Air Quality, Climate and Economic Impacts of Biogas Management Technologies

Paper # 98

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ABSTRACT

Anaerobically digested organic waste (e.g. manure, sewage, food waste, and municipal solid waste) produces biogas, a source of renewable energy. A recent analysis indicates that this resource in California could produce nearly 93 billion cubic feet per year of biomethane from available digestible material.[1] The availability and use of this gas could reduce almost 16 MMT CO_2e/yr in California by displacing fossil fuels.[2,3] Currently, many biogas producers [e.g. dairies, wastewater treatment facilities (WWTF), municipal solid waste digesters (MSWD) and landfills] generate electricity on-site with internal combustion engines and microturbines, which emit ozone-forming criteria pollutants [i.e. nitrogen oxides (NO_x)]. The majority of California's dairies, WWTFs, and landfills are located in ozone non-attainment air basins where strict regulation of criteria pollutants complicates permitting. Unable to invest in costly capital improvements needed to meet permit requirements, many facilities flare their biogas, and some have shut down biogas-to-energy projects altogether. Innovative alternatives such as natural gas pipeline injection, fuel cells, and the use of biogas as a vehicular fuel can achieve cross-media environmental benefits. A more complete understanding of the environmental and economic performance of biogas-to-energy technologies enables state and local governments, regulators, and potential project developers to identify geographically-appropriate and cost-effective biogas management options.

Drawing upon well-established data in the literature and information from on-going biogas-to-energy projects, this research is analyzing several criteria air pollutants, greenhouse gas emissions, and costs associated with several biogas management technologies. Its hypothesis is that each biogas management approach has its own economic and environmental effects; these varying effects make each approach more or less applicable for different policy environments and fuel inputs. This paper discusses the data gathering and analysis process to be used for this effort. It anticipates the research's final results (i.e. a side-by-side comparison of biogas management technologies from different biogas sources based on air quality, greenhouse gas emissions, and operational readiness.)

INTRODUCTION

With ample volumes of organic waste, entities within US Environmental Protection Agency's (EPA) Pacific Southwest Region (Region 9) could generate a significant amount of renewable energy. Table 1 shows that potential energy from biogas in California includes over 50 trillion BTU from landfill gas,[1,2] and almost 40 trillion BTU from combined organic residues (food waste, landfill disposal stream, some crop residues and animal manure) at stand-alone facilities or co-digested at WWTPs.[1,2,4,5,6]

Table 1. Biomethane Potential in California[1]

Resource	Biomethane Potential (billion cubic feet)		Technical Energy Potential (billion BTU)	* Technical Factor Assumption
	Gross Amount	Technical or Recoverable Amount*		
Dairy Manure	33.3	16.7	16,700	50% of manure is recovered
Poultry Manure	6.1	3.1	3,100	50% of manure is recovered
Landfill Gas	70.8	53.1	53,100	75% recovery of gas produced
Waste Water Treatment Plants	7.7	7.7	7,700	100% recovery of gas produced
Municipal Solid Waste (food & grass / leaves fraction)	18.3	12.3	12,300	67% of feedstock is recovered
Technical Total		92.9	92,900	

Due to air pollution concerns, many biogas producers currently flare their biogas and some have shut down biogas-to-energy projects altogether. This has stifled the growth of biogas production in California. Innovative alternatives to on-site electricity generation, such as natural gas pipeline injection, fuel cells, and the use of biogas as a vehicle fuel can achieve cross-media environmental benefits, including: greenhouse gas (GHG) emissions mitigation, air and water quality improvements, odor and waste reduction, and fossil fuel displacement. However, organic waste managers and regulators alike need better information about the overall environmental and economic performance of available biogas management technologies.

