specifications and requirements for the meters to be installed and determine the size and quantity of meters required;
- Review the design and layout provided by Customer for analytical equipment to be installed by Customer in accordance with manufacturer's recommendations;
- Reviewing the design and layout provided by Customer for odorant equipment to be installed by Customer in accordance with applicable health and safety codes for the storage of odorant, including (insert applicable local, state, county regulatory agencies);
- Review drawings, designs and specifications provided by Customer for the equipment set forth below. Company reserves the right to require changes to the design in order to meet company standards; and
- Review the design and 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) may include:

- Gas service and associated metering equipment for back up 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 H_2O 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 gauges on plant outlet line
- Analyzer Building – prefab concrete building to house RTU and all analytical equipment with electric service and Power Conditioning, and Battery Back Up system, gas detector(s)
- Odorant Building – negative pressure concreted 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).
- Such other equipment and facilities that may be required under Company's interconnection specifications or by law or regulation.

Illustrative 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 EPC 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 electric generation or gas supply 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, licenses, 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, threw, over, or under any real property owned or controlled by the Company.

Appendix F – Example of Gas Sales Agreement (aka Interconnect Agreement)[20]

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"), an _____ organized and existing under the laws of _____.

WHEREAS, Seller owns an anaerobic digester within a _____ located in _____, New York that recovers digester raw biogas from _____ and upgrades the raw biogas to renewable natural gas ("RNG"); 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 RNG 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 "Critical Day shall mean any day during which the average temperature is less than ____ °F

1.3 The term "dekatherm" means a unit of heat energy equal to 1,000,000 BTUs.

1.4 The term "Day" means a period of twenty-four (24) consecutive hours beginning and

20 This sample agreement is for illustrative purposes only. Each Operator will have a company specific/project specific agreement which considers/incorporates Articles and content contained within the sample provided.

ending at 9:00 AM Central Standard Time.

1.5 The term “Delivery Point” shall mean the point at which the facilities owned by the Seller connect to facilities owned by the Buyer, as shown on Exhibit A hereto.

[Attach Schematic drawing]

1.6 “Interconnection Facilities” means the facilities necessary to connect Seller’s plant to Buyer’s natural gas transmission and/or distribution system and the additions, modifications and upgrades to Buyer’s natural gas transmission and/or distribution system necessary to permit the safe and reliable delivery of RNG at the Delivery Point. Such facilities may be owned by the Buyer or Seller, as specified herein.

1.7 The term “Maximum Daily Quantity” (or "MDQ”) means ____Dt, which is the maximum amount of RNG that Buyer is obligated to purchase and receive on any Day during the term of this Agreement.

1.8 [If a Minimum Quantity applies], the term “Minimum Daily Quantity” means ____Dt which is the minimum amount of RNG that Seller is obligated to deliver on any Day during the term of the Agreement.

1.9 The term “MMbtu” means one million Btu.

1.10 The term “mdth” means one thousand dekatherms.

1.11 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).

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

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

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

1.15 “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, on each Day during the term of this Agreement, at the Delivery Point, a quantity of RNG equal to at least the Minimum Quantity, if applicable, but not exceeding the MDQ..

3.2 Seller shall tender RNG for delivery at a substantially uniform rate of flow throughout each 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 or for other reasons.

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 {specify monthly local price index}

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. Unless otherwise negotiated by the parties, Seller shall retain all beneficial environmental, renewable energy and similar rights associated with the generation of such RNG. 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 and all beneficial environmental, renewable energy and similar rights associated with the generation of such RNG 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 natural gas transmission and distribution system 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 thereof, 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 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 gas quality limits set forth below, and
c. be monitored as to conformity with all 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 (Sample: The operator and developer should consider use of limits in Section F Feedstock, Pipeline Gas Quality and Safety Assessment Considerations as a starting place for specification development.)

