

Denali Emerging Energy Technology Grant:
“Improving Cold Region Biogas Digester Efficiency”
Year 2 Quarterly Report, Y2Q2 – June 29, 2011



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i. Y2Q2 Summary

The project is in the final stages of Phase II research and researchers have begun disassembly at the Cordova site. To date, efforts to test and demonstrate applications of biogas technology have been largely successful and recommendations for future use of the anaerobic digestion technology in Alaska have been recently submitted for publication. At this time breakdown of project materials is advised due to decreased daily monitoring and student participation at the Cordova site. Efforts in the final quarter will focus namely on sample analysis and the dissemination of information on biogas technology to communities throughout Alaska.

During the second quarter of this year, research efforts focused specifically on demonstrating biogas collection, usage and testing the physical/chemical properties of the gas. Much of this research was carried out by Cordova High School students, who presented their research at this year's Alaska State Science Fair. In addition, research scientists at the University of Alaska, Fairbanks concentrated efforts to develop a gas collection system, demonstrate its use in powering cooks stoves and an electrical generator, data analysis, and final collection of gas samples from the Cordova field site. A gas collection system was developed in Fairbanks and installed in Cordova on June 1, 2011. The 500 gallon capacity tank collected biogas from all active reactor vessels inside the Conex and was connected to a variety of gas-powered devices. The collection system remained at the site until June 16, 2011 when the project was disassembled and tanks were returned to Fairbanks, AK.

Following the relocation of research technician Casey Pape to Fairbanks on March 25, 2011, feeding and daily maintenance of the reactors was halted as of April 18, 2011 due to decreased supervision and hazard awareness. The Conex doors were locked, temperatures in both rooms were increase to 35°C and reactor valves were left open. Excess liable organic material was allowed to continue to react and vent to the atmosphere. As of June 1, 2011, the collective biogas output of all six reactors was recorded at around 155 L indicating significant reduction in the amount of liable carbon located within each of the tanks (previous daily production rates approx. 1000 Lday⁻¹ ΣAll tanks).

During this quarter, two additional reports were prepared. The first report, on the 'scaling' of biogas projects as well as recommendations for the future of anaerobic digestion technology in Alaska, is still in internal review among the UAF researchers. Second, researchers at UAF worked together with ACEP and Cooperative Extension Services (CES) on a flyer publication intending to inform Alaskans interested in biogas technology. The flyer is now available in print as of June 18, 2011 and can be obtained through either ACEP or CES (www.uaf.edu/acep/publications/).

Researcher Casey Pape gave a lecture presentation to the Fairbanks public on the project on June 21, 2011 for ACEP's June talk as part of their 'Community Energy Lecture Series'. Information regarding the talk can be found on ACEP's website and INE website:

<http://www.uaf.edu/acep/publications/>
<http://www.ustream.tv/recorded/15536826>
<http://ine.uaf.edu/>

ii. Schedule and milestone information

The project continues to closely follow the original outlined plan:

- Construct Digestors for Phase 1 by December 15, 2009 – Completed January 21, 2010
- Commence Data Collection by February 1, 2010 – Achieved January 18, 2010
- June 25-27, 2010, project meeting onsite in Cordova (all team members present); High school student presentations
- Perform mid-term Analysis of Data by July 30, 2010 – Completed informally internally as a project team, and formally in Quarterly reports 2 and 3.
- Year 1 Q4 Report, December 15, 2010
- Phase II Scoping, deadline for revised report: Completed March 15, 2011
- Phase I Report, including analysis of all Phase I data: Completed March 15, 2011
- Year 2, Q1 Report: Submitted on March 15, 2011
- Scaling Report: Submitted [internally] April 15, 2011
- Year 2, Q2 Report: Extended to June 29, 2011 (this report)
- Year 2, Q3 Report due September 15, 2011
- Scaling Report: Final draft to Denali Commission September 30, 2011
- Final project report due September 30, 2011

ii.a) Personnel:

Cordova Electric Cooperative <http://cordovaelectric.com/>

Clay Koplin – Grant Administrator. Koplin has managed most of the financial aspects of the project thus far on behalf of the Cordova Electric Cooperative, serving as the project manager. Koplin also serves as a technical advisor to the project.

University of Alaska, Fairbanks <http://www.alaska.edu/uaf/cem/ine/walter/>

Katey Walter Anthony – Research Director. Walter-Anthony acts as the primary investigator, and has spearheaded the scientific goals and directions of the project. She provides continual scientific expertise and project management. She contributed to the data analysis, interpretation and writing of this and all reports.

Casey Pape – Research Technician. Pape joined the project in early September, 2010, to assume the role of primary project technician. Pape worked on-site in Cordova until March 2011, maintaining the digester experiment, including data collection, analysis, and troubleshooting. Pape led the preparation of the current quarterly report with assistance from other team members. Pape relocated to Fairbanks on March 25, 2011 and will continue working on the project with closer access to lab instruments, consultation with Walter Anthony and ACEP. Pape travels intermittently to Cordova. Pape plans to remain with the project until its completion in September 2011.

Dane McFadden – Project Intern. Currently an undergraduate at Stanford University, Dane McFadden helped maintain digester performance during August 2010. Job responsibilities included: maintaining daily gas data collection, feeding, chemistry measurements and gas sampling. McFadden will be using his experience here in Cordova as his required internship at Stanford University.

Laurel McFadden – previous Research Technician. McFadden, served the project as Research Technician from the start of the project until August 2010, when she left to begin graduate school at UAA. McFadden was a key contributor to the project development and took

the lead on organization and preparation for the initial construction and setup. McFadden completed the first draft of a Biogas Handbook for Alaskans, which will be submitted as a deliverable in final form to the Denali Commission by the end of the project.

Peter Anthony – Research Technician. Anthony consults on the project and continues to provide technical expertise to the maintenance and application of digestors. He participated in all on-site project meetings in Cordova and provided recommendations for simplification and winterization of the gas collection system in preparation for Phase II. Anthony continues to conduct the gas chromatography analyses of biogas composition for the project.

Jeffrey Werner – State FFA Director. Werner is interested in using the effluent from anaerobic digestors as a liquid fertilizer for agricultural crops. Located at the horticultural center at UAF, Werner remains enthusiastic about the possibilities of the potential uses of the once thought of waste product.

Cordova High School <http://blogs.cordovasd.org/chs/>

Adam Low – Science Teacher. Low was integral in bringing in student involvement via classroom curriculum and extracurricular projects. Low was in charge of maintaining a consistent feeding regime and guiding student involvement with the project. While Pape was away from Cordova, Low had the added responsibility of maintaining gas flow and chemistry measurements as well as general troubleshooting. Additionally, Low worked with science club students to set up a greenhouse experiment in which to test effluent samples for their potential use as a liquid fertilizer. Low also assisted in collecting and shipping effluent samples to other project colleagues in Germany in efforts to greater proliferate psychrophilic digester technology.

As of June 5, 2011, Low moved from his home in Cordova to Hawaii with his family and is no longer involved with the biogas project. He has been an integral part of the research project to date, the loss of his help and assistance is most regrettable.

Cordova High School Students – Volunteers. The students of Cordova High School have been highly involved with construction, feeding, maintenance, demonstration of the use of biogas in science fair projects for Phase II, and public presentations for the project. They include the seventeen Chemistry class students and Science Club students (Craig Bailer, Ben Americus, Adam Zamudio, Sophia Myers, James Allen, Eli Beedle, Josh Hamberger, Keegan Crowley, Kris Ranney, and Carl Ranney).

SOLAR Cities <http://solarcities.blogspot.com/>

TH Culhane – Biogas Expert. With an extensive history in biogas technologies, Culhane developed the water-pressure tank design and provided extensive technical knowledge to the engineering of the project at its outset. He worked with and advised the on-site construction in January 2010 and provides expert advice from his home base in Germany. Recently, Culhane requested a 1-L sample of psychrophilic effluent in efforts to test the success of psychrophilic digestors in different locations in Europe, Asia and Africa with different weather patterns and climate regimes as part of a tangential outreach project that Culhane and Walter Anthony have, funded by the National Geographic Society and Blackstone Ranch.

Sybille Culhane – Co-founder of SOLAR Cities. S. Culhane assisted in initial construction efforts and managing financial aspects of SOLAR Cities involvement.

Chena Hot Springs <http://www.chenahotsprings.com/>

Bernie Carl – Owner of Chena Hot Springs. Carl has expressed interest in deploying a digester at Chena Hot Springs, and has offered space for testing a digester in his greenhouse.

