Jim Easterly, Jonathan Cristiani, Jay Kemp, Sammy Blair,
Emily Degner, Cailee Crist, and Matt Prather
Black & Veatch Corporation

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Introduction

In 2018, Southern California Gas Company (SCG) commissioned Black & Veatch to perform a characterization and evaluation of current biogas upgrading technologies that would allow the injection of upgraded biogas into SCG natural gas pipelines, with a focus on technology availability, performance, and cost. This paper provides a high-level overview of the analysis performed and key findings.

Background

Biogas is produced via the degradation of organic material in the absence of oxygen by bacteria that are broadly referred to as anaerobes. This process occurs in landfills to form landfill gas (LFG), in wastewater treatment plant (WWTP) applications, and in anaerobic digestion (AD). The resultant biogas consists primarily of methane (CH_4) and requires the removal of water, hydrogen sulfide (H_2S), ammonia (NH_3), siloxanes, nitrogen (N_2), oxygen (O_2), and carbon dioxide (CO_2) in order to meet pipeline specifications.

A variety of California state programs, including the Global Warming Solutions Act, Senate Bill 1383, and the Low Carbon Fuel Standard (LCFS), coupled with the United States (US) Renewable Fuel Standard (RFS), are driving interest and investment in RNG production projects throughout the US. This report seeks to better enable such project developments through an increased understanding of the applications for which certain biogas cleaning technologies may be most appropriate.

Motivation

Prospective RNG projects will be required to meet California Assembly Bill 1900 and SCG Rule 30. Previously, Black & Veatch and SCG evaluated various biogas cleaning technologies while adhering to requirement for the renewable natural gas (RNG) to have a minimum heating value of 990 British Thermal Units per standard cubic foot (BTU/scf). However, in a recent California Public Utilities Commission Decision, the minimum heating value was lowered to 970 BTU/scf and the four California gas utilities are in the process of updating their gas

quality specifications. As part of the current study, SCG would now like to understand the impacts of lowering that requirement to a minimum heating value of 974 BTU/scf, which is considered the lowest achievable heating value for **standard biogas applications** while meeting all other Rule 30 gas quality specifications. The primary objective of this study was to develop abbreviated conceptual designs and screening-level capital and operations & maintenance (O&M) costs for four biogas cleaning applications based on the lowered 974 Btu/scf minimum heating value requirement, perform economic modeling to determine the levelized cost of gas (LCOG) for each of the scenarios investigated, and summarize project development considerations, such as permitting requirements and project schedules, based on these technical and economic factors.

Applications and Technologies

Abbreviated conceptual designs were prepared for cleaning raw biogas to pipeline quality RNG and injection into the SCG pipeline at 200 psig, using the flowrates and compositions shown in Table 1 as a design basis. These biogas compositions are considered typical for such applications in Southern California, based on research by SCG and Black & Veatch.

Table 1. Application-Specific Biogas Design Basis

Application	Biogas Flowrate *scfm*	CH_4 *%*	CO_2 *%*	H_2O *%*	N_2 *%*	O_2 *%*	H_2S *ppm_v*	NH_3 *ppm_v*	Si from Siloxanes *mg/Nm^3*
LFG	3,000	53.5	28.5	6	10	2	100	10	12
Landfill-Diverted Organics AD	1,050	65	29	6	0	0	500	200	7
WWTP	1,050	59.6	31.9	6	2	0.5	200	30	14
WWTP	200	59.6	31.9	6	2	0.5	200	30	14

Several technology providers were surveyed to determine the appropriate designs for each application. While preferred technologies for removal of H_2S, N_2, O_2, and siloxanes did not vary considerably, a number of options are available for CO_2 removal including the following:

- Pressure Swing Adsorption
- Membrane Separation
- Water Scrubbing
- Amine Scrubbing

RNG Economics

Base Case Economics

Black & Veatch developed preliminary estimates of the capital and O&M costs required for the installation of biogas upgrading systems and interconnection to the SCG system. These cost estimates are based on current market pricing from four leading suppliers and reference

recent and ongoing cost estimating experience for similar projects. An economic model was used to provide an estimate of the 20-year LCOG. The economic model considers all-in capital costs, financing parameters, O&M costs, and biogas technical considerations (such as methane losses from the upgrading processes) associated with the project. Based on the technologies considered in the analysis, the range of results for capital and O&M costs and LCOG at different flowrates can be seen in Table 2. Note that these costs are solely for biogas cleaning and injection into the utility pipeline, and do not include any costs for biogas production.