Gas Quality Specification	Low	High
Heat Content) (BTU/scf)		
Wobbe Number +/- 4% from historical supply		
Relative Density		
Water Vapor Content (lbs./MM scf)		
Product Gas Mercaptans (ppmv, does not include gas odorants))		
Hydrocarbon Dew Point, (°F) CHDP		
Hydrogen Sulfide (grain/100 scf)		
Total Sulfur (grain/100 scf)		
Total Diluent Gases including the following individual constituent limits: Carbon Dioxide 2% max Nitrogen 2% max Oxygen (O_2) 0.4% max		
Hydrogen		
Total Bacteria (as particulates)		
Mercury		
Other Volatile Metals		
Siloxanes		
Ammonia		
Non-Halogenated Semi-Volatile and Volatile Compounds		
Halocarbons		
Aldehyde/Ketones		

NOTES:

1. *Commercially Free (Comm Free) is defined as "Not Detectable" relative to typical pipeline gas flowing at the interconnect location that results in RNG being "compositionally equivalent" to flowing supplies. 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 or the lowest level detected for pipeline gas flowing at the interconnect point.*
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"*

*5 Testing should only take place when **COC's are reasonably expected,** as mutually agreed by both parties.*

6.4 Seller shall maintain in good working order its interconnection Facilities and other facilities and equipment 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 Plant start-up gas quality sampling and testing plan (the "Plan") to ensure all equipment is functioning as 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. The owner of such metering equipment shall use reasonable efforts to give the other Party more than twenty-four (24) hour notice of such inspections, tests or adjustments.

7.3 Periodic tests of such metering equipment, by the owner of such equipment at intervals not to exceed two times per year, will be made at any reasonable time upon request by the other Party. 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 by the equipment owner. If an additional test of the metering equipment is made at the request of the non-owning Party 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, such Party 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 the owner of such metering equipment 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 by the party owning the meter equipment. 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 [Not clear that Buyer will be rendering invoices] after the inaccuracy is discovered. Should any metering equipment fail to register the gas delivered or received during any period of time during the term of this Agreement, 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 Interconnection Facilities. In the case of emergencies that render the Interconnection Facilities unsafe, the Buyer may perform emergency services that it deems necessary to make the Interconnection 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 construct, install, operate and maintain Interconnection Facilities required by the Buyer in connection with the delivery of RNG pursuant to this Agreement, as specified in Attachment A-1 (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 Buyer for the fully loaded cost incurred by Buyer in performing the Services, Unscheduled Services and/or Emergency Services. Seller's reimbursement shall be made pursuant to Section 9.2 below.

8.4 **EQUIPMENT REPLACEMENT AT END OF LIFE** – Seller shall reimburse the Buyer for the fully loaded cost to replace Buyer's Interconnection Facilities when such equipment reaches the end of its service life. Seller's reimbursement shall be made pursuant to Section 9.2 below.

ARTICLE 9: BILLING AND PAYMENT FOR RNG DELIVERIES

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 electronic mail to the other Party as soon as possible (not to exceed two (2) 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 as soon as possible (not to exceed two (2) days) 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 Seller to deliver to the Buyer the Minimum Quantity of RNG pursuant to Article 3 above for any Critical Day or on more than five (5) cumulative Days in any thirty (30) day period.

c. Failure by a party to perform any other 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 / CERTAIN DAMAGES 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. The non-defaulting party's written notice shall specify the termination date which may be no earlier than the defaulting party's receipt of the termination notice and no later than twenty (20) days thereafter.

b. If Seller fails to deliver the Minimum Quantity of RNG to Buyer as specified in Section 12.1(b) above, Seller shall pay to Buyer, within five (5) Business Days of its receipt of Buyer's invoice, the difference between the purchase price paid by Buyer to obtain any replacement Gas and the Price of Gas set forth in Article 4 above (adjusted for commercially reasonable differences in transportation costs to or from the Delivery Point) multiplied by the quantity of Gas that Seller failed to deliver to Buyer, plus any applicable penalties or charges incurred by Buyer related to violation of interstate pipeline Operational Flow Orders or other similar requirements.