Others <http://www.cordovaenergycenter.org/>

Brandon Shaw – Website Development. Shaw designed the CordovaEnergyCenter.org website, where the project is hosted. He also assisted at the initial construction site, and was integral in the assembly of the flow meter system.

Keywords: Biogas, anaerobic digester, reactor, psychrophiles, mesophiles, methane, methanogens, Alaska, cold-climate, thermokarst lakes.

iii. Narrative summary of the project status and accomplishments to date, and addressing the following questions: is the project on schedule, is the project on budget, and what actions are planned to address any project problems.

iii.a) Notable Accomplishments:

Collection, passive compression, and usages of biogas – Phase II experiments to collect, store and utilize biogas have been successful, demonstrating that biogas technology is directly transferable for collectors utilizing psychrophilic cultures. Demonstration projects have largely surpassed researcher expectation and Phase II demonstrations have been mostly concluded at this time. To date, a modified propane burner stove, 4-cycle combustion engine and gas-powered 1850 Watt generator have been demonstrated to work well on biogas produced from the experiment in Cordova. Optimal burn and device efficiencies are not known, but visual accounts confirm high [device] performance.

Biogas production – Thorough understanding of variables that limit biogas – An extensive dataset of daily biogas production from each of the tanks in the experiment has been collected. At peak productivity under experiment set conditions, production levels of flammable gas reached high quantities (between 30 – 345L/day per 1000L tank). The gas has been shown to be safely and easily collectable using passive techniques and retains high flammability when exposed to spark or flame. Even at almost nominal pressures, the gas holds continuous flame and burns clean with no visible soot or residue left after combustion.

Proven flammability – One of the primary goals of this project was to determine if the psychrophiles that produce methane in thermokarst lakes could be harnessed in an artificial environment to produce biogas. With the initial production of biogas from both psychrophilic and mesophilic microbes we proved flammability possible (refer to Y1Q2 report).

Biogas from conventional anaerobic digestors possesses methane content typically between 40-60%. Recently it has been discovered that our biogas contains increasingly high concentrations of methane (50-82%). It is possible that the increased methane concentration(s) observed in our tanks are the result of using psychrophilic methanogens whereas typical anaerobic digestors commonly use mesophilic bacteria

and archea found in bovine and animal manure. Additional measurements of gas content will be obtained during the final project quarter to confirm consistency in this trend. Stable isotope analysis could also help distinguish pathways of methanogenesis in the manure-vs.-psychrophile tanks. If this high CH₄-content of psychrophilic biogags holds constant, then this is an important finding as it implicates the use of psychrophilic methanogens for improving the energy content of biogas as opposed to more common mesophilic anaerobic digester systems.

Successful Chemical Remediation of Digester Tanks – As mentioned before in section iii.a) early in the experiment, observed declining pH was foreseen as a potential threat to the digestors' microbial health and action was taken to restore pH to previous levels. Ideally, digester psychrophilic and mesophilic-communities perform under optimal conditions at a pH of around 6.8-7.2, observing tank pH(s) much lower than this (pH 3.5 – 6) was an indication that the tanks were acidifying and VFA's were likely being produced in large quantities. Using chemical remediation we successfully prevented all digestors, except #3 and #2 (possibly), from "crashing" or "souring" from prolonged exposure to low pH.

Remediation was performed in two steps. The first step involved ceasing to feed the digesters until alkalinity was restored. The second step entailed adding calculated quantities of Calcium Carbonate (Lime), and Sodium Hydroxide in order to bring the pH back to the initial conditions. Care was taken to restore the pH in a gradual manner as to not "shock" the microbial communities. Slow remediation was also essential as over treating the tanks could cause them to become too basic, as anaerobic digester bacteria are particularly sensitive to increased ammonium concentration and this is to be avoided as even slightly basic tanks can cause total failure of mesophilic communities (pers. com. TH Culhane). All digestors are now at relatively stable pH values with the exception of Tank 3.

We note that biogas production is highly sensitive to environmental variables and political regulations, and many efforts to produce biogas often experience considerable setbacks. A recent multi-million dollar project reported that their first kilowatt hour of energy from biogas was finally achieved after two and a half years of effort (<http://www2.timesdispatch.com/business/2011/jun/23/tdbiz03-manure-entrepreneur-turns-dairy-waste-into-ar-1127374/>). With flammable biogas production observed within the first several weeks of this project, and again with hundreds of kilowatt hours produced in the first four months following acidification/remediation, we claim that highly successful biogas management and production was achieved in this project thanks to the diligence of researchers, teachers, students, the CEC and support from the Denali Commission.

Proven High Methane Content of Biogas – GC analysis during Phase I of gas samples collected from tanks 1, 4, 5, and 6 showed high levels of detected methane in most cases. Preliminary analysis shows that methane concentrations have increased since the onset of Phase I research. To some extent this is an indication that observed healthy proportions of microbes in several tanks enough to support active methanogenesis. More work will have to be performed on the GC in the final quarter to understand long term trends and behavior of our tanks.

Student education – This project has the fortunate opportunity of involving High School students in rural Alaska in a primary scientific study. Cordova High School students have the unique ability to see some of the technical aspects and complications that go along with scientific research. The science club and chemistry class provide an excellent platform to organize student involvement. Previously, students have had the opportunity to troubleshoot and take the lead on feeding procedures for the project resulting in several very clever and innovative ideas being implemented.

The students of Cordova High School presented on the project several times now and were received well with each new appearance. The students demonstrate a thorough understanding of the issues involved with conducting new technology research as well as the factors that contributed to lessons learned during this project. CHS students and teacher Low presented biogas projects for the Alaska State science fair. Student results, reports and photographs from the biogas demonstrations are provided in section iii.b.1 and Appendices III and IV.

Community outreach – High school students and UAF researchers were given the opportunity to present on project ideas and preliminary results at meetings with the Alaska Power Association and Alaska state legislators in Juneau, and at a variety of conferences, including the Alaska Rural Energy Conference (April 27-29th, 2011) and the Alaska Forum on the Environment (February 7-11th, 2011). Most recently, the project research was featured during ACEP’s lecture series for the month of June 2011. The talk, given by Casey Pape, was hosted at the Blue Loon in Fairbanks. Slides as well of video of the speech can be found online (web link in section i). Titles of our project presentations and other public dissemination documents are:

Walter Anthony, K., Culhane, TH., Koplín, C., McFadden, L., Low, A. “Improving Cold Region Biogas Digester Efficiency.” McFadden, L. Alaska Forum on the Environment. Anchorage, Alaska. February 8-12, 2010.

Walter Anthony, K., Culhane, TH., Koplín, C., McFadden, L., Low, A. “Improving Cold Region Biogas Digester Efficiency.” Low, A., Hess, E., Allen, J., Americus, I., Americus, B., Zamudio, A. Alaska Rural Energy Conference. Fairbanks, Alaska. April 27-29, 2010.

Pape, C. and the Project Team, “Energy from Psychrophilic Bacteria: A Cold-Region Alternative for Biogas”, ACEP Community Energy Lecture Series, Fairbanks, Alaska, June 21, 2011.

New Scientist article featuring this project: ‘Cold climates no bar to biogas production’. November 4, 2010.

<http://www.newscientist.com/article/mg20827854.000-cold-climates-no-bar-to-biogas-production.html>

The project was recently featured by Alaskan Dispatch Magazine in an article on rural Alaska entitled, ‘Biogas could bring new energy to rural Alaska’. January 17,

2011. <http://www.alaskadispatch.com/article/biogas-could-bring-new-energy-rural-alaska?page=0,0>

Low, A. "Youth Participation: Improving Cold Region Biogas Digester Efficiency." Low, A., Bailer, C., Allen, J., Americus, B., Zamudio, A. Alaska Forum on the Environment. Anchorage, Alaska. February 8, 2011.

Walter Anthony, K., Culhane, TH., Koplin, C., Low, A., Pape, C. "Improving Cold Region Biogas Digester Efficiency." Low, A., Bailer, C., Allen, J., Americus, B., Zamudio, A. Denali Commission Public Forum on the Emerging Energy Technology Grant. Juneau, Alaska. February 14-15, 2011.

The project was also mentioned in Senator Lesil McGuire's recent press release on the 'Deadline for Emerging Energy Technology Fund Grant Applications Approaching'. Released March 3, 2011.

<http://www.aksenate.org/mcguire/030311EmergingEnergyFund.pdf>

Last year, the chemistry students took a class trip to the Alaska Power Association in Feb. 2010. Students C. Bailer, D. Hess, C. Morrissett, J. Smyke, S. Lindow, and T. Kelley presented on the project and it was received well among those who attended the meeting. The project team intends to present at next years' Alaska Rural Energy Conference in Juneau, Sept. 27-29, 2011.