This research aspires to fill these knowledge gaps by comparing different biogas management technologies for air quality, greenhouse gas, and economic impacts. A more complete understanding of the environmental and economic performance of biogas-to-energy technologies will allow state and local governments, regulators, and potential project developers to identify geographically appropriate and cost-effective biogas management options. Once completed, this research will provide all parties with a more comprehensive understanding of each technology's environmental and economic costs, enabling more sites to be permitted. It will also further EPA's regional priorities, including waste reduction, renewable energy development, climate change mitigation, and improved air and water quality. Future biogas developers are expected to use these data and make more informed choices about which technologies to pursue. These combined benefits will assist biogas technologies in reaching their market potential, and will help states meet their renewable and low-carbon energy commitments. Although this project was initiated in California and has particular relevance to the San Joaquin Valley and South Coast Air Quality Management Districts, the results are designed to be directly transferable to other regions of the country as well as internationally.

Our hypothesis is that each biogas management approach has its characteristic economic and environmental effects and that these effects make each approach more or less applicable for different policy environments and fuel inputs. This effort aspires to compare several biogas management technologies for air quality, greenhouse gas, and economic impacts.

The California Biomass Collaborative (CBC) at the University of California - Davis (UC Davis) worked in partnership with the EPA's Region 9 and Office of Research and Development (ORD) National Risk Management Research Laboratory (NRMRL) to investigate different biogas management technologies for air quality, greenhouse gas, and economic impacts. The research effort at CBC was led by Rob Williams.

PROJECT APPROACH

Several actions were completed to ensure success. A high level of quality assurance (QA) was emphasized in data collection and analysis. A stakeholder committee was formed to help with data and information collection, analysis, reporting and outreach. The analyses to be completed incorporates well-established data and literature as well as information from on-going biogas-to-energy projects. The final report will summarize project findings with a goal to provide a more complete understanding of the environmental and economic performance of biogas-to-energy technologies to allow state and local governments, regulators, and potential project developers to identify geographically-appropriate and cost-effective biogas management options.

Quality Assurance

A Quality Assurance Project Plan (QAPP) was prepared to detail the data collection and analysis process for this project.[7] This project uses secondary data. That is, this project will not generate new data, but will collect existing data from projects being undertaken by various partners, including but not limited to California Energy Commission, CalRecycle, AgStar, and the California Public Utility Commission. Data must meet EPA Quality Assurance Requirements for Using Secondary Data.[8]

Quantitative information on biogas-to-energy systems is being collected and analyzed to better understand each system's environmental and economic performance. Here, biogas-to-energy system means the components needed to process, clean and use (or convert) the biogas. It excludes the biogas production components themselves (landfills, digesters, feedstock transportation and processing, etc.) although these sources impact the quality of biogas available for use. Environmental performance refers to system air emissions (pollutants and greenhouse gas emissions). Economic performance means cost per unit of energy (or product) delivered for a biogas to energy system. The QAPP describes the types, scope, and objectives of economic analyses undertaken.

Stakeholder Committee

A stakeholder committee was convened by EPA to provide input on which research questions are most important to advance the biogas industry, to identify the most effective way to present the final information, and help identify sources of useful data. UC Davis and EPA jointly selected the stakeholder committee members. The stakeholder committee will also review draft analyses and reports.

Data Gathering

UC Davis is collecting quantitative data from ongoing projects and literature reviews concerning air quality, greenhouse gas impacts and multimedia emissions, biogas quality (e.g. purity and contaminants, energy content), economic, and operational performance for biogas projects using different management technologies including flaring, reciprocating engines, microturbines, fuel cells, natural gas pipeline injection, and vehicle fueling [liquid natural gas (LNG) or compressed natural gas (CNG)]. Data are to be collected for significant sources of biogas including, but not limited to, the following sources of biogas: a) landfills; b) wastewater treatment facilities (WWTF); c) dairy digesters; and d) municipal solid waste digesters (MSWD).

Information is being gathered from peer reviewed and ‘gray’ literature, operating permits, source test reports, operator and expert interviews, California Environmental Quality Act (CEQA) or National Environmental Policy Act (NEPA) documents, and other sources. Data are being compiled from operating or demonstration systems, or projections for systems under development. Data were from (or for) systems in California, North America or Europe.

