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Bio-Gas Beneficial Utilization Study for the Clean Water Plant

Proposal

City of Waukesha, WI

January 30, 2018

STRAND ASSOCIATES®

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January 29, 2018

Mr. Jeff Harenda
Plant Manager
City of Waukesha Clean Water Plant
600 Sentry Drive
Waukesha, WI 53185

Re: Proposal for Bio-Gas Beneficial Utilization Study

Dear Mr. Harenda:

On behalf of Strand Associates, Inc.®, thank you for the opportunity to submit an engineering proposal to identify and study feasible options for further beneficial bio-gas utilization. We believe Waukesha will find us ideally qualified to deliver this project because our:

- **More than 71 years of service signifies organizational strength and commitment to quality.**
- **Understanding of and experience at the Waukesha CWP is unmatched and streamlines our efforts for this project.**
- **Knowledge of the key technical issues and available solutions delivers confidence.**
- **Project scope is based on extensive experience on dozens of similar projects and demonstrates our ability to expertly and efficiently develop the best solutions for the City.**

Should there be any questions or if additional information is needed, please call.

We look forward to working with the City on this project and providing Waukesha with the exceptional knowledge, care, and detail needed to make this project a success.

Sincerely,

STRAND ASSOCIATES, INC.®

Travis J. Anderson., P.E.
Project Manager

Scott W. Stearns, P.E., BCEE
Quality Control Engineer

P180.063/TJA:mah

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Project Approach

Proposed Approach Enhances Collaboration and Delivers the Best Solutions for Optimizing Expenditures

We are confident that our Project Approach will result in the best solutions for the City.

The Bio-Gas Beneficial Utilization Study for the Waukesha Clean Water Plant (CWP) will help direct and guide both short- and long-term capital improvements related to the digester gas utilization strategy and will meet the requirements of the Focus on Energy incentive program. Our established working relationship with City staff, including Dr. Fred Abadi, Jeff Harenda, Nate Tillis, Greg Markle, and Jon Schapekahm, along with our national expertise provides the City peace of mind this project will be successful. We have successfully implemented the approach described below on many projects, as confirmed in the *Qualifications of Firm* section. We are confident that this method will result in the most effective and efficient use of the City's resources. Our approach to this important project is as follows.

Task 1 – Project Kickoff Meeting, Data Analysis, and Bi-Weekly Meetings

Initially, we will request and review any plant operational data, reports, and related documents that we either do not already have access to via the supervisory control and data acquisition (SCADA) system or were not provided with the proposal. We will also schedule a kickoff meeting with City staff to discuss the work plan (scope, schedule, and other details) for the project and the key issues. At the kickoff meeting, we will present a PowerPoint presentation to show the City the types of equipment and evaluations that we plan to conduct for this project, along with photos from our similar projects. After the kickoff meeting, we will prepare meeting minutes, including decisions and action items, and distribute to those in attendance. Similar to previous projects, we whole-heartedly agree that bi-weekly meetings significantly improve the communication process. For each meeting, we will summarize significant tasks that have been completed, identify tasks or project elements upcoming, and summarize any outstanding issues that may require City action.

Task 2 – Review of Existing and Future Biogas Production and Energy Demands

Current annual average biogas productions is approximately 130,000 cubic feet per day (cf/day) of biogas. The digestion facilities are currently loaded at approximately 50 percent with two active digesters in service, which suggests that if fully loaded, the digestion facilities would produce approximately 260,000 cf/day of biogas. This assumes that Digester No. 3 will be used only for gas/sludge storage and not as an active digester.

Waukesha CWP digestion facilities.

We will develop a detailed analysis of historical energy using information provided from utility (natural gas and electric) billings as well as trending information from the SCADA system. This information will help us understand current seasonal average and peak energy demands at the facility to establish a baseline for energy usage to be compared against proposed biogas utilization improvements. The review of existing conditions will also include a summary of the design specifications of the existing digestion and gas handling equipment to determine the maximum gas production capacity.

The future loadings, digester gas production, and related parameters will be projected using the forecasted CWP loadings developed in Facilities Plan that we prepared in 2011.

There are several technologies shown to increase biogas production and increase digestion efficiency. Waste activated sludge (WAS) is difficult to digest under anaerobic conditions. Biological cells contain significant water and unless the cell is broken open, much of the water is retained and poor WAS (or thickened WAS) digestion can result. In addition, poor volatile solids destruction (high VS concentration of digested biosolids) can result in poor dewatering performance.