Website development- Website developer Brandon Shaw designed a site (www.cordovaenergycenter.org) for the Cordova Energy Center, the venue at which the biogas experiment has been conducted. The website provides a venue for students and community members to obtain information about the project and how to get involved. It is important to update the website often as a means to show visitors that the project is still underway, that is still producing results and that people are still encouraged to get involved.

iii.b) Project Status

Phase II Research

The project is currently in Phase II: the testing and demonstration of biogas technology in Alaska. Research interests during this quarter were to develop a gas collection system for storage of produced biogas, demonstrate the utility of biogas in a variety of gas powered devices and to encourage student experimentation and self-driven research by making the gas accessible in a safe learning environment.

iii.b.1) Overview of student-led Phase II biogas projects

Science club students at Cordova High School were encouraged to submit individual research proposals which, upon receiving funding through the grant and Cordova School

District, many students used as part of their state science fair project (Appendix III). Many student projects exceeded expectation and their work has greatly improved the overall grant project portfolio. Student projects ranged in varying degree of scale and complexity and are a testament to the creativity and innovation that can result from projects that include some facet of academic student learning/involvement.

There were four student [managed] projects that were supported through the grant this year. Students were first asked to present project proposals in order to get researcher and teacher approval then submit a final project report along with photo documentation before April 15, 2011. Photos and original project reports are provided in Appendices III and IV, and summarized here:

Student run greenhouse to test effluent nutrient levels (Elaina Allen, Shannon Lindow, Jessica Smyke, and Carl Ranney) – On November 24, 2010, CHS science club students began a five month experiment to test the nutrient availability of psychrophilic effluent taken from Tank 4. The students planted lilies, radishes, carrots, lettuce and parsley in a heated greenhouse setting up both experimental and control populations to test the effects of effluent fertilizer on plant growth. Effluent treatments were delivered in mixture ratio 1:16 effluent to water so as not damage the plants. The control group was just given sterilized sandy soil and water treatments.

Students contend that there was a noticeable difference in height, fullness and health of many plants treated with effluent over those which only received water. This was more so observed among the flowering plants, *Lilium Pumilum* and Asiatic Pink Pixies, which responded very well to effluent treatments; however, others like *Lilium Regales* and Asiatic Orange Pixies hardly grew at all when given effluent treatment. Less of a difference in size was noted among the food crop plants, but it was observed that plants fertilized with effluent tasted better on many occasions. One exception was the root and carrot plants, which were said to not be very appetizing when given effluent fertilizer (Appendix III).

No other mass comparison or root-shoot ratio analysis was performed at this time.

Calorimetry Experiments (Craig Bailer) – A standard calorimetry experiment was set up in order to test the comparable heat content of project biogas with that of another common heating fuel – propane. In this experiment, two soda cans were assembled with thermometers, ring stands and modified Bunsen burners set 1.5 inches from the bottom of the can. Each can was filled with 100 mL of water and individual balloons were filled with biogas and propane respectively. Flow rate and burn time were measured, and steps were repeated for both gases. The student used the gas to heat the water in each of the cans and then calculate the resulting heat content of the gas (**Equation 1**).

The test revealed that the measured heat content of biogas was much less than propane. By comparison, the propane used in this experiment was observed to contain an energy density of approximately 570 Btu/ft³ whereas biogas was shown to be approximately 180 Btu/ft³. Using propane as a control

illustrates that this high-school lab technique underestimated the energy density of the gas as propane and biogas energy values are both well known throughout the scientific literature (2,500 Btu/ft³ and 600 Btu/ft³ respectively). Still this is a great initial test to understand the relative energy content of gas produced at the Cordova site.

$$Q = Mc\Delta T$$

Q = Heat Energy(J)

M = Mass (g)

c = Specific Heat

ΔT = Change in temperature (T_f – T_i)

Equation 1. Heat Capacity Equation for a closed system. Solving for heat energy (Q) the students at CHS were able to obtain initial estimates on the heat content of biogas.

Running an Engine on Biogas (Ben Americus and Adam Zamudio) – Prior to having a gas collection and storage system in place at the Cordova site, students attempted to run a gas powered engine on biogas. Over a two month period, CHS students obtained an 1850 Watt 4-cycle Husky generator with Subaru engine and began converting the engine to run on biogas. A regulator and conversion kit was installed in order to feed biogas or propane fuel equivalent into the engine carburetor, therefore powering the device as the fuel line to the gasoline tank was disconnected.

The engine was demonstrated to run effectively and continuously on propane, but was unsuccessful when attempted with biogas. The student's reasoning was that they had inadequate supply of biogas. At that time, students were using tire inner tubes and bypassing the shraeder valve. At low pressure and heavy restriction the generator was not able to be powered by biogas, but the students effectively converted the generator to run on gaseous fuels.

Biogas was demonstrated to power a lawnmower engine using the same conversion techniques and the students were very excited to attempt the experiment again once a collection and delivery system could be provided. Later, on June 14, 2011, the generator was demonstrated to run properly on biogas once a storage and pressure system was installed and the gas pressure was increased to around 0.5psi (Appendix II).

Cleaning Biogas (Keegan Crowley) – Efforts to purify biogas were taken in order to see how easily impurities could be removed from the synthesized gas. In this experiment, students bubbled measured amounts of biogas through a 4 ft column containing saturated lime water (CaCO₃), recovering and measuring the gas once it reached the top of the column. The gas was pumped manually using a one-way hand pump and samples of gas, upstream and downstream, were analyzed for CO₂ and heat content.

Their results indicated that bubbling biogas through a lime water column measurably altered the composition of the gas. Carbon dioxide levels in the

biogas were reduced by 21.7% and the measured heat content was reported to have increased by 21.8%; illustrating that biogas can be easily purified to become more competitive with other fuel types (for more on heat content, refer to Equation 1).

The scholastic year ended on June 3, 2011, and student involvement with the project is likely to be nominal until the start of the next school year. The project team would like to thank all Cordova High School students who participated in the project for their efforts and wish them a safe and happy summer break. Students involved with the project will be contacted again in September 2011 in order to participate and present on the project at the Alaska Rural Energy Conference 2011 (Sept. 27-29th) in Juneau, AK.

Of those involved with the project, a special recognition and thanks should be given to CHS teacher Adam Low and all of his efforts to encourage student learning and enhancement through use of the Biogas project. As of June 5, 2011, Low relocated with his family to Hawaii and will no longer be able to assist with the project. Low's efforts were pivotal in many of the project successes to date. His enthusiasm and assistance will be missed. Low still remains as a valued advisor and consultant to the project.

iii.b.2) Gas Collection System

Development of a gas collection system for storage and pressurization of biogas is one of the most important design elements to consider when implementing a biogas reactor for personal or small-scale use. To this end, construction and installation of a gas collector was a pivotal part of Phase II research. Over the course of the project, several gas storage designs were tested for their utility. On April 6, 2011 a meeting was held at ACEP in order to discuss options for gas collection systems to test and install in Cordova. ACEP engineers and UAF researchers concluded that a telescoping-style collector had the greatest amount of utility and should be pursued for the project (Appendix II). Apart from the small-scale inner tube collector used by students, other designs involving larger bladder-type collectors and standard high compression were largely dismissed given the time and logistical needs of those who would likely implement a biogas reactor in rural Alaska.

On May 23, 2011, two HDPE water tanks were purchased from Greer Tank and Welding, Inc. and delivered to ACEP building on the UAF campus. The larger, 1000 gallon receiver tank was used to hold and stabilize an internal 500 gallon tank which would be used to store biogas. Cutting the bottom section out the 500 gallon tank, the exterior tank could be filled half-full with water and still allow the internal tank to move freely inside (Appendix II). Tubing and securing brackets were installed in order to transport the tank to Cordova on May 28, 2011 and the collection system was fully installed at the Cordova biogas site on June 1, 2011. The tank consolidated gas produced from tanks 1, 4, 5 and 6 from June 1-June 15, 2011 when the project was dissembled and shipped back to Fairbanks. The tank is currently located outside the ACEP building and will likely be used in the future for other biogas-related projects.

