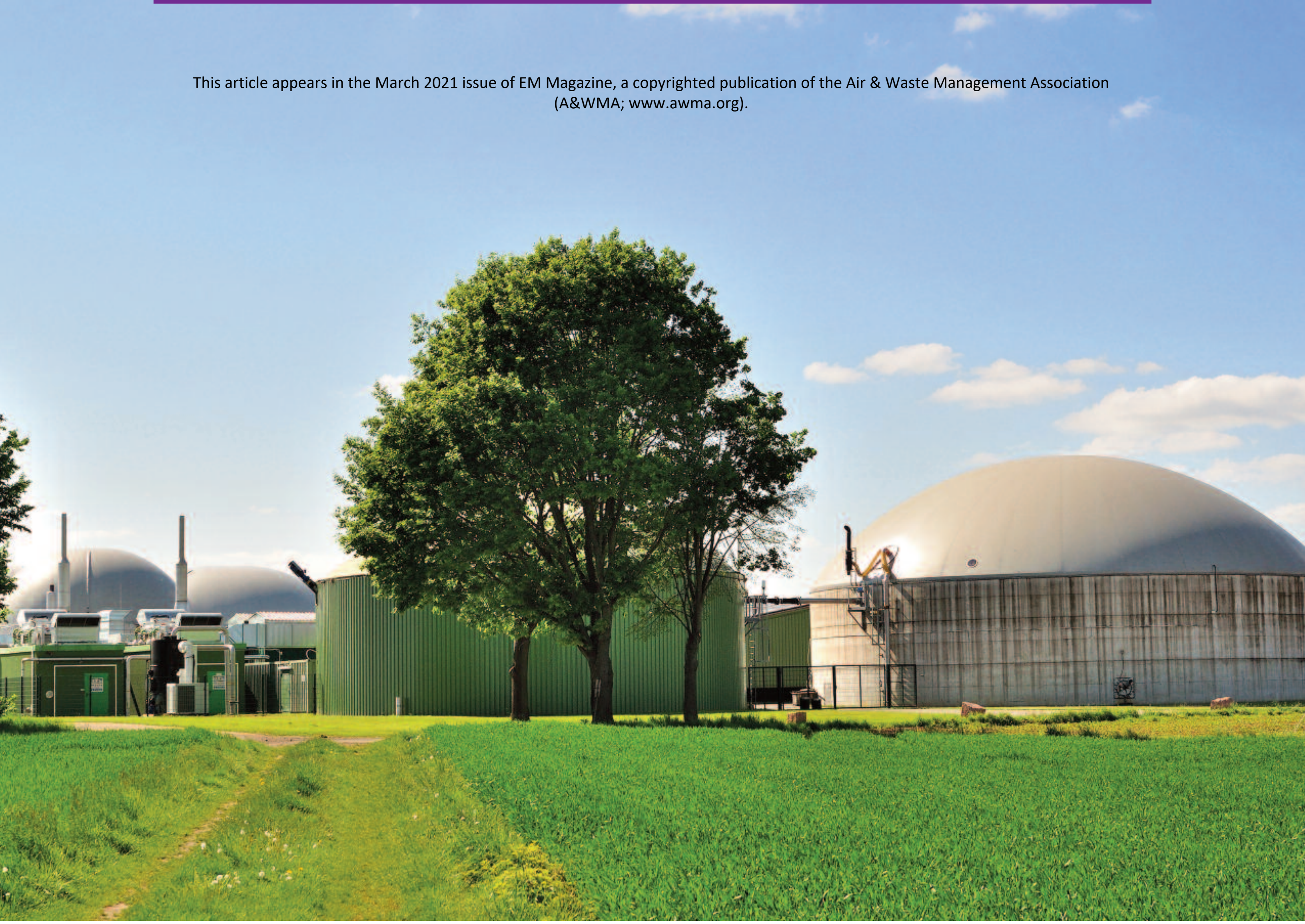

Renewable Natural Gas, Part 1:

Product Quality Verification is Fundamental to Commercialization of Biogas from Waste Streams

In this the first of a two-part series, the authors examine the production of biogas produced by anaerobic digestion and its upgrading to renewable natural gas. Look for part two in the May 2021 issue of *EM*.