CNP's Pondus cell lysing equipment.

Numerous technologies have been developed within the last several years that lyse biological cells to improve VS destruction, biosolids dewaterability, and digester gas production. One of the more promising alternatives is CNP's PONDUS Hydrolysis Process, which has recently been installed in Kenosha, Wisconsin.

The typical application includes pumping all or a portion of the TWAS through the device to lyse the cells, and the effluent from the device is then discharged to the anaerobic digesters. Reported results of these systems vary considerably, and the advantages potentially gained with such equipment are reduced if the digesters are lightly loaded, as is the case currently at the CWP. There are only a few full-scale installations in the United States at this time, though more installations are found in Europe. Before installing any of these systems, we strongly recommend conducting a pilot test with trailer-mounted equipment stationed at the CWP.

The OpenCel technology was evaluated as part of the 2011 Facilities Plan and was identified for possible future consideration. Since that evaluation, Trojan Technologies purchased OpenCel, but it is not yet out with its research so they will not be recommended for further consideration.

In addition, and even though there are significant staff reservations, this analysis could include projections that would account for potential increases in biogas from co-digestion of FOG and other high strength wastes (HSW).

Our experience with numerous installations will enable us to efficiently develop these projections, which will provide the basis for the remaining tasks.

Task 3 – Review Feasible Biogas Utilization Alternatives

This portion of the study will include identification and high-level evaluation screening of alternatives to meet both near-term and long-term challenges. This task will identify several potential alternatives, screen these alternatives based on high-level costs and nonmonetary evaluations, and then develop a shortlist for more detailed analyses. A summary of the various biogas alternatives to be evaluated is shown in *Figure 1*.

Alternatives evaluation will be based on both current and future conditions.

B0-1: Cell Lysing
Cell lysing systems will be evaluated and may improve VS destruction, digester gas production, and solids dewaterability.

B0-2: High Strength Waste
The digester system has adequate capacity to receive additional loadings. The addition of high strength waste will be evaluated to determine the potential benefits of increased gas production.

BC-1: Gas Conditioning
Most alternatives require removal of siloxanes and hydrogen sulfide from the digester gas. Locating this equipment outdoors allows access for media replacement.

BU-2 – Biosolids Drying
Biosolids drying will be evaluated and may be combined with other alternatives. There appears to be adequate space in the Centrifuge Room of Structure 430 for the new drying equipment.

BU-1a: Engine Cogeneration
Structure 510 has space available for an engine generator and is in close proximity to the digestion complex.

BU-3: Vehicle Fueling Station
We will evaluate the opportunity for producing bioCNG for use as fuel in the City's vehicle fleet. The close proximity of the Municipal Garage provides an opportunity for partnership and beneficial reuse of biogas within the City.

BU-1b: Microturbine Cogeneration
Microturbines are more efficient when located outdoors. The microturbine units could be located south of Structure 510.

BC-2: Pipeline Quality Gas
Pipeline quality gas requires removal of carbon dioxide through a membrane or pressure swing adsorption system.

BU-0: Boilers
Continued use of the current dual fuel boilers will be evaluated both with and without implementation of cogeneration.

Biogas Optimization	Biogas Conditioning	Biogas Utilization
B0-O: No optimization	BC-0: No conditioning	BU-0: Boilers & Flare
B0-1: Cell lysing	BC-1: H_2S, siloxane, & moisture removal	BU-1: Cogeneration (engines or microturbines)
B0-2: High strength waste	BC-2: CO_2 removal (pipeline quality gas)	BU-2: Biosolids drying
		BU-3: BioCNG/Vehicle fuel

Figure 1: Biogas Alternatives

There are essentially three major categories of options to be considered:

- **Biogas Optimization**
  - BO-0 is a "do nothing" alternative.
  - BO-1 would include a cell lysing process modification to increase biogas production. The cost of this equipment would need to be offset by the value of increased biogas utilization.
  - BO-2 would consider accepting HSW, allowing the full capacity of the digestion facilities to be utilized. We understand plant staff have justified reservations about accepting HSW, which may have significant impact on plant operations. These elements would be captured in our non-monetary summary of alternatives.