The gas collection tank is specified to store up to 500 gallons of gas at a time. The telescoping tank weighs approx. 120lbs and provides enough continuous pressure to sustain a flame when burned. The inlet and outlet tubing is ¼ in gas hose and connects to standard ¼ in gas flare compression fittings. In order to run devices that demand high rates of gas flow,

additional water weight was used to increase the gas pressure inside the tank. With about 1500 lbs of weight, the gas pressure increased to about 0.5 psi. This was enough pressure to run the 1850 Watt generator (see *Phase II Research*). Additional weight could be added if needed, but was not required to run devices used in this experiment.

iii.b.3) Powering Devices on Biogas

In addition to the student driven research (section iii.b.1), UAF researcher, Casey Pape, demonstrated several applications of biogas this quarter to illustrate its potential function and utility to Alaskans interested in the technology. Most notably, this was accomplished through demonstration of biogas usage as a cooking fuel and as a combustion fuel which could be used to power engines and common appliances. In addition, measures were taken to minimize fuel consumption as well as quantify hourly demand and pressure requirements for each application.

The vast majority of small-scale biogas projects are used in order to supply single family dwellings with daily cooking fuel in order to prepare meals and sterilize water. As a result, replication of the ability to cook a meal and/or boil water using biogas was of a high priority during Phase II. Previously, the project had acquired a large, natural gas, single-burner stove which was intended to be powered off of biogas. When initially connected to a supply of biogas, the burner failed to light, though the biogas would exhibit strong flame when burned directly. Later, it became apparent that the burner was specified for high rates of flow and fuel consumption (i.e. designed to boil large quantities of water quickly) and would not work under low pressure conditions at which the gas was being supplied. Modifying the stove so that proper function could be utilized with less fuel demand was required in order to sustain a flame and demonstrate the ability to cook a meal. The result was a simplified burner that, though less powerful than the original stove, was perfectly sufficient at boiling water once lit (Appendix II).

Using biogas to fuel this stove, 4 Liters of water were boiled ($T_i = 15^\circ\text{C}$), placed in a covered pot, in 20 min and sustained a continuous flame throughout the demonstration despite being in an open, outdoor environment. The stove was used to cook a meal consisting of hot dogs and carrots and consumed roughly 300 L of biogas per hour (~80 Gal/hr).

The next demonstration was designed to illustrate 'transduction' of the energy stored in biogas and convert it into some other usable form – electricity. As mentioned in the previous section, CHS students involved with the project had once already attempted to power a generator off of biogas, but were unsuccessful in that attempt. The reason for this was simply because of inadequate biogas supply, as students did not yet have access to a large store of biogas which they could easily pressurize. Once connected to an ample supply of biogas in our new gas collection system, the converted 1850 Watt Husky generator ran normally. When first connected to the biogas collection tank, the generator failed to turn over, indicating that it had insufficient supply or access to fuel. This was due to the extreme low pressure at which the biogas (at that time) was being stored. We increased pressure in order to sustain combustion. Since the tank used to store the biogas was large (Diameter: 60in), the amount of weight needed to increase the pressure would need to be substantial (e.g. it would take the weight of a mid-sized SUV in order to generate 1 psi).

Increasing the pressure was accomplished by adding a second tank on top of the collection vessel and filling it with approx. 175 Gal of water ($D_{\text{H}_2\text{O}} @ 15^\circ\text{C} = 1000\text{kg}/\text{m}^3$ or 8.34

lb/US gallon). The resulting water weight (approx. 1500 lbs) was enough to increase the pressure in the gas line to about 0.5psi, which was sufficient to power the generator. The generator performed optimally (i.e. continuously @ 120 V 60 Hz AC, enough to sustain a CFL bulb) for over an hour before exhausting the biogas storage tank. To this end, the 1850 Watt generator was rated at a consumption rate of approx. 300 gal/hr or ~1,100 L/hr (Appendix II).

iii.b.4) Scaling Report

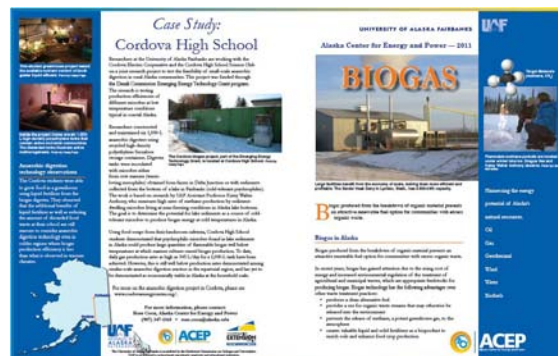
In addition to Phase II efforts, this quarter, UAF researchers drafted a report on biogas technology entitled: “Scaling and Feasibility Recommendations for Alaska”. The report details the current U.S. and global trends in Anaerobic Digestion (AD) technology as well as recommendations for future Alaskan biogas projects. The report contains assessments of Alaskan energy consumption and initial evaluation of basic waste streams, those which would be necessary feedstock for biogas production. Various cases studies are discussed along with additional resources and links to other projects which may be useful for future work performed in Alaska. The report was submitted April 15, 2011 internally to the project PIs, and will be submitted in final form to the Denali Commission for public dissemination in September 2011.

iii.b.5) ACEP Flyer

In addition to the ‘scaling and feasibility’ report, UAF researchers and ACEP staff collaborated with Cooperative Extension Services (CES) to produce a flyer publication on ‘Biogas’ for Alaskans interested in the technology. The flyer is intended to be a general introduction to AD technology and inform readers what is happening around the state as well as where to go to find additional information. The Cordova Biogas project is well represented on the back page of the flyer with references made to the project website, project contributors and funding provided by the Denali Commission as part of the ‘emerging energy technology grant’ program. The flyer was finalized for publication in mid-June and was available in print for the June 21st lecture at the Blue Loon in Fairbanks.

The flyer is now available in print through ACEP and Cooperative Extension Services and can be located online at:

www.uaf.edu/acep/publications/



The ACEP and CES flyer on ‘Biogas’ in Alaska. The flyer became available as of June 21, 2011 and is available electronically and in print through CES.

iii.b.6) Gas flow measurements

Due to the lack of an extensive dataset that accurately demonstrated biogas production among all reactor tanks, the research team conducted an intermediate phase in the second year first quarter to obtain a solid data set for hypothesis testing. The study was entitled Phase 1.5 as it contained both elements of Phase I and Phase II (see Phase I Final Report for details regarding Phase 1.5). Recent data obtained in June 2011 at the Cordova field site was in accordance with previously approved measurement techniques and has been added here to the Phase 1.5 data set.

On June 1, 2011 the collective total amount of biogas produced from each tank was approx. 155L, indicating that most of the available carbon inside each reactor had been consumed and liberated to the atmosphere during the 'shut-off' period from April 18-June 11, 2011 (see section i. Y2Q2 Summary). Feeding was resumed on June 11, 2011 and flow meter data were analyzed to see if any feeding-response curves resulted (Figure 1). Tank 1 was the only tank fed for multiple days (from June 11- 13th, 2011) and individual gas flows are known, though not shown here. Tank 1 exhibited the highest amount of gas production for the period (roughly half of the synthesized gas). The flow data recorded for this period suggests that gas production increased substantially with increased feeding, however, the increase was not linear and suggests that microbial activity may have been limiting in this case. On June 13, 2011 the bleeding and recording procedures changed slightly as gas was collected inside of the gas collector further 'downstream' of the Sierra flowmeter. The resistance of the tank may explain the decrease in observed gas production on June 13th (Table 1). Ultimately, a longer retention time is needed in order to fully understand feeding-response curves and elucidate optimum culture incubation times.

Table 1. Biogas summary data for Phase 1.5. The numbers present average gas production within a 24hr period for each tank. Data are not normalized by the volume of slurry inside each tank. Normalized data are presented in the Phase I Final Report. On several occasions, gas pressure contained in the headspace of the reactors caused tanks to expel some of their liquid contents from the tanks. Dates of occurrences of tanks spills are both documented and undocumented as students may not have reported a spill during several instances when researcher and teacher support was not available.