Biogas is an energy-rich gas produced by anaerobic decomposition or thermochemical conversion of biomass. Biogas produced via anaerobic digestion is composed mostly of methane (CH_4), the same primary component of natural gas, as well as carbon dioxide (CO_2). This biogas can be upgraded to increase the methane content and remove undesirable constituents, which yields renewable natural gas (RNG), a product that is interchangeable with traditional fossil natural gas from oil- and gas wells. Biogas produced via thermochemical conversion (e.g., high-temperature thermal gasification) is referred to as syngas and typically contains significant amounts of carbon monoxide (CO) and hydrogen (H_2). Syngas can also be upgraded to RNG. However, the focus of this article is the production of biogas produced by anaerobic digestion, and its upgrading to RNG.

Wastes from consolidated animal feed operations (CAFO) and municipal and industrial wastewater treatment plants, as well as from various forms of biomass such as food waste and landfills, are candidate feedstocks. There is much interest in the generation of biogas and subsequent injection into the existing natural gas pipeline system because the process reduces greenhouse gas emissions, supports alternative transportation fuels objectives (i.e., low carbon fuel standards), and helps utilities meet state or local requirements regarding the use of renewable energy sources.

The CH_4 content of raw (untreated) biogas produced via anaerobic digestion typically varies from 40%–60%, with CO_2 making up the majority of the remainder. Before biogas can be injected into pipelines, it must be upgraded to RNG. The upgrading process increases CH_4 content and removes constituents that are potentially problematic to pipeline integrity and end-use requirements. The complexity of the upgrade process varies with the source of the biogas; regardless of the source, the goal is creating RNG, a commercial product that is chemically and functionally identical to conventional natural gas.

Pipeline operators establish RNG quality requirements that are defined in tariffs established by the operator. The RNG supplier must verify the gas quality meets tariff requirements before the RNG is injected into the pipeline. Tariffs also apply to natural gas injection into pipelines, but the quality criteria for RNG derived from biogas are considerably more extensive for RNG, requiring testing for additional contaminants, because the source of the gas (e.g., landfill gas) may contain components deleterious to the pipeline itself or end users of the gas. Tariff requirements can vary widely depending on the biogas source and the pipeline operator.

Interestingly, the testing procedures required to demonstrate conformance with tariff requirements derive from the

Figure 1. Equipment for Representative Sampling of Biogas Feed to Gas Upgrade Systems.
Photo courtesy of Valtronics.