c. If the Agreement is terminated pursuant to Section 12.1 above, the non-defaulting party shall determine the outstanding amounts, including termination damages, that are owed by each party to the other under the Agreement and shall, in a timely manner, provide a written statement of account to the defaulting party setting forth the net amount that one party owes to the other party. In either case, the net amount shall be paid within 30 Days of the defaulting party's receipt of the written statement of account.

d. Seller shall provide security in the amount of $_____ in a form acceptable to Buyer to guarantee its performance under this Agreement. Buyer shall be permitted to draw

on such security following an Event of Default.

ARTICLE 13: MISCELLANEOUS

13.1 Assignment. 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 its rights and obligations to an affiliate of Buyer at any time upon 30 days prior written notice to Seller.

13.2 Electric Power and Compressed Air. Seller shall provide, at no cost to Buyer, all the electricity and compressed air required for Buyer to operate, if applicable, the facilities that will measure, regulate and odorize the RNG gas delivered by Seller to Buyer under this Agreement for Buyer's Interconnection Facilities.

13.3 Compliance with Applicable Laws/Termination Right. The sale and delivery of RNG by Seller and the purchase and receipt thereof by Buyer are subject to all valid laws with respect to the subject matter hereof and to all valid present and future statutes, 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 Entire Agreement. 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 Headings. All headings appearing herein are for convenience only and shall not be considered a part of this Agreement for any purpose.

13.6 Waivers. 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 Severability. In the event that any provision in this Agreement is deemed as a matter of law to be unenforceable or null and void, such unenforceable or void provision shall be deemed severable from this Agreement and the obligations of the Parties under this Agreement shall continue in full force and effect as if such severable provision was not contained herein.

13.8 No Third Party Beneficiaries. This Agreement is not intended to and does not create rights, remedies, or benefits of any character whatsoever in favor of any persons, corporations, associations, or entities other than the Parties, and the obligations herein assumed are solely for the use and benefit of the Parties, their successors in interest and their permitted assigns.

13.9 Amendments. The Parties may by mutual agreement amend the agreement or its Attachments, by a written instrument duly executed by both Parties. Such an amendment shall become effective and a part of this agreement upon satisfaction of all applicable laws and regulations.

13.10 Confidentiality. Company/Project specific mutually agreeable non-disclosure agreement.

13.11 Indemnification. Company/Project specific mutually agreeable indemnification language.

13.12 Subcontractors. [Needs to be added]

13.13 Limitation of Liability. Neither Party shall be liable to the other Party in tort (including negligence or strict liability) or otherwise for loss of profits or revenue, loss of use of gas system related to or connected with the Project, cost of capital, claims of customers, or for any other special, indirect, incidental, or consequential damages of any kind or natural whatsoever arising from the activities to be performed hereunder. Notwithstanding the forgoing, the disclaimer set forth herein shall not be deemed to release, discharge, limit or otherwise affect Seller's obligation or liabilities arising out of the criminal, reckless, willful misconduct or the grossly negligent acts or omissions of Seller or its subcontractors or any of their respective agents, servants, employees or representatives.

13.14 Governing Law. 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.

13.15 Waiver of Trial by Jury. Each Party hereby waives trial by jury in any action, proceeding or counterclaim brought by a Party against the other on all matters whatsoever arising out of or in any way connected with this Agreement or any claim of damage resulting from any act or omission of the Parties in any way connected with this Agreement.

13.16 Multiple Counterparts. This Agreement may be executed in several counterparts, each of which is an original and all of which constitute one and the same instrument.