Gas Production Summary Data (Raw Data)							
Date	15°C Room			25°C Room			All Tanks
	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	
12/11/2010	28	0	0	127	151	0	
1/17/2011	20	0	0	208	145	24	
1/18/2011	21	0	0	257	163	28	
1/19/2011	32	0	0	202	197	41	
1/20/2011	49	0	0	330	318	91	
1/21/2011	28	0	0	166	192	89	
1/22/2011	40	0	0	238	280	208	
1/23/2011	59	0	0	346	320	264	
1/24/2011	50	0	0	141	169	115	
1/26/2011	46	0	0	358	433	332	
1/29/2011	35	0	0	175*	183	145	
1/30/2011	35	0	0	175	183	145	

1/31/2011	63	0	0	155	169*	136	
2/1/2011	47	0	0	182	215	171	
2/2/2011	46	0	0	179	236	150	
2/3/2011	42	0	0	148*	140	102*	
2/4/2011	33	0	0	231	230	220	
2/25/2011	28	0	0	91*	148	113	
2/26/2011	1	0	0	150	166*	157	
2/27/2011	27	0	0	141	182	156	
2/28/2011	51	0	0	140	191	162	
3/1/2011	22	0	0	166	210	181	
3/2/2011	41	0	0	155	186	169	
3/3/2011	28	0	0	137	174	157	
3/4/2011	24	0	0	145*	163*	163	
3/5/2011	32	0	0	146	185	161	
3/6/2011	18	0	0	152	197	165	
3/7/2011	33	0	0	146	182	165	
3/8/2011	39	0	0	163	203	146*	
3/9/2011	37	0	0	166	198	157	
3/10/2011	35	0	0	215	266	255	
6/1/2011	41	0	0	12	72	30	155
6/11/2011	91						199
6/12/2011	100						189
6/13/2011	74						120
Average	35.4	0.0	0.0	179.4	201.4	143.7	166.0
Standard Dev	12.8	0.0	0.0	69.6	65.3	71.6	36.1
Total	1131.4	0.0	0.0	5741.0	6446.0	4597.7	663.8

* Days in which a documented leaks occurred (exact volume released is not known)

Biogas Production (Dec. 11, 2010 - Jun. 13, 2011)

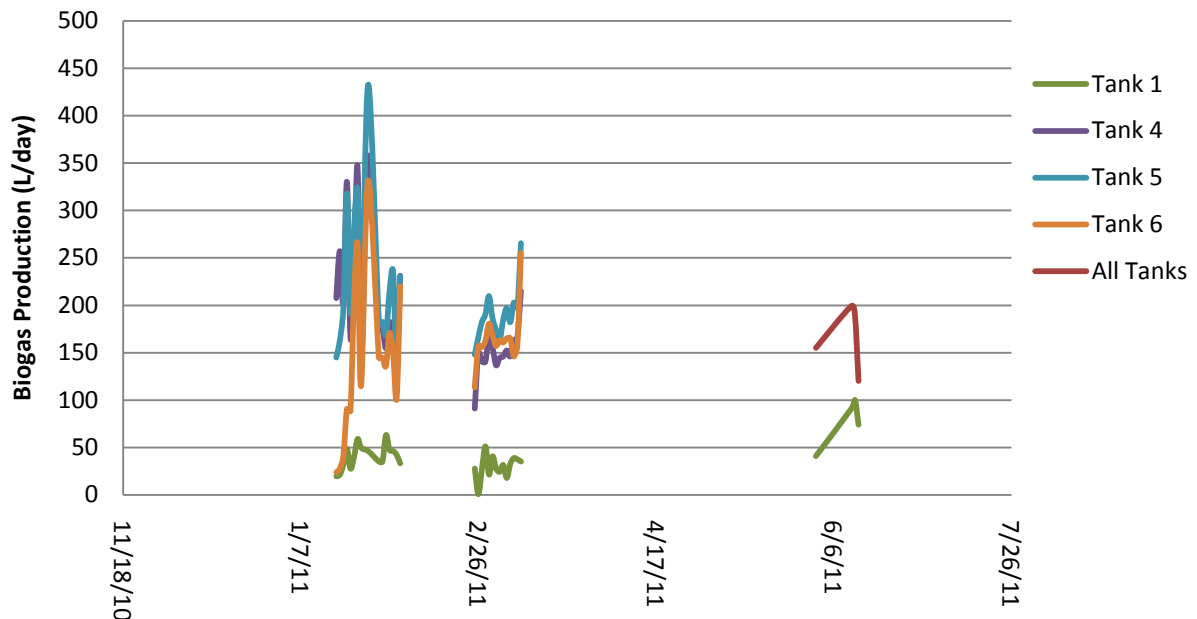


Figure 1. Current flow measurements from Phase 1.5 and graphical representation of un-normalized data presented in Table 1. Biogas production shows marked increase from the beginning of the week (01/17/11) and the end (01/23/11). Tank(s) # 2 and 3 valves were closed and were not observed to have produced gas above nominal levels for the

entire period. Any noise recorded by the Serria Top-Track 820 mass flow meters was given a value of zero. Data gaps may exist during times where either no flow data was being recorded or data collected did not align with the above mentioned protocol(s).

For more information regarding data collected during Phase I please refer to the 'Phase I Data Report' submitted March 15, 2011. Supplemental chemistry data is provided at the end of this report (See Appendix I)

iii.b.7) Temperature control in the Conex

Temperature is one of the most important factors that influences methanogenic metabolic rate (House 1978). The Conex used to house the digestors was designed by the project team to maintain two rooms at separate cold (15 °C) and tepid (25 °C) temperatures (as opposed to conventional biogas 37-40 deg C, 'warm' temperatures). The temperature is visually monitored by digital thermometers (less accurate) and recorded by (more accurate +/-0.47°C , Drift +/-0.1 °C/yr) dataloggers suspended in both rooms as well as inside the slurry of each digester. Several dataloggers, suspended at different depths within some of the tanks, were recovered during project breakdown on June 15, 2011. Summary data from all temperature loggers over the course of the experiment are illustrated in Figure 2.

On April 18, 2011 the Conex doors were locked and all feeding was ceased due to lack of researcher supervision and concerns raised over proper safety. The tanks were no longer fed and all valves were turned to the 'OPEN' position so that residual gas would be vented to the outside atmosphere. The temperature inside the Conex was increased to 35°C in order to allow increase microbial activity and further decomposition of organic material inside each reactor. The temperature loggers were uninstalled on June 15, 2011 in accordance with project breakdown procedures. Data from the temperature loggers are shown in Figure 2.

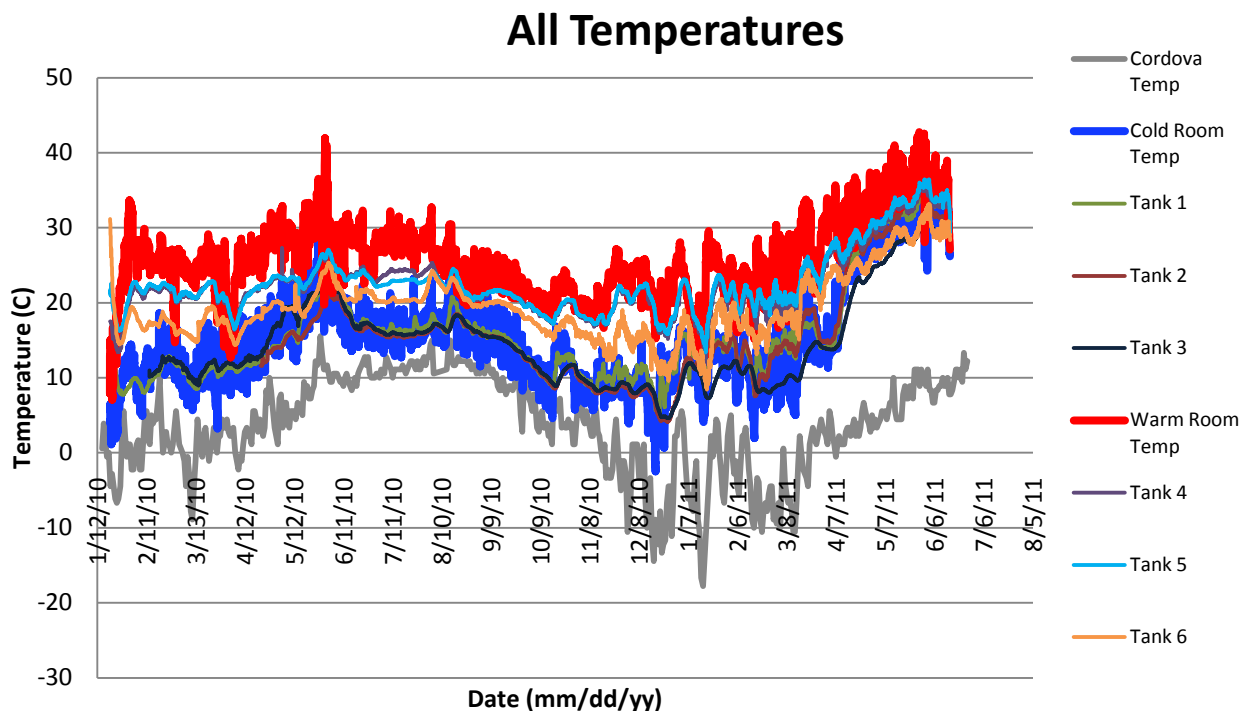


Figure 2. Mean hourly temperature of the data loggers in the Conex cold and tepid room, and mean daily temperature recorded in Cordova. As the temperatures in Cordova began to drop from temperate summer conditions, the Conex experienced a noticeable and unfavorable drop in temperature during the winter, but returned to warmer temperatures the next summer. Digester temperatures tended to track room temperatures, which followed the trend of outdoor air temperatures. Biogas project temperatures are measured with Hoboware U22-001 Water Temp Pro V2 loggers recording hourly. Cordova air temperature data was obtained from online sources (source: wunderground.com)