For each technology, the degree of technology readiness and data credibility is being assigned a value. Degree of technical readiness is based on the level of development of the technology on a five-point scale ranging from early conceptual stage through to commercially proven. Data credibility is rated on a four-point system. Rating Level 1 includes direct contact with operator, technology vendor, commercial project development team or recognized expert. Rating Level 2 includes a peer reviewed journal with results based on independently measured validated data. Rating Level 3 includes Government reports, conference presentations (non-marketing), and peer-reviewed journal articles that fail to meet independence/validation criteria for Level 2. Rating Level 4 includes non-reviewed articles, websites, marketing presentations, advertisements, press, etc.

Information for each technology needed to support the analyses includes: a) technical readiness level; b) biogas quality requirements (impacting the degree and type of gas processing); c) traditional air pollutant emissions by technology [nitrogen oxides (NO_x) sulfur oxides (SO_x), particulate matter (PM), carbon monoxide (CO), and volatile organic compounds (VOC)], d) greenhouse gas emissions [methane (CH_4), carbon dioxide (CO_2), and nitrous oxide (N_2O)]; e) capital and operating costs; f) mass and energy balance (i.e., system efficiency); and g) other as identified. For all technologies, the level of biogas pre-treatment necessary is to be included in the analysis. This may include, but is not limited to: a) hydrogen sulfide (H_2S); b) water; c) siloxane; and d) CO_2 removal.

Data Synthesis

UC Davis continues to analyze the collected data to create a side-by-side comparison of biogas management technologies from different biogas sources based on air quality, greenhouse gases, and economics/operations. Table 2 provides a visual example of what this side-by side comparison will look like. Technical readiness, economic performance and environmental consequences are the most significant factors for data source qualification. Operational factors typically provide inputs into the evaluation of the primary parameters (economics, environmental outputs, etc.), so are considered secondary parameters as individual parameters. Secondary parameters may strongly influence primary study parameters (i.e., efficiency).

Table 2. Format for Side-By-Side Comparison of Technologies

Equipment	Equipment Size	Energy Efficiency (%)	Emissions Information for NOx, CO, PM, VOC, SOx		Tech-nology Readi-ness (1 – 5 Scale)	Emissions Information for CO_2, N_2O, CH_4	Multi-media (e.g. water & land) impacts
	Basis: Biogas Input, Energy Output, or Equipment Rating (MWe)		Mass per unit energy	Notes on Emission Control Equipment		Mass per unit energy	
Flare							
Reciprocating Engine							
Microturbine							
Gas Turbine							
Fuel Cell							
Vehicle Fueling							
Pipeline Injection							

There are additional dimensions to this analysis. These include the quality of the biogas fed to the biogas utilization equipment (e.g. purity, contaminants, energy content, and consistency of supply). Biogas quality needs to be linked to its source (e.g. dairy digesters, MSWDs, food waste digesters, WWTPs). The levelized cost (i.e. cost per MM BTUs) and the estimated utilization rate of each technology will be considered.

Data are being evaluated in terms of type (i.e., commercial plant data vs. engineering calculations) with greater weight placed on data collected from sources at higher technology readiness levels. The quality of information is being evaluated by UC Davis for internal consistency, completeness, and reasonableness. UC Davis did not perform data quality audits of literature or vendor data due to the limited availability of raw data and budget restrictions. When quantitative data are presented, they are being validated using reasonableness checks based on standard engineering practices such as mass and energy balance or capital cost estimation methods and using other approaches such as prior relevant experience of stakeholders or industry guidelines. Where sufficient data are available, comparisons within sources and between independent sources are being made to determine the degree of internal and inter-source consistency that is present in the data sets.