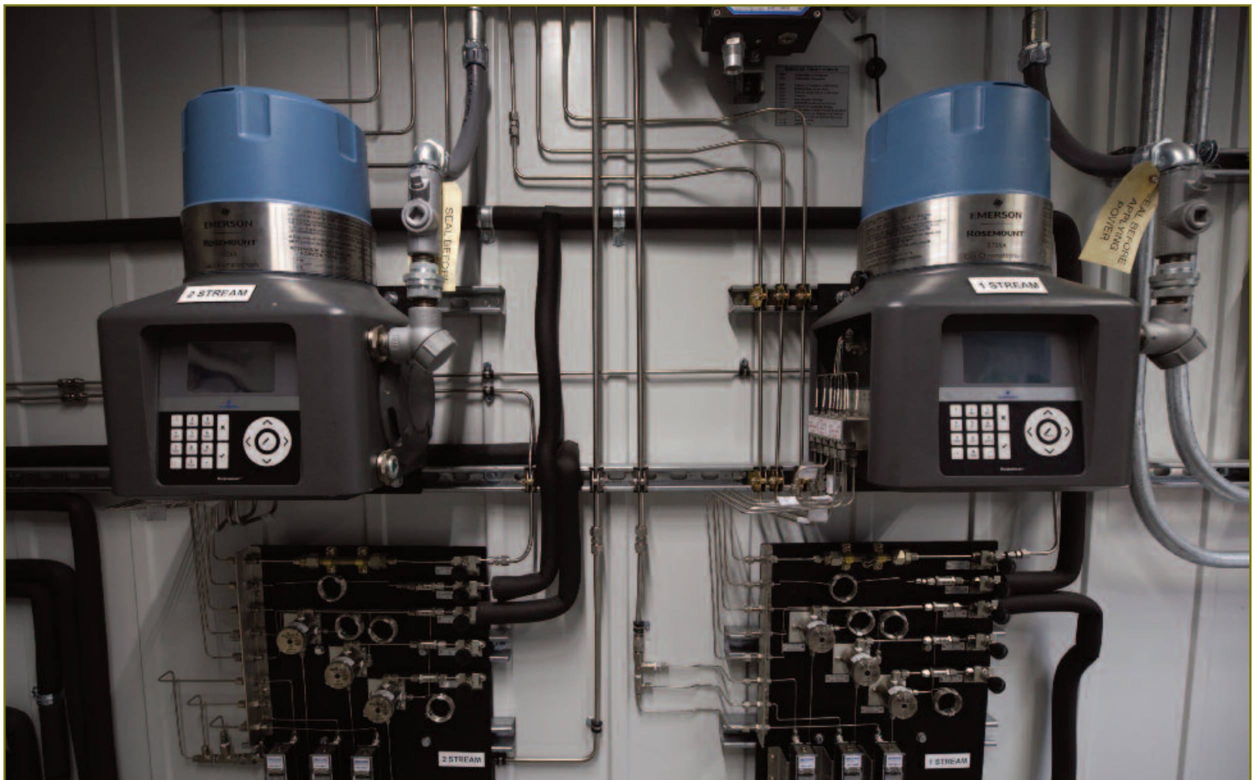

Figure 2. Gas Chromatograph Systems for the Measurement of Select Essential Parameters in RNG Product.

Photo courtesy of Valtronics.

conventional testing methods used to demonstrate compliance with limits imposed on air pollutant emission sources by the U.S. Environmental Protection Agency (EPA), specifically, the EPA's New Source Performance Standards (NSPS) or its National Emission Standards for Hazardous Air Pollutants (NESHAPS). Because the marketability of the biogas is ultimately contingent upon conformance to RNG tariffs established by the operator, it is important to understand how gas quality standards vary with the biogas source and how test methods are used to verify RNG quality.

This article ("Part 1") provides an overview of biogas generating processes, typical RNG tariff requirements associated with each biogas feedstock, and the test methods and monitoring systems required to demonstrate compliance with RNG tariff requirements. A second article ("Part 2"), to appear in a subsequent issue of *EM*, will focus on the marketability of RNG, specifically on how renewable fuel standards and programs can provide access to a market that values the reduced carbon intensity of RNG derived from biogas.

Biogas Production

As noted above, biogas produced via anaerobic digestion is composed mostly of CH_4, the same primary component of natural gas, as well as CO_2. The CH_4 content of this raw (untreated) biogas typically varies from 40%–60%, with CO_2 making up the majority of the remainder. The upgrade process is designed to increase the CH_4 content, reduce the CO_2 and moisture contents, and manage "constituents of concern" (COCs) such that the resulting product satisfies tariff requirements for RNG. Examples of specific COCs are discussed below. Demonstration that that the upgraded biogas meets tariff requirements for RNG is accomplished by periodic testing and continuous monitoring. As noted by the Northeast Gas Association and the Gas Technology Institute, if a COC is not reasonably expected to be found above background levels in flowing gas supplies at the point of interconnect (the point where RNG is injected into a larger gas pipeline system), testing may not be required.[1]

Historically important sources of biogas derived from public waste streams are landfills and wastewater treatment plants. Landfills produce CH_4-rich landfill gas, which results from the anaerobic decomposition of the solid waste (organic fraction) that has been deposited in the landfill. Wastewater treatment plants produce CH_4-rich biogas as the result of the anaerobic decomposition of the solids content of the municipal wastewater (i.e., the sewage sludge or biosolids). At many landfills and wastewater plants, this biogas has been flared or used as a fuel to power equipment on site. Although biogas from landfills and wastewater treatment plants can be upgraded to RNG, COCs such as metals, sulfur compounds, and siloxanes may be present in the biogas because these materials are present in waste streams. With processing to increase the methane content, reduce the water content, and remove COCs, the biogas from landfills and wastewater treatment plants can be upgraded to RNG that meets tariff requirements for injection into natural gas pipelines.