- **Biogas Conditioning**
  - BC-0 is a "do nothing" alternative.
  - BC-1 would include hydrogen sulfide, moisture, and, if required, siloxane removal. This level of biogas conditioning is required for cogeneration options, including internal combustion engines and microturbines.

Dubuque biogas conditioning equipment for hydrogen sulfide and siloxane removal.

  - BC-2 would include carbon dioxide removal through either membrane separation, pressure swing adsorption, water scrubbing, or chemical scrubbing. Chemical scrubbing using amines has been successful in European applications but has yet to be implemented in the United States. This level of biogas conditioning is necessary for both pipeline quality gas and compressed natural gas vehicle fuel. An important aspect of the evaluation of the use of the biogas for pipeline quality natural gas will be an analysis of the anticipated revenues from gas sales, renewable identification numbers (RINs), and low carbon fuel standard credits. Based on current gas usage of 130,000 CF/d, the value of the gas is approximately $1,000,000 per year. This is the net value and does not consider potential capital costs, gas utility connection fees, additional City O&M costs, and RIN brokering fees. For the study, we will provide preliminary coordination with We Energies regarding the feasibility, location, basic connection requirements, and costs. Once these costs have been developed, the current values for pipeline quality gas will be ranged, based on Renewable Fuel Standard RIN valuation, including a Low Carbon Fuel Standard credit valuation. This evaluation will also consider the potential for involvement of a third party to provide the gas conditioning equipment in exchange for rights to purchase the digester gas as part of a long-term contract.

Below is a summary of biogas conditioning required for various end-uses.

Gas Condition	Boilers	Gas Engine	Micro-turbine	Pipeline Quality Gas	bioCNG
Hydrogen Sulfide Removal				•	•
Moisture Removal (Glycol Chiller)		•	•	•	•
Siloxane Removal			•	•	•
Carbon Dioxide Removal				•	•
Compression (3 to 5 psi)		•			
Compression (75 to 100 psi)			•	•	
Compression (3,800 psi)					•

- **Biogas Utilization**
  - BU-0 is a "do nothing" alternative that consists of burning the biogas in the boilers and flaring the excess gas.

Existing Waukesha boiler.

  - BU-1a includes an internal combustion engine coupled with a generator with heat recovery off the engine and the exhaust. Supplemental heat (in excess of that produced off the engine) would be provided, if needed, by burning biogas in the existing boilers. Excess biogas would be flared.
  - BU-1b includes gas microturbines coupled with a generator with heat recovery systems. Supplemental heat (in excess of that produced off the microturbines) would be provided by burning biogas in the existing boilers. Excess biogas would be flared.
  - BU-2 includes continued use of the biogas for heating the digesters along with sludge drying. This study will primarily focus on the paddle-type sludge dryer because of the relative simplicity compared to a belt-type sludge dryer. From a material handling perspective, the ideal location for the sludge dryer would be in the same room as the centrifuge. Dewatered sludge from the centrifuge would be routed to the new dryer and the dried sludge would then be routed to the existing conveyor system in Structure 430. Likely only one sludge dryer would be required since there is adequate liquid sludge storage that could be utilized if the dryer was out of service. One possible paddle-type sludge dryer is the Komline-Sanderson Model 9W-840, which has a capacity of approximately 3,300 wet lb/hr. A conceptual layout of the Centrifuge Room showing a potential location for the Model 9W-840 is presented in *Figure 2*.

Komline Sanderson dryer.