iii.b.8) Project Site Breakdown

Research technician Casey Pape traveled to the Cordova site from May 28, 2011 to June 16, 2011 in order to finalize Phase II demonstration of gas collection and utilization as well as lead the breakdown of the digesters. Pape and other project team members from CEC began disassembly on June 14, 2011. Each of the reactor vessel's contents was evacuated using an industrial garbage pump into a secondary storage container which was used to screen out most of the sediment and heavy solids that were located within each of the tanks. The remaining liquid was discharged into the local storm water runoff drain as it contained no harmful material. In order to finish evacuating all of the tank contents, each tank had to be cut and the bottom sludge layer agitated in order to loosen the remaining material of each tank, allowing them to drain more easily. The remaining tank components were disposed of at the local bailer waste compactor site and all instrumentation was returned either to CHS or UAF labs when Pape returned to Fairbanks. The project Conex is now vacant as of June 27th 2011, and aside from the R-10 foam insulation and updated electrical system provided by the project, the Conex was returned to the school in its original condition prior to the onset of this project. Spare materials (e.g. construction materials, garbage cans, water pumps, pipe fittings, ball valves, and spare tubing), along with the converted Husky generator and stove instruments were left at the Cordova High School Energy Center for future use by students and teachers.

iii.c) Health and Safety

Conventional small-scale anaerobic digestors are generally considered to be non-hazardous when given proper ventilation and maintenance. Still anaerobic digestors are used for the synthesis of combustible gases and have some safety concerns associated with them. As of April 18, 2011 the project Conex was locked and given a "standby" status upon discussing the project with UAF Environmental Health and Safety workers. EH&S had expressed some concern over proper project ventilation and the intrinsic safety of some of the equipment used on-site. With decrease supervision, coinciding with Pape's relocation to Fairbanks, it was determined that the best plan was to minimize access to the inside of the Conex, cease feeding experiments, increase the temperature and open all valves in order to react all remaining organics within the reactors. Upon revisiting the project in June 2011, researchers consulted with EH&S in order to follow the best procedures for finalizing the gas collection, demonstration of gas utilization, and site breakdown. No health problems or accidents were ever reported during the course of this project.

Electrical and Power: The project site is maintained by electrical heat and power supply. At present, that electricity has been provided by extension cords that run from inside the school and out to Conex. The CEC recently renovated the electrical system and increased the power capacity of the site. The project Conex electrical system now complies with all state and federal building and transmission codes and is wired for both 120V and 240V AC power.

Flammability: Biogas is very flammable and it is important that measures be taken to prevent any undesirable fires that may cause explosion. No open flame was allowed within the Conex and students handling biogas were instructed to wear appropriate eye protection at all times. Students conducting experiments with biogas were required to wear eye safety glasses and proceed under adult or teacher supervision. No injuries due to fire or explosions occurred during this project though several fire alarms were been triggered when demonstrating biogas flammability was conducted without proper ventilation.

Ventilation: The build-up of certain gases in an enclosed space can be toxic. Biogas digestors produce methane, carbon dioxide, hydrogen sulfide, and other gases which can be deadly at high concentrations. It is apparent to anyone entering the Conex which houses the experiment that a noticeable “barn-like” smell can be detected. The smell is due to volatile organics. Methane is odorless. This smell was significantly reduced once the new tank gas outlets were installed. Tanks were monitored daily and were not thought to pose any threat to human health. The air was cycled daily to a certain extent when the Conex container was opened for daily download of the gas flow data. Tubes are connected to the tanks to allow lighter than air constituents escape the container. H₂S tags were located in the Conex throughout the duration of the experiment to visually monitor H₂S levels in the Conex. They never reached any level of concern. The Cordova fire department had visited the site and tested it for noxious gases. The results of the fire departments’ testing came up negative for any toxic gases.

iii.d) Schedule of project

The project is still on schedule as defined by the original project outline. Phase I is complete and Phase II is in its final stages. Throughout the rest of the project research efforts will focus on sample and data analysis, writing of reports and information for public dissemination. The last quarterly (Y2Q3) report will be prepared for September 15, 2011. The final project report will be completed and submitted on September 30, 2011 including all the findings of Phase II research.

iii.e) Project budget

We anticipate that the budget is on target. At this time, the budget is not expected to exceed the grant, and the matching contribution is expected to significantly exceed the grant requirement. Clay Koplín will provide more details on the budget when he returns from vacation.

iii.f) Hurdles and solutions

Project problems and solutions were mentioned in iii.a, and are outlined in more detail here.

Confidence in biogas measurements: Due to offsets between the flow meter calibration levels and our gas production rates, we were not able, until Phase I.5, to provide the true values of biogas produced. Previous values represented averaged daily flow rates as opposed to cumulative daily gas production. Though this is generally an acceptable method for smoothing out noise in any data set, the true biogas production rates was underestimated. **Solution:** Casey Pape determined a new method to achieve our goal of daily gas production determinations by closing tanks, allowing them to swell with produced gas, opening the valves over a short period of time to allow high rates of gas flow within the level of the flow meter calibration. We now have an extensive dataset on the biogas production among tanks in the experiment and can make clear predictions about the future of biogas small-scale technology in Alaska. Data collection was updated on June 13, 2011 and the project report was submitted in the *Phase I Data report*. Date submitted March 15, 2011.

Other potential considerations:

The following factors are important considerations that generally can lead to problems in biogas technology. While we have no reason to think that any of these factors caused a problem in our systems, for the sake of thoroughness, here we evaluate each as a potential problem in the context of our study.

Temperature fluctuation. Problem: It is a major goal of this study to preserve the ‘cold’ (15°C) and ‘tepid’ (25°C) conditions as was defined in the original project proposal for the purpose of incubation of microbes. The Conex constructed for the project is insulated with R-10 pink foam insulation, but has poor seals and air spaces that cause it to have a heat/cooling regime that mimics that of the local environment of Cordova. Over the course of this quarter, average temperatures for both ‘cold’ and ‘tepid’ rooms was 4.2°C and 1.9°C below target values respectively. This is not ideal and will need to be better monitored in the future as our impression of the day to day gas production is that it should be consistent if temperature and food inputs are maintained at a constant level. **Solution:** Following the meeting with EH&S, the project Conex heating systems was increased in order to increase methanogenic activity and deplete each of the tanks of any liable organic material which they might contain. After April 28, 2011, the average temperature within each of the tanks was recorded on average around 35°C.

Logistical and management concerns:

Digester/tank and fittings integrity. Problem: Generally speaking, the more holes and fittings installed on a digester or any gas-holding container increases the chance for a leak to develop. At the beginning of the 2010-2011 scholastic year, the project gas outlet system installed on each of the tanks were known to have as many as 20-30 separate joints and fittings. This many fittings can make it very difficult to ensure the vessels remain leak-proof and anaerobic. When Pape arrived to the project, leaks were uncovered among the secondary gas containment systems outdoors and resulted in biogas collected in the outside tanks no longer being flammable. Simple tests of pressurizing the tanks revealed that many contained significant leaks that compromised

researcher efforts to record gas flow. Much of the data may have been skewed during the Phase I study as tanks showing no signs of biogas production have been demonstrated to be active after leaks were repaired. Recurring issues continually compromised research efforts to understand gas production as multiple leaks were continually discovered among several tanks and within different joints throughout the gas outlet system. **Solution:** As of February 25, 2011 the last of the tank retrofits were completed by Pape and no leaks have been detected since. All tanks expected to be producing biogas exhibited the ability to maintain a positive pressure throughout the remainder of the project. Soapy water test on June 1, 2011 did not reveal any additional leaks and the problem is thought to have been resolved.