Table 2. Application-Specific RNG Economics

Application	**Biogas Flowrate** *scfm*	**Capital Cost** *$K*	**O&M Cost** *$K/yr*	**LCOG – Base Case** *$/MMBTU*	**LCOG – Decreased Interconnection Cost** *$/MMBTU*
LFG	3,000	19,500 to 29,800	1,770 to 2,230	7 to 9	6.80 to 8.80
Landfill-Diverted Organics AD	1,050	7,900 to 10,000	630 to 800	6 to 7	5.50 to 5.80
WWTP	1,050	7,700 to 11,100	580 to 780	6 to 8	5.60 to 6.60
WWTP	200	5,500 to 6,300	220 to 240	19 to 22	14.60 to 16.70

Economic Sensitivities

To examine the variations in RNG costs as certain project parameters were modified, sensitivity analyses were performed. These analyses considered the impacts of the following and are summarized in Table 3.

- Potential reductions in interconnection costs.
- Renewable transportation fuel incentives that may be applicable to RNG projects in California.
- Increased pipeline injection pressure.

Key findings from the economic analysis include the following:

- Base case economics suggest a 12-13% reduction in LCOG compared with prior studies, which is attributable to an adjusted design basis, greater deployment of biogas cleaning systems in the US, a lack of Owner's costs [1] included in capital cost estimates and lowering the RNG minimum heating value from 990 to 974 BTU/scf.

[1] Potential Owner's costs can include project development (site selection, public relations), financing (advisors, reserve fund), taxes, utility interconnections, contingency, project management, startup/construction support, and spare parts.

- Economies of scale work against smaller biogas upgrading projects due to the fact that interconnection costs significantly impact the cost of RNG for smaller projects.
- Renewable transportation fuel incentive programs can yield economically-favorable biogas cleaning projects based on current commodity pricing and LCFS credit values.

Table 3. Economic Sensitivity Analysis Summary

Sensitivity	Test	Impact
Pipeline interconnection costs	Reduction in interconnection costs by 50% via Biomethane Monetary Incentive Program.	Reduction in LCOG by 4-5% for large projects and 22-24% for small projects. [2]
Renewable transportation fuel incentives	Determine 10-year, non-escalated incentive value to breakeven with commodity value of natural gas ($3/MMBTU).	Would require an incentive as low as $4/MMBTU for AD projects and as high as $20/MMBTU for small WWTP projects.
Pipeline injection pressure	Increase pipeline injection pressure from 200 psig to 400 psig.	Increase in LCOG by 2-5%.

About Black & Veatch

Black & Veatch is an employee-owned engineering, procurement, consulting, and construction company with a 100-year legacy of creating a better world for humanity today, and for generations to come. Black & Veatch now has over 10,000 employees worldwide with its headquarters in Overland Park, KS and over 100 offices worldwide. As an innovator, collaborator and future maker, Black & Veatch is characterized by curiosity, a trait that helps us find solutions to your most complex challenges. Safety, sustainability and responsibility also are ingrained into every Black & Veatch professional, and they're designed into all projects. Black & Veatch is recognized as one of the most diverse and broad ranging providers of bioenergy systems and services. From project development to turnkey design and construction, we have worked with project developers, utilities, lenders and government agencies on bioenergy projects throughout the world.

[2] An interconnection cost of $3.5 million is included base case capital costs, which is reduced to $1.75 million as part of this sensitivity analysis.