Increasingly, livestock operations are using anaerobic digesters to produce biogas from manure and bedding material. Although biogas from livestock operations must be upgraded to RNG, the consistency of the digester waste feedstock and the relative absence of deleterious materials in the feedstock reduce the number of COCs, particularly metals, siloxanes, and halocarbons. Because manure is the feedstock for RNG production, there are concerns about bacterial contamination, particularly bacteria capable of corroding pipelines and associated equipment.

Similarly, biogas produced from the anaerobic digestion of food waste at food-processing wastewater treatment plants is likely free of many of the COCs associated with biogas from landfills or municipal wastewater treatment plants. In short, the source of the biogas and associated COCs, determine the requirements to upgrade it to RNG. As noted above, biogas produced by thermo-chemical processes is referred to as syngas. Although syngas is not the focus of this article, it is noted that the COCs present in syngas can differ from those described above for biogas generated via anaerobic digestion.

Tariff Requirements

Tariff requirements will vary with the pipeline operator and the source of biogas. It is important to note that the pipeline operator establishes the gas quality requirements for injection into their system (regardless of the gas source), and as a result, the tariff criteria can be significantly different depending on the pipeline owner. These tariff requirements can be divided into two categories:

1. **Essential parameters** such as hydrocarbon composition, Wobbe Number, specific gravity and heat content, nonhydrocarbons (i.e., inert and diluents including oxygen, nitrogen, and carbon dioxide), sulfur compounds (total and speciated), temperature, pressure, and moisture. Note that the Wobbe Number, or Wobbe Index, is the main indicator of the interchangeability of fuel gases. If two fuels have identical Wobbe Numbers for given pressure and valve settings, the energy output will also be identical. It is calculated by dividing heating value of the gas by the square root of its specific gravity.

2. **Constituents of Concern (COCs),** which include the parameters listed in Table 1. Importantly, Table 1 identifies recommended COCs based on the source of the RNG.

Figure 3. RNG Sampling Trains for Aldehydes and Ketones, Metals, and Bacteria.
Photo courtesy of Thomas Dunder.

Table 1. Typical Biogas Constituents of Concern (COC) Based on RNG Source.[1]

Parameter	Landfill	Agricultural and Clean Organics	WWTP	Source-Separated Organics and Facility-Separated Organics	High-Temperature Thermal Gasifier, Syngas
Water Content	Y	Y	Y	Y	Y
Sulfur, including Hydrogen Sulfide	Y	Y	Y	Y	Y
Hydrogen	Y	Y	Y	Y	Y
Carbon dioxide	Y	Y	Y	Y	Y
Nitrogen	Y	Y	Y	Y	Y
Oxygen	Y	Y	Y	Y	Y
Ammonia	Y	Y	Y	Y	Y
Biologicals (bacteria or spores ≤0.2 micron)	Y	Y	Y	Y	
Mercury	Y		Y		Y
Volatile metals	Y				Y
Siloxanes	Y		Y	Y	
Volatile Organic Compounds	Y		Y		Y
Semi–volatile Organic Compounds	Y				Y
Halocarbons	Y		Y		Y
Aldehydes and Ketones	Y				Y
Polychlorinated biphenyls (PCBs)[2]					
Pesticides[2]					

Notes:

1. *Source:* Interconnect Guide for Renewable Natural Gas (RNG) in New York State. August 2019, Appendix H (https://www.northeastgas.org/pdf/nga_gti_interconnect_0919.pdf).
Note that these COCs can vary by pipeline operator.

2. Not required unless the facility has a verified history of PCB/Pesticide contamination or use.

The tariff requirements established by the pipeline operator will establish testing frequencies for various parameters. Most of the essential parameters identified above will be measured continuously. Other parameters will be measured periodically, with increased frequency when the RNG is first injected into the pipeline. Continuous measurements allow any off-spec gas to be flared instead of being injected to the pipeline. Detection of off-spec gas during periodic testing events may require increased testing until the RNG meets requirements as evidenced by multiple consecutive testing events.

Biogas Upgrading

There is a range of technologies available to upgrade biogas to RNG. While a discussion of those technologies is beyond the scope of this article, it is sufficient to note that that the gas upgrade system (GUS) generally involves the following operations: moisture and ammonia removal, COC removal, CO_2 removal, CH_4 concentration, and flaring of residual "tail" gases from the GUS.