Balance of responsibilities. Problem: The project is designed to be conducted in joint partnership between Cordova High School, a public utility (CEC) and the University of Alaska, Fairbanks. Collective effort between these parties is necessary in order to maintain the project and pursue additional research development during the Phase II study. Students were very capable of feeding and maintain digestors from day to day, but both students and high school staff were ill-equipped to combat many of the more technical problems that arose due to the nature of high quality data collection required in Phase I. Phase I data collection required full time on-site technical support from UAF. When the project switched focus in Phase II, there was a decreased need for UAF staff to provide daily support during all parts of Phase II. **Solution:** The project full-time technician (Casey Pape) relocated to Fairbanks, AK on March 18, 2011 in order to pursue further analysis of samples catalogued over the previous year as well as begin efforts to research options for upscaling biogas technology in Alaska. Adam Low and CHS students did a wonderful job filling in for Pape while away on previous work commitments in the past maintained the project with a high level of professionalism after Pape relocated. The CHS students learned a lot from the project in Phase II by conducting experiments using biogas.

References:

House, David. (1978) *The Complete Biogas Handbook*. (Alternative House Information, United States), 52.

Appendix I. (Chemical Data Supplement)

pH Results (Tanks #1-6)

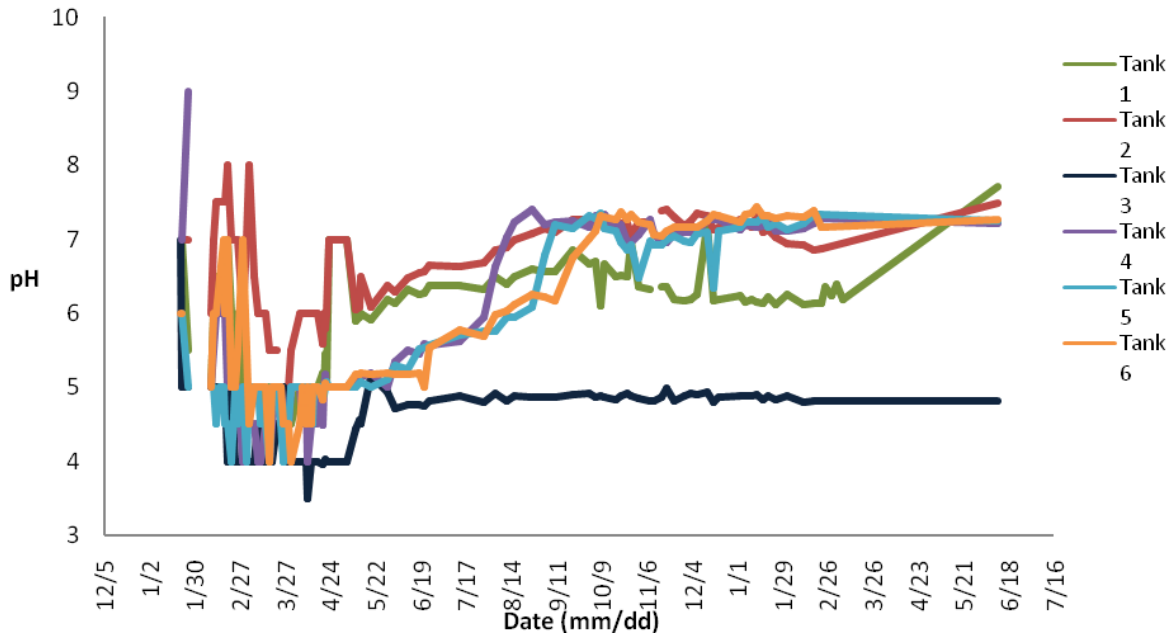


Figure 3. Results indicate that the pH in Tank 1 fell slightly since Y1Q3 report, but has recovered to almost neutral pH following the cessation of feeding on April 18, 2011 (currently pH 7.71). We halted daily feeding to allow the opportunity for pH to recover on its own, without reverting to chemical remediation treatments. pH was measured with Macherey-Nagel litmus paper January 21-April 16 2010, and with more precision using an Oakton PC510 pH meter since April 17, 2010 until the present.

Oxidation-Reduction Potential (Tank #1-6)

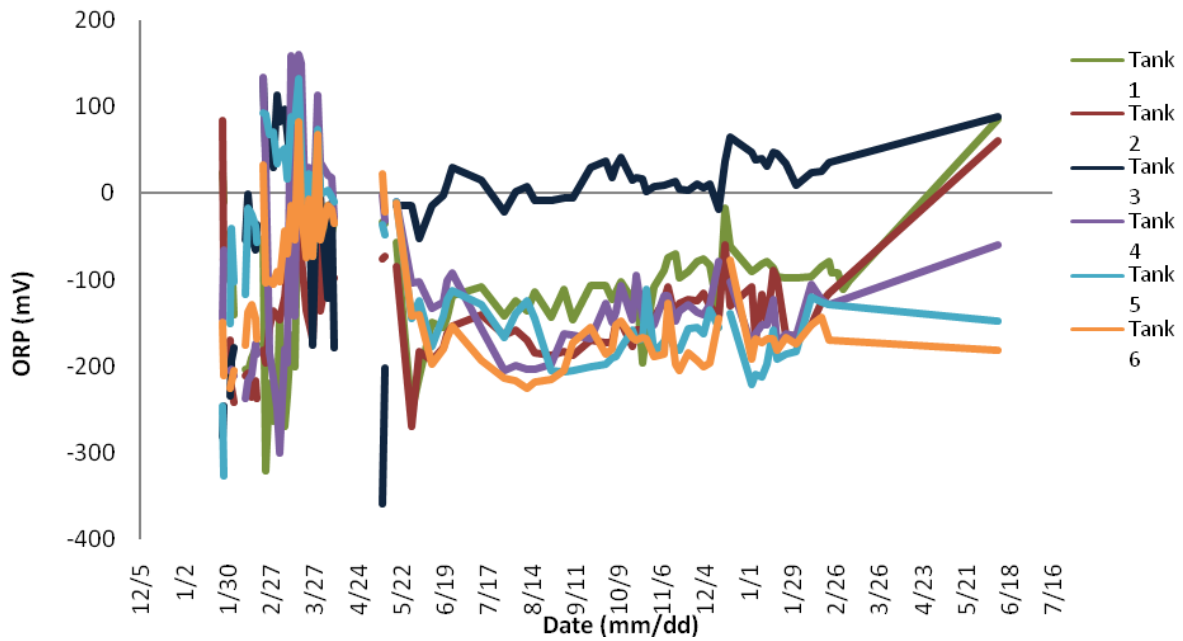


Figure 4. Oxidation-reduction potential (ORP) indicates the availability of oxidative molecules and ions in the system. ORP is a valuable measure as it determines the likelihood that bacteria will follow the methane fermentation pathway. For healthy methane production, samples should have an ORP of -300. From January 21-April 9, ORP was measured with an Xplorer GLX Pasco PS-2002 Multi-Datalogger. From May 10 forward, it was measured with an Oakton PC510 ORP meter.

Dissolved Oxygen (Tanks #1-6)

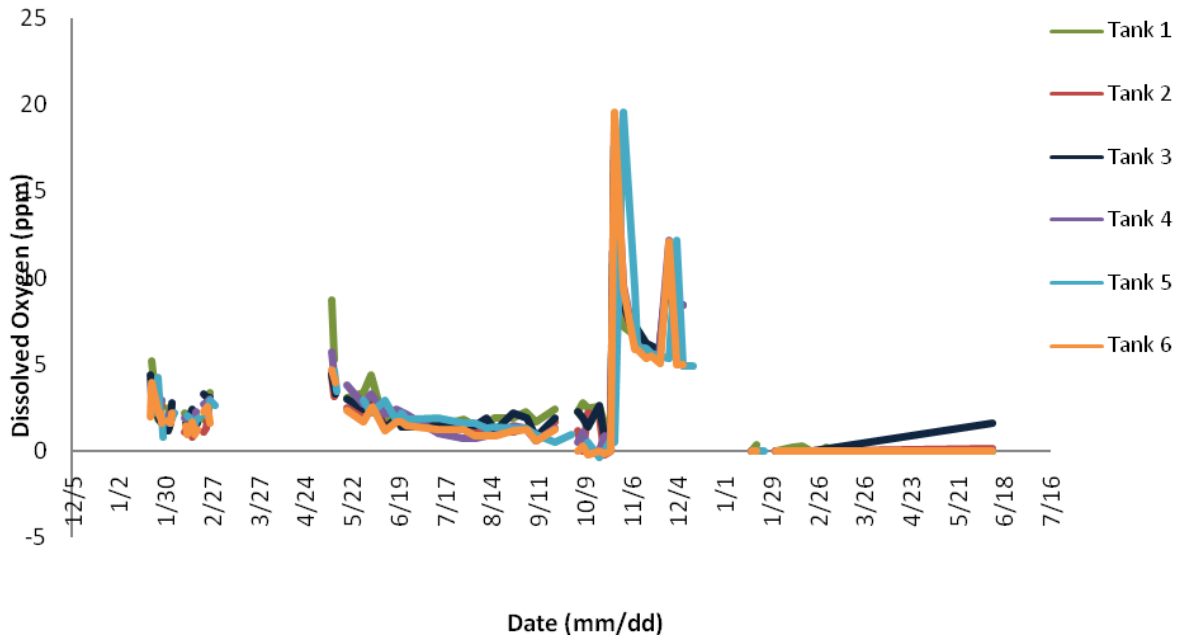


Figure 5. DO measurements were taken with an Xplorer GLX Pasco PS-2002 Multi-Datalogger until March 24, following which they have been taken by a Hanna HI9142 DO meter. As of October 1, 2010, the Hanna instrument could no longer be calibrated properly. Proper function was restored after servicing the instrument in December 2010.