13.17 Notices. All notices ("Notices") required by this Agreement, including without limitation, requests, demands, and statements, shall be in writing and may be sent by electronic mail or other mutually acceptable electronic means, a nationally-recognized overnight courier service, first-class mail, or may be hand-delivered. If the Day on which the Email is received is not a Business Day or is after 5:00 p.m., then such Email shall be deemed to have been received on the next Business Day. Notice sent by overnight courier service, courier or hand-delivery shall be deemed to have been received on the next Business Day after it was sent or delivered, or such earlier time as is confirmed by the receiving party; and notice via first class mail shall be considered delivered within 4 Business Days after mailing.

CONTACT INFORMATION REQUIREMENTS & NOTIFICATIONS

- Buyer Notices
- Buyer Billing
- Buyer Gas Control

- Seller Notices
- Seller Billing
- Seller Gas Control

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:

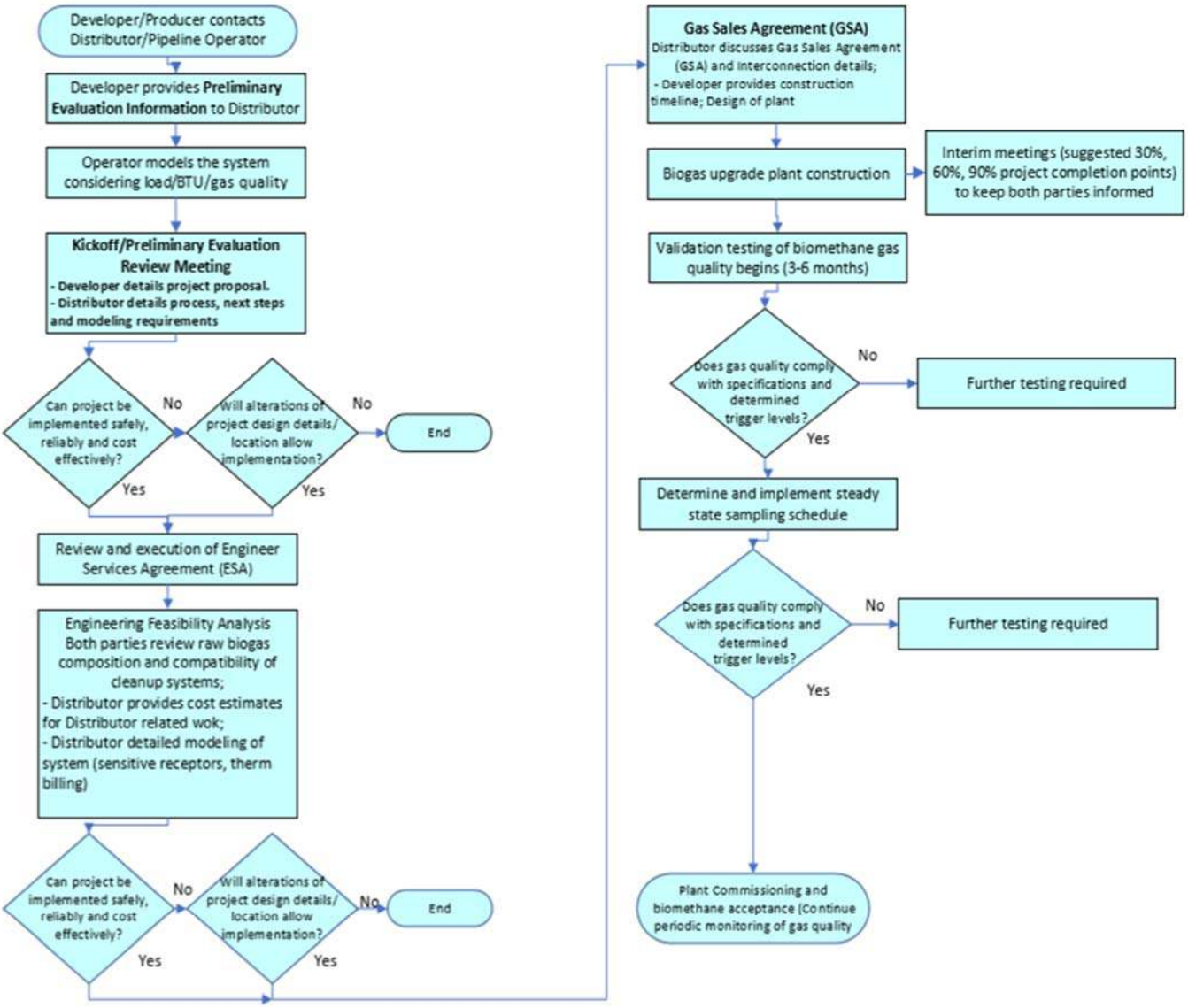
ATTACHMENT A-1. INTERCONNECTION SCOPE OF WORK