Final Product

As described above, this research is collecting quantitative data from ongoing projects and literature review on air quality, greenhouse gas impacts and multimedia emissions, biogas quality (e.g. purity and contaminants, energy content), economic, and operational performance for biogas projects using different management technologies. The collected data are being analyzed and used to create a side-by-side comparison of biogas management technologies from different biogas sources based on air quality, greenhouse gases, and economics and operations.

The final report will detail the comparison and providing context for decision-makers to understand environmental and economic considerations when choosing a biogas management technology.

RESULTS AND DISCUSSION

Stakeholder Committee Meeting

On April 5, 2013, EPA hosted the first stakeholder committee meeting, in which interested parties from federal and state agencies, local air districts, non-profits, industry groups, and wastewater utilities provided input on the study design, suggested potential data sources, articulated their own data needs, and asked questions. The committee was formed to help with data and information collection, analysis, reporting and outreach. The following 23 individuals representing 14 different organizations either attended the meeting in-person or via webinar:

Randa Abushaban (Orange County Sanitation District)
Caitlin Bush (EPA Region 9)
Joe Choperena (Sustainable Conservation)
Allison Costa (EPA AgStar)
Wendy Davis-Hoover (EPA ORD)
Charlotte Ely (EPA Region 9)
Kevin Eslinger (California Air Resources Board)
Jacques Franco (CalRecycle)

Jacqui Gaskill [USDA Natural Resources Conservation Service (NRCS)]
John Harrington (NRCS)
Steve Kaffka (UC Davis)
Greg Kester (California Association of Sanitation Agencies)
Michael Kosusko (EPA ORD)
Mark McDannel (LA County Sanitation)
Laura Moreno (EPA Region 9)
Tom Mossinger (Carollo Engineers)
Garry O'Neill (California Energy Commission)
Michael Schuppenhauer (representing the American Biogas Council)
John Shears (Center for Energy Efficiency and Renewable Technologies)
Johnnie Siliznoff (NRCS)
Ted Strauss (NRCS)
Kristine Wiley (Gas Technology Institute)
Rob Williams (UC Davis)

The stakeholders discussed the scope of useful data that could be gathered as opposed to what had been proposed, which were constrained by project resources. These included data for upstream impacts and the breadth of economic analyses. A qualitative discussion of upstream impacts was added to plans for the final report. The synergy of this project with other CBC programs was discussed. Stakeholders identified potential data resources with data for biogas quality, gas conditioning and pipeline interconnection costs. They also identified and offered access to many information sources being collected by their organizations and others. In answer to the authors' question about their data needs, the need for information about technologies at the cusp of being implemented was identified. Such information would inform future targeted solicitations for technology development or implementation.

Once EPA and UC Davis have developed drafts of the final products (i.e. the side-by-side comparison and the associated report), additional stakeholder committee meetings will be held and participants will be invited to again provide input and ask questions.

SUMMARY

The California Biomass Collaborative (CBC) at the University of California - Davis is working in partnership with the EPA's Pacific Southwest Region (Region 9) and Office of Research and Development (ORD) to investigate different biogas management technologies for air quality, greenhouse gas, and economic impacts. A stakeholder committee was formed to help with data and information collection, analysis, reporting and outreach. The final report will summarize project findings with a goal to provide a more complete understanding of the environmental and economic performance of biogas-to-energy technologies to allow state and local governments, regulators, and potential project developers to identify geographically-appropriate and cost-effective biogas management options.

To date, a framework for compiling biogas management information has been established. Data gathering has been slow. It has been particularly difficult to gather economic information.

ACKNOWLEDGEMENTS

The authors would like to thank our stakeholder group for its participation and support. Bob Wright of EPA’s National Risk Management Research Laboratory (NRMRL) provided QA support above and beyond the call of duty during this effort. We thank him. Wendy Davis-Hoover, EPA NRMRL (retired), acted as alternative project manager for much of this project. I thank her for her support and wish her a long and happy retirement.

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KEY WORDS

A&WMA, lifecycle, waste-to-energy, bioenergy, GHG Emissions, digestion, waste management