Depending on the program, some of the above components for biogas upgrade may be located close to the source of biogas generation, while others are located close to the pipeline interconnection. For example, a project that connects digesters from multiple farms to a GUS at the interconnection will likely address moisture, ammonia, and possibly hydrogen sulfide at the farm. The balance of upgrade operations will be applied at the GUS site to the combined gas streams from all the farms.

Gas Testing

Both the biogas feed to the GUS and the upgraded biogas require testing. The biogas feed is tested to provide information for GUS operation. The upgraded biogas is tested to demonstrate that it meets tariff requirements as RNG.

Gas quality parameters are measured by two different approaches: continuous monitoring and periodic onsite sampling. In the case of continuous monitoring, instrumentation is installed at the GUS facility to measure target parameters in the biogas feed and the RNG product. The biogas feed is typically monitored continuously for CH_4, CO_2, nitrogen, oxygen, and hydrogen sulfide. Continuous monitoring data for the biogas feed provides information for the operation of the biogas upgrading equipment. The RNG product is monitored continuously for the essential parameters identified above, supporting a portion of the tariff monitoring requirements. Periodic monitoring is required to demonstrate the balance of tariff monitoring requirements; these periodic measurements are not amenable to continuous measurement.

For periodic monitoring, a test team travels to the GUS facility and collects samples for measurement of the parameters specified in the tariff not measured by continuous monitoring systems. Examples of parameters mandated by tariff equirements include methane, mercaptans, carbon monoxide, hydrogen, dust/gums/solid matter, biologicals, siloxanes, odorants, volatile organic compounds, metals (e.g., arsenic, antimony, copper, lead), aldehydes and ketones, *p*-dichlorobenzene, *n*-nitroso-di-*n*-propylamine, vinyl chloride, and toluene. After collection, these samples are sent offsite for laboratory analysis.

Test Methods

The test instrumentation and methods used for both continuous and periodic monitoring programs have typically been adapted for biogas and RNG testing by modifying the EPA reference methods long applied to air pollution emission measurements. Those standard methods for measuring air pollution emissions are found in Appendix A to 40 CFR 60 (Standards of Performance for New Stationary Sources, Test Methods) or in the EPA's Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air. For example, RNG sampling for volatile metals is based on EPA Method 29,[2] RNG sampling for semi-volatile organic compounds, volatile organic compounds, and halocarbons is based on EPA TO-14[3] and TO-15,[4] and RNG sampling for aldehydes and ketones is based on TO-11.[5] Additionally, ASTM methods are used for RNG testing. For example, heating value is measured by ASTM D3588, a method commonly incorporated into performance test programs for gas-fired turbines. Figures 1 and 2 are photographs of equipment typically associated with the measurement of biogas feed and product RNG parameters, respectively. Figure 3 is a photograph of a series of active sampling trains at the outlet of a GUS. The Gas Technology Institute offers an illustrated guide for RNG sampling[6] and the Northeast Gas Association and Gas Technology Institute have compiled a summary of test methods and run times.[7]

Safety is an important consideration when conducting sampling programs at GUS sites, since biogas and RNG are inherently flammable/explosive, and the COC, hydrogen sulfide, is a potent toxin and asphyxiate. Sampling equipment should be intrinsically safe or designed to operate using the positive pressure flow from the source. In addition to the proper selection of sampling equipment, the test team should be equipped with a multi-gas monitor for the measurement of lower explosive limit, hydrogen sulfide, sulfur dioxide, and oxygen.

Conclusion

Renewable natural gas is an increasingly important and valuable fuel product that can be generated from organic materials that are otherwise wastes such as municipal solid waste, sewage sludge (biosolids), and animal manure. Processing these waste materials via anaerobic digestion produces methane-rich biogas. With sufficient upgrading of the biogas to meet the quality standards (as defined in tariffs) for injection into traditional natural gas pipelines, the resulting RNG becomes a viable substitute for, and indistinguishable from, conventional natural gas. In summary, technology is available for reliable and continuous generation of RNG from various waste sources, and proven testing and measurement technology is used to verify gas quality. Part 2 of this article will explore the economic, regulatory, and societal drivers that increasingly favor RNG as an alternative energy source. **em**

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