- Include scope of work (including references to applicable specifications), division of responsibility (including permitting), schedule and budget for construction of the interconnection facilities
- Also include provisions applicable to payment, change orders, insurance, deposits or security related to the construction of the interconnection facilities

ATTACHMENT A-2. PROCEDURES FOR COMMISSIONING AND START-UP

- Provisions addressing how operations will be coordinated and gas quality testing conducted during commissioning and initial start-up (and related payments and invoicing)

Appendix G – Overall Gas to Grid Process



Appendix H – 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 goal here is to test only for what may be reasonably expected based on the feedstock biomass. ***If the developer has supporting technical information that the raw gas analysis need not consider the analytes in the COC table then testing may not be required.*** Based on general available data (ensuing tables), blue shading identifies possible COCs of interest to a feedstock while white shading represents COCs that are potentially not of interest

Parameter	Landfill	Agricultural and Clean Organics	WWTP	Source Separated Organics and Facility Separated Organics[21]	Gasifier, Syngas
Water Content[22]					
Sulfur, including Hydrogen Sulfide					
Hydrogen					
Carbon dioxide					
Nitrogen					
Oxygen					
Ammonia					
Biologicals (bacteria or spores ≤0.2 micron)					
Mercury					
Volatile metals					
Siloxanes					
Volatile Organic Compounds					
Semi-volatile Organic Compounds					
Halocarbons					
Aldehydes and Ketones					
Polychlorinated biphenyls (PCBs) [(23)]					
Pesticides [(11)]					

21 Analytes of concern were selected based on experience with other biomass sources and the relative likelihood for constituents to be present.

22 Water vapor content of <7 lbs/MMscf is an industry acceptable practice for defining “dry” gas for purposes of metering and measurement. Actual pipeline supplies are typically less than 4 lbs/MMscf and this constituent value should be relatively consistent with flowing supplies at the point of interconnect.

23 Not required unless the facility has a verified history of PCB/Pesticide contamination or use. Prior studies have confirmed that under ordinary conditions, these analytes are not likely to be found in the gas phase due to vapor pressure limitations.

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.