Appendix II. (Gas Collection System)



Newly installed gas collection system. The 500 gallon capacity tank was installed on June 1, 2011 and was removed when the project was disassembled on June 15 of the same year. While in operation the tank consolidated and stored gas synthesized from all reactors vessels inside the Conex. The original tanks were purchased from Greer Tanks and Welding, Inc. in Fairbanks, AK on May 23, 2011. These tanks will be available for future biogas projects at UAF or donated to an Alaska resident for implementation of home-scale biogas production in Fairbanks.



Picture of the tank during assembly. When completed, internal tank (right) will have the bottom sections removed in order to allow the tank to move freely up and down in within the tank media.



Picture of both tanks together. The gas storage tank (Black) sleeves conveniently inside of the larger 1000 gallon (White) containment vessel. The tight design parameters of these tanks means that the gas storage tanks can fill and discharge freely within the tanks without fear of tipping or air contamination.



The completed storage tank, prior to being assembled inside of the larger containment vessel. CHS Janitor Romey assists in the assembly within the Cordova Energy Center, located at CHS.



The gas storage vessel was calibrated and given indication markings for how much gas is stored inside. The aluminum bar attached to the tank is used as a level indication that can be viewed once the tank is fully assembled.
This looks great, Casey!



One gallon of boiling water is used to illustrate biogas usage as a cooking fuel. The modified stove pictured sustained a constant flame with a burn rate of about 300 L/hr.



Biogas being used to power a generator. Note the additional water weight used to increase the pressure of the gas supply for running an electrical generator. The water weight was not required for cook stove operation on biogas.

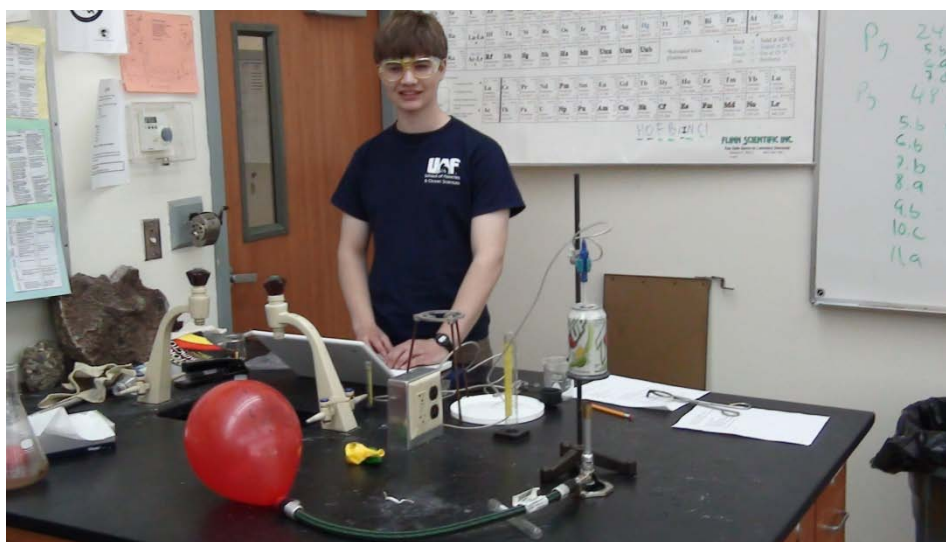


This 1850 Watt Husky generator ran completely on biogas for over an hour before exhausting the biogas storage tank and powering down. Starter fluid was used in order to start the device, but then was sustained entirely on gas collected from inside the Conex (behind). The estimated burn rate for this device is around 1,100 L/hr or 300 gal/hr @ 0.5psi.

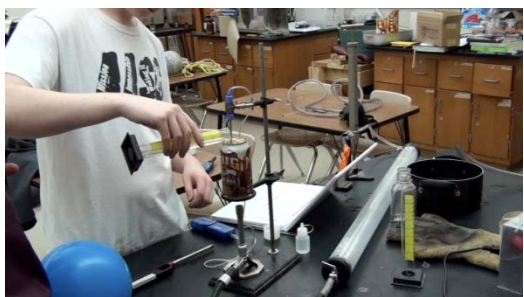
Appendix III. (Student Projects and Pictures)



CHS student present their biogas and other science projects at the Alaska State Science Fair in Anchorage, AK, April 15-17, 2011. Students received honorable mention and many won their category for their work with biogas. First place was awarded to CHS student Sophie Myers, whose project centered on the study of fluid dynamics of shark skin.



Student Craig Bailer prepares his calorimetry experiment for testing the heat content of biogas vs. propane.



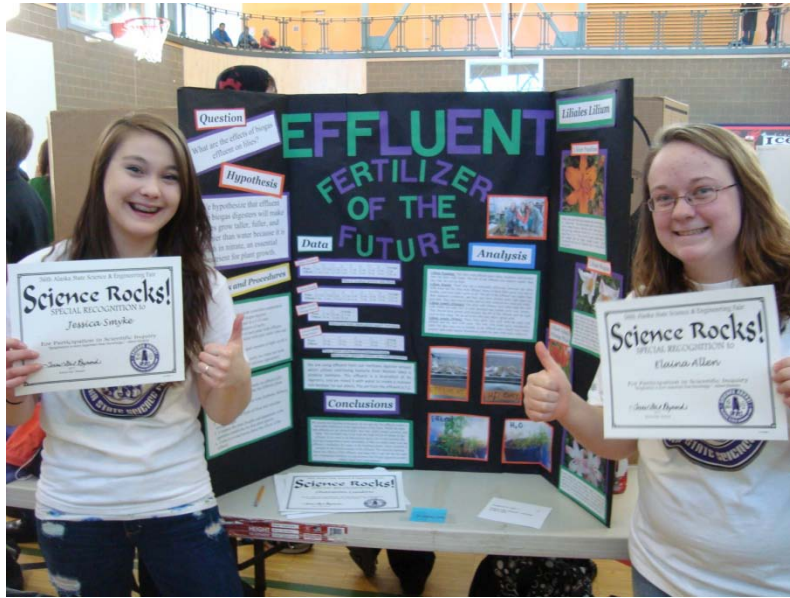
Student Keegan Crowley performs a calorimetry experiment to test the heat content of biogas prior to purifying the gas through lime water.



Here, students Keegan Crowley and Ben Americas attempt to purify biogas along with teacher Adam Low.



Keegan reports his findings at the state science fair, Anchorage, 2011.



CHS students Elaina Allen and Shannon Lindow touting their awards for their project on AD effluent as liquid fertilizer.



Students used the liquid effluent from tank 4 to test an experimental greenhouse over the course of the school year. Here, student Sophie Myers uses a diluted solution of effluent to water and treat plants in the Cordova Energy Center.



Student Brian seen here along with Josh Hamberger burning biogas. Students were acutely aware of biogas properties and potential uses for Alaskans interested in the technology.



CHS Students Ben Americus and Adam Zamudio present on their work to run a generator off of biogas at the state science fair, Anchorage, AK April 15-17, 2011.



Students rig a common lawnmower to run off of biogas.



A 4-cycle 1850 Watt Husky generator was converted to run on biogas and other available gaseous fuel types. Here students celebrate as the generator successfully starts using propane.



The current project profile when viewed from outside. At this point the project has a very minimal footprint. Previous gas pressure systems have been dismantled and the project team has taken a minimalistic approach. This is how the project appeared until final breakdown commenced on June 15, 2011.

Appendix IV (Student Reports)

See attached documents.