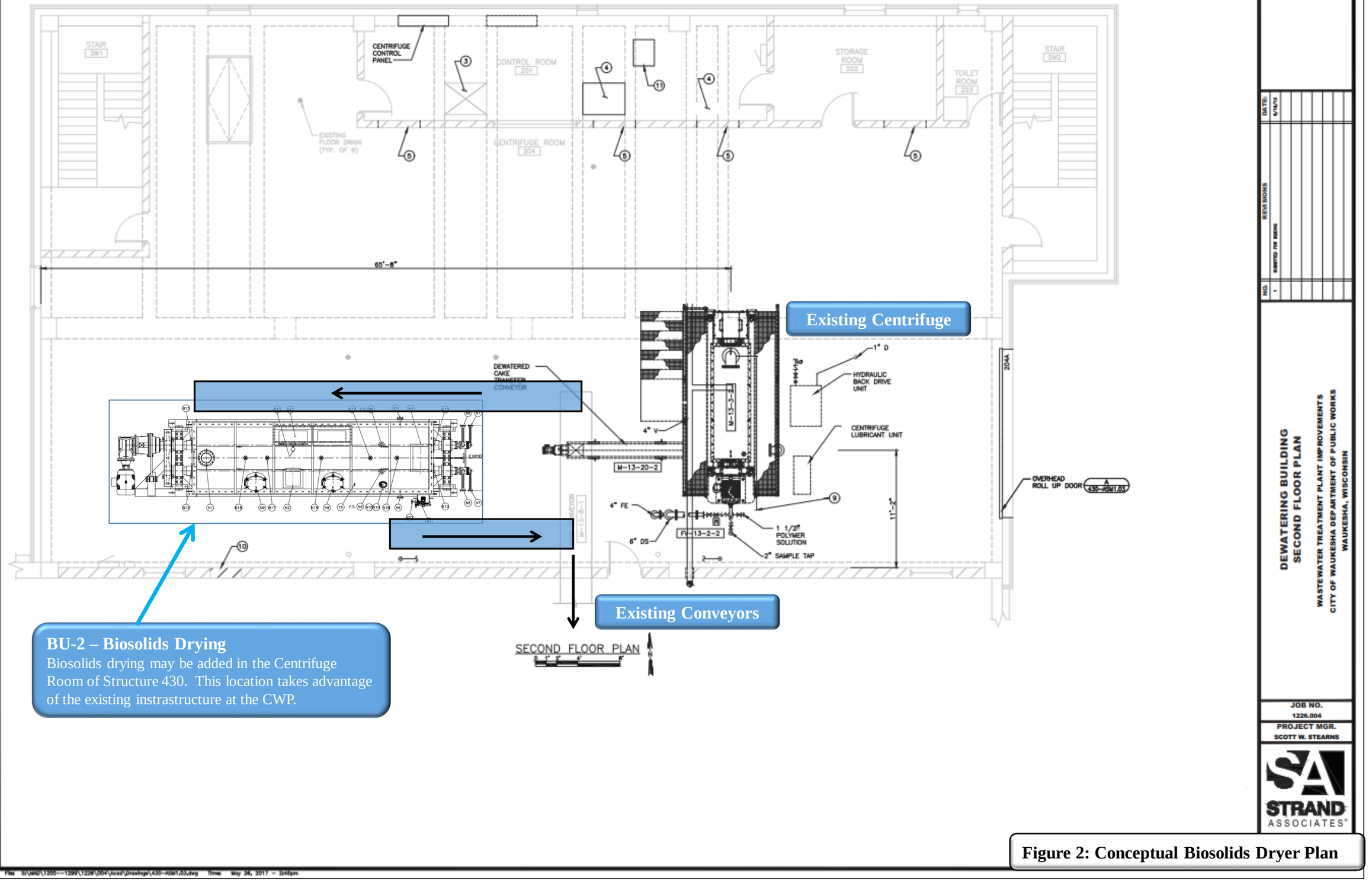


Figure 2: Conceptual Biosolids Dryer Plan

- BU-3 includes additional equipment to allow for vehicle fuel biogas reuse. With operational data from plant staff, we will develop approximate fuel usage projections from City vehicles along with approximate switchover costs to allow compressed natural gas (CNG) usage.

Biogas compress natural gas.

Lawn mower retrofit to operate on CNG.

These evaluations will include development of an energy and solids balance through the solids processing facilities to assist in sizing the potential digester gas end-use options. For each of these options, we will include a base case using current loadings, a case using the projected future loadings, and a high-level case assuming loading the digesters to their maximum capacity.

The evaluation of alternatives will include energy and mass balances, capital costs, operating costs, including purchase of natural gas for either digester heating or biosolids drying in alternatives that divert the biogas from this purpose, maintenance costs, future equipment replacement costs, and salvage costs over the 20-year life of the project. The various costs will be included in a present-worth evaluation to better compare the various alternatives on an equal monetary basis.

Task 4 – Review Meeting with City

At approximately 75 percent completion, we will meet with the City to discuss the project progress and the results of the evaluations to date. We will make a presentation of the project evaluations, recommendations, project budget, and schedule.