Parameter	AGA 4A Reported Range	Range Found in Upgraded Landfill-Derived RNG	Range Found in Pipeline Natural Gas Samples
Total Sulfur	maximum 0.5 to 20 grains per 100 SCF	BDL (0.003) to 0.32 grains per 100 SCF	BDL (0.003) to 1.1 grains per 100 SCF
Hydrogen Sulfide	maximum 0.25 to 1.0 grains per 100 SCF	BDL (0.003) to 0.03 grains per 100 SCF	BDL (0.003) to 0.36 grains per 100 SCF
Hydrogen	max. 0.04 to 0.1 vol%	BDL (0.1) to 1.0 vol%	BDL (0.1) to 0.3 vol%
Carbon dioxide	maximum 1 to 3 vol%	BDL (0.03) to 2.2 vol%	BDL (0.03) to 2.6 vol%
Nitrogen	maximum 1 to 4 vol%	0.5 to 9.5 vol%	BDL (0.03) to 12.7 vol%
Oxygen	max. 0.001 to 1 vol% majority: 0.1 to 0.2 vol%	BDL (0.03) to 1.3 vol%	BDL (0.03) to 1.2 vol%
Diluents + Inerts	maximum 3 to 6 vol%	0.6 to 10.0 vol%	0.3 to 12.7 vol %
Ammonia	none	BDL (10 ppmv)	BDL (10 ppmv)
Total Bacteria	none	$2.46x10^4$ to $3.29x10^8$ # per 100 SCF	$3.47x10^4$ to $6.39x10^7$ # per 100 SCF
Mercury	none	BDL (0.01) to 0.3 µg/m^3	BDL (0.01) to 0.06 µg/m^3
Other Volatile Metals	none	BDL (30) to 250 µg/m^3 (Cr, Cu, Mn, Pb, Sb, Zn)	BDL (30) to 213 µg/m^3 (As, Cu, Pb, Zn)
Siloxanes (D4)	none	BDL[1](0.5 mg/m^3) to 6.0 mg Si/m^3	BDL[1]
Non-Halogenated Semi-Volatile and Volatile Compounds	none	BDL[2] to 1.4 ppmv (BTEX, phthalates)	BDL[2] to 471 ppmv (1,3-butadiene, acrylonitrile, BTEX)
Halocarbons	none	BDL (0.1) to 3.6 ppmv (Freons, chloroethane, vinyl chloride)	BDL (0.1 ppmv)
Aldehyde/Ketones	none	BDL (10) to 522 ppbv	BDL (10) to 103 ppbv
Polychlorinated biphenyls (PCBs)	none	BDL (1 ppbv)	BDL (1 ppbv)
Pesticides [3]	none	BDL (0.3 to 3 ppbv	BDL (0.3 to 3 ppbv)

[1] Detection limits for siloxane ranged from 0.5 mg Si/m^3 to 0.1 as analysis methods improved resulting in publication of ASTM D8230.
[2] Detection limits vary from 1 ppmv (volatiles) to 5 ppbv (semi-volatiles), depending on compound analyzed..
[3] Current achievable detection limit range is 0.3 to 3 ppbv

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.

Parameter	AGA 4A Reported Range	Range Found in Upgraded Dairy-Derived RNG	Range Found in Pipeline Natural Gas Samples
Total Sulfur	maximum 0.5 to 20 grains per 100 SCF	BDL (0.003) to 0.31 grains per 100 SCF	BDL (0.003) to 1.1 grains per 100 SCF
Hydrogen Sulfide	maximum 0.25 to 1.0 grains per 100 SCF	BDL (0.003 ppmv)	BDL (0.003) to 0.36 grains per 100 SCF
Hydrogen	max. 0.04 to 0.1 vol%	BDL (0.1 vol%)	BDL (0.1) to 0.3 vol%
Carbon dioxide	maximum 1 to 3 vol%	0.06 to 0.95 vol%	BDL (0.03) to 2.6 vol%
Nitrogen	maximum 1 to 4 vol%	0.20 to 7.81 vol%	BDL (0.03) to 12.7 vol%
Oxygen	max. 0.001 to 1 vol% majority: 0.1 to 0.2 vol%	BDL (0.03) to 1.99 vol%	BDL (0.03) to 1.2 vol%
Diluents + Inerts	maximum 3 to 6 vol%	0.37 to 10.65 vol%	0.3 to 12.7 vol %
Ammonia	none	BDL (10 ppmv)	BDL (10 ppmv)
Total Bacteria	none	$3.28x10^3$ to $1.02x10^7$ # per 100 SCF	$3.47x10^4$ to $6.39x10^7$ # per 100 SCF
Mercury	none	BDL (0.01 µg/m^3)	BDL (0.01) to 0.06 µg/m^3
Other Volatile Metals	none	BDL (20 µg/m^3)	BDL (30) to 213 µg/m^3 (As, Cu, Pb, Zn)
Siloxanes (D4)	none	BDL[1](0.5 mg/m^3)	BDL[1]
Non-Halogenated Semi-Volatile and Volatile Compounds	none	BDL[2] to 0.1 ppmv (BTEX, N-nitroso-di-n-propylamine, benzyl alcohol)	BDL[2] to 471 ppmv (1,3-butadiene, acrylonitrile, BTEX)
Halocarbons	none	BDL (0.1 ppmv)	BDL (0.1 ppmv)
Aldehyde/Ketones	none	not tested	BDL (10) to 103 ppbv
Polychlorinated biphenyls (PCBs)	none	BDL (1 ppbv)	BDL (1 ppbv)
Pesticides[3]	none	BDL (0.3 to 3 ppbv to 0.5 ppbv gamma-chlordane))	BDL (0.3 to 3 ppbv)