We will welcome input from the City at all phases of the project.

Task 5 – Develop Draft Report for City Review

The draft report will be developed summarizing the results of Tasks 1 through 4. Additional implementation considerations such as potential funding, including Focus on Energy grants or incentives, and project delivery will be summarized in a final section, and we will submit the draft report for review. The project schedule allows ample time for City review and detailed discussion, as needed.

Task 6 – Finalize Report

Following City review and a teleconference for discussion of the City's comments, a final version of the report will then be prepared and provided in both paper and electronic format.

Qualifications of Firm

Experience-Based Expertise Provides the City with Dedicated Collaboration Throughout the Project

Wastewater engineering has been a core service provided by our firm since our founding in 1946. We have prepared more than 200 wastewater treatment plant (WWTP) facilities plans and designed hundreds of WWTP projects totaling more than a billion dollars in construction costs within the last 20 years alone. We are one of the leading wastewater engineering firms in the entire Midwest, and our success has led to consistent growth and national recognition of our wastewater group. We are ranked in Engineering News Record's top 20 of all engineering firms in the United States for wastewater engineering services, and yet we remain locally committed to our home base in Wisconsin, where we are headquartered and where the majority of our wastewater services are still provided today.

Our project team has significant experience with the evaluation, plan development, and implementation of digester gas utilization projects, including co-digestion receiving facilities, cogeneration systems, and related project elements at wastewater treatment plants with similar capacities to the Waukesha CWP. The table below includes a representative list of our firm's anaerobic digestion and digester gas utilization experience, including the general scope of our project work and the comparable size of the facility. Following this table are five project descriptions that provide details on the most relevant projects. If the City so desires, we would be happy to provide additional information regarding these projects.

Our experience with anaerobic digesters results in cost-effective implementation.

Client and Location	Project ID	Plant Size (mgd)	Biosolids Planning	Anaerobic Digestion	Biogas Use Analysis	Cogen	High-Strength Waste	Drying Evaluated
Lexington-Fayette Urban County Gov't	Town Branch WWTP Expansion	30	●	●	●	●	●	
Louisville MSD, KY	Biosolids Planning and Preliminary Design	120	●	●				●
Madison Metropolitan Sewerage District, WI	Energy Master Plan	50		●	●	●	●	
FRWRD, IL	Biosolids and Biogas Master Plan	38	●	●	●	●	●	●
KRMA, IL	Planning, Design, and Construction	20	●	●	●	●	●	●
Glenbard, IL	Planning, Design, and Construction	16.2	●	●	●	●	●	●
Manitowoc, WI	Planning, Design and Construction	15.5	●	●	●	●	●	
Parkersburg, WV	Planning, Design, and Construction	15	●	●	●			●
Brookfield, WI	Planning, Design, and Construction	12.5	●	●	●	●	●	
Fond du Lac, WI	Planning, Design, and Construction	10	●	●	●	●	●	●
Dubuque, IA	Planning, Design, and Construction	11	●	●	●	●	●	●
RMMSD, WI	Facilities Plan	4.5	●	●	●			
Whitewater, WI	Biosolids/Biogas Study, Design, and Construction	3.5	●	●	●	●	●	
Cedar Rapids, IA	Anaerobic Treatment for High-Strength Industrial Waste Plan	3.5		●	●	●	●	
Stoughton, WI	Biosolids Studies, Designs, and Construction	2.1	●	●	●			
Chippewa Falls, WI	Biosolids Planning	3.3	●	●	●	●	●	
Howard County, MD	Anaerobic Treatment for High-Strength Industrial Waste Plan	0.4		●	●	●	●	
Dane County, WI	Manure Management Study and Facility Plan	5,800 animal units	●	●	●	●	●	●

We have included detailed project descriptions to highlight similar project experience through the projects we recently completed in Dubuque, Iowa; Fond du Lac, Wisconsin; Kankakee and Elgin, Illinois; and Lexington, Kentucky.

Our firm has been providing wastewater and renewable energy engineering services for decades and our particular experience with biogas reuse projects spans more than 30 years.

Anaerobic Digestion, Co-Digestion, Cogeneration Facilities – Dubuque, IA

Contact Information	Planning Start Date	Design Start Date	Construction Completion Date
Steve Sampson Brown, P.E., Project Engineer 50 West 13th Street Dubuque, IA 52001 563-589-4270	May 2007	September 2010	February 2014

The City of Dubuque is widely considered to be a model "sustainable" community. Nowhere is this more apparent than with the City's decisions related to wastewater biosolids digestion and follow-up projects and studies related to renewable energy, biogas conditioning and cogeneration, co-digestion, and food residuals management. We were hired to conduct long-range planning for the aging WWTP, which was built in the 1960s and 1970s. The plant had historically incinerated wastewater sludge followed by landfilling of the ash, and one of the goals of this project was to determine whether a more sustainable approach for solids management could be implemented. Throughout the planning effort, the City's sustainable goals were incorporated into the evaluations through carbon footprint and greenhouse gas emission analyses, energy evaluations, and related measures. In the end, anaerobic digestion of the City's biosolids was recommended and ultimately implemented, followed by centrifuges and land application. Our analysis also considered sludge drying, but this has not been included in the improvements, to-date. In our most recent project, we designed the following biogas-related components:

Dubuque anaerobic digesters and biogas conditioning.

- Hydrogen sulfide removal using "sulfa-treat" media vessels
- Mechanical chilling for moisture removal
- Siloxane removal using activated carbon-based technology
- Cogeneration of conditioned biogas using microturbines (three at 200-kW each, expandable to 1,000 kW)
- Heat recovery for digester and building heat

In addition, we conducted a feasibility study to determine the potential of accepting solid food residuals at the treatment plant. This effort resulted in a preliminary design of a wet processing facility to accept approximately 20 tons/day of separated food scraps, grinding and slurrying processes, and pumping to discharge the material to the treatment plant's anaerobic digesters. We also conducted a feasibility study to determine whether bioCNG production is a viable use for excess biogas at the plant. This study evaluated how best to use potential bioCNG, including in-City fleet vehicles, biosolids hauling vehicle, plant vehicles and equipment, and combinations of these uses. We are currently evaluating options to construct high-strength waste storage facilities for high-strength wastes and FOG receiving at the plant to help the plant better manage the large volumes of high-strength wastes trucked into the plant on a daily basis.

Dubuque PSA skid.

Most recently, we assisted the City by evaluating the pipeline quality gas system improvements that consisted of a third party at-risk provider with rights to all the digester gas with use of the existing gas conditioning system, which included hydrogen sulfide and siloxane removal. New equipment provided by the third party consists of a pressure swing absorption system to remove carbon dioxide from the system and pipeline injection monitoring. The City will receive a percentage of the gross revenues from gas sales and RINs, and all the natural gas required to operate its digester boilers and microtubines. Operational costs above the current, including additional electricity, gas cleaning media, labor, etc., is also covered by the third party.

Anaerobic Digestion, Co-Digestion, Cogeneration Facilities – Fond du Lac, WI

Contact Information	Planning Start Date	Design Start Date	Construction Completion Date
Autumn Fisher, Superintendent 700 Doty Street Fond du Lac, WI 54936 920-322-3663	October 2009	January 2011	February 2013

The City of Fond du Lac operates a water pollution control plant that treats wastewater from the City and 15 outlying communities.

Fond du Lac WWTP.

Since the 1970s, the plant has used energy-intensive, high-purity oxygen-activated sludge and Zimpro sludge conditioning, with dewatered sludge being landfilled. In 2002, process upsets occurred at the plant causing permit violations. Our recommended plan included plant improvements and upgrades, with a significant part of the upgrades being for biosolids management changes. The Zimpro equipment was expensive to operate and becoming more maintenance-intensive as the equipment began to wear out and odors were significant. Landfilling, although relatively low-cost at the time, was becoming more expensive.

We conducted detailed evaluations of a wide range of biosolids stabilization and management alternatives, including helping the City set the direction for biosolids management, including continuing with Zimpro, anaerobic digestion (Class A and Class B), pasteurization, composting, drying, and combinations of these alternatives. Anaerobic digestion was selected as the best alternative for the City, and design and construction of the facilities commenced. Centrifuges were included for digested biosolids dewatering and off-site storage with contract hauling was selected as the preferred biosolids disposal option.