[1] Detection limits for siloxane ranged from 0.5 mg Si/m^3 to 0.1 as analysis methods improved resulting in publication of ASTM D8230.

[2] Detection limits vary from 1 ppmv (volatiles) to 5 ppbv (semi-volatiles), depending on compound analyzed..

[3] Current achievable detection limit range is 0.3 to 3 ppbv.

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.

Parameter	AGA 4A Reported Range	Range Found in Upgraded WWTP-Derived RNG	Range Found in Natural Gas Samples
Total Sulfur	maximum 0.5 to 20 grains per 100 SCF	BDL (0.003) to 0.01 grains per 100 SCF	BDL (0.003) to 1.1 grains per 100 SCF
Hydrogen Sulfide	maximum 0.25 to 1.0 grains per 100 SCF	BDL (0.003) to 0.01 grains per 100 SCF	BDL (0.003) to 0.36 grains per 100 SCF
Hydrogen	max. 0.04 to 0.1 vol%	BDL (0.1 vol%)	BDL (0.1) to 0.3 vol%
Carbon dioxide	maximum 1 to 3 vol%	0.49 to 0.66 vol%	BDL (0.03) to 2.6 vol%
Nitrogen	maximum 1 to 4 vol%	BDL (0.03 vol%)	BDL (0.03) to 12.7 vol%
Oxygen	max. 0.001 to 1 vol% majority: 0.1 to 0.2 vol%	BDL (0.03 vol%)	BDL (0.03) to 1.2 vol%
Diluents + Inerts	maximum 3 to 6 vol%	0.49 to 0.66 vol%	0.3 to 12.7 vol %
Ammonia	none	BDL (10 ppmv)	BDL (10 ppmv)
Total Bacteria	none	$9.85x10^5$ to $2.14x10^6$ # per 100 SCF	$3.47x10^4$ to $6.39x10^7$ # per 100 SCF
Mercury	none	BDL (0.01 µg/m^3)	BDL (0.01) to 0.06 µg/m^3
Other Volatile Metals	none	BDL to 229 µg/m^3 (Zn)	BDL (30) to 213 µg/m^3 (As, Cu, Pb, Zn)
Siloxanes (D4)	none	BDL (0.51 mg/m^3)	BDL[1]
Non-Halogenated Semi-Volatile and Volatile Compounds	none	BDL[2] to 6 ppbv (phthalate)	BDL[2] to 471 ppmv (1,3-butadiene, acrylonitrile, BTEX)
Halocarbons	none	BDL (0.1 ppmv)	BDL (0.1 ppmv)
Aldehyde/Ketones	none	BDL (10 ppbv)	BDL (10) to 103 ppbv
Polychlorinated biphenyls (PCBs)	none	BDL (1 ppbv)	BDL (1 ppbv)
Pesticides[3]	none	BDL (0.3 to 3 ppbv)	BDL (.3 to 3 ppbv)

[1] Detection limits for siloxane ranged from 0.5 mg Si/m^3 to 0.1 as analysis methods improved resulting in publication of ASTM D8230.
[2] Detection limits vary from 1 ppmv (volatiles) to 5 ppbv (semi-volatiles) depending on compound analyzed.
[3] Current achievable detection limit range is 0.3 to 3 ppbv