We were hired in 2011 to develop plans and designs, and perform construction observation of a new engine generator system using biogas produced through anaerobic digestion. The project was bid in 2011 and construction was completed in 2013 and it included biological hydrogen sulfide removal using a packed tower system, mechanical chilling for moisture removal, siloxane removal using activated carbon-based technology, cogeneration of conditioned biogas using an internal combustion engine (450 kW), and heat recovery for digester and building heat. In addition, the project included two 20,000-gallon silos for storage of high-strength wastes prior to digestion.

Anaerobic Digestion Upgrades, Digester Gas Conditioning, Cogeneration - Kankakee River Metropolitan Agency – Kankakee, IL

Contact Information	Planning Start Date	Design Start Date	Construction Completion Date
Richard Simms, Executive Director 1600 West Brookmont Boulevard Kankakee, IL 60901 815-936-1462	September 2009	April 2011	July 2015

Biological H_2S scrubbers.

The Kankakee River Metropolitan Agency (KRMA) provides wastewater services for the city of Kankakee and villages of Bradley, Bourbonnais, and Aroma Park, Illinois. The facility has an average daily flow of 25 mgd and a peak flow of 100 mgd. Because of the major industrial contribution, the organic loading is 40,000 pounds per day. We have provided continuous services to KRMA's regional wastewater treatment facility since 2001 and, since then, have completed numerous projects for KRMA.

Master facilities planning was completed, which included significant capital improvement planning and equipment replacement, hydraulic maximization of flow through the WWTP, biosolids management upgrades, and facilities and processes required to meet new ammonia and nutrient standards being imposed on the facility. We recently completed plan development, design, and construction-related services for a new cogeneration system at the KRMA WWTP to replace an existing system. The project included the following elements:

We were hired to provide fast-track biosolids planning after an explosion at KRMA's WWTP destroyed the plant's ability to process sludge.

- Biological hydrogen sulfide removal using a packed tower system
- Mechanical chilling for moisture removal
- Cogeneration of conditioned biogas using an internal combustion engine (450 kW)
- Heat recovery for digester and building heat

In addition to the project noted above, construction was completed in 2015 for $45 million of WWTP improvements. The upgrades included significant biosolids-related improvements, including:

- New gas holding covers for two digesters and rehabilitation for three digesters
- Draft tube mixing system
- Foam suppression system
- Digester gas safety equipment, including waste gas burner
- Boilers and heat exchangers
- Site electrical improvements

Biosolids and Biogas Facilities Master Plan – Fox River Water Reclamation District, Elgin, IL

Contact Information	Planning Start Date	Design Start Date	Construction Completion Date
Robert Trueblood, Executive Director 1957 North LaFox South Elgin, IL 60177 847-742-2068	December 2012	September 2014	Anticipated Completion 2019

The Fox River Water Reclamation District (FRWRD) has three water reclamation facilities (WRFs) in Elgin with a combined treatment capacity of approximately 38 mgd. Biosolids from the north and west WRFs are treated at the main (Albin D. Pagorski) WRF. Most of the biosolids and biogas facilities are at or beyond their expected service life. A master plan was commissioned to address both immediate and future needs.

Fox River Water Reclamation District's Albin D. Pagorski water reclamation facility.

The master plan included an evaluation of the existing capacity and condition of equipment, review of phosphorus and other pending regulations that could impact biosolids production and beneficial reuse, including sludge drying, review of established and innovative technologies, ranking of potential technologies based on cost and nonmonetary factors, detailed review of shortlisted alternatives, development of a 5-year capital improvements plan and 20-year facilities plan, and determination of future "road signs" (e.g., energy costs) that may drive selection of one alternative over another. In addition, a high-strength waste HSW market study was developed to identify potential HSW suppliers, potential volumes that may be received at the plant, and potential revenue from HSW acceptance.

The recommended plan includes continued use of anaerobic digestion with cogeneration of heat and power from the biogas. Digested biosolids will continue to be dewatered, and when the existing belt filter presses reach the end of their service life, they may be replaced with centrifuges and sludge dryers. Covered on-site storage was recommended for the dewatered biosolids.

Biogas master planning included a high-strength waste market study.

Alternatives that were retained for potential future implementation, depending on effluent limits and other factors, include recovery of phosphorus and removal of ammonia from biosolids side-streams, implementation of temperature-phased anaerobic digestion if Class A biosolids are required, and acceptance of grease or other hauled wastes for digestion and additional energy generation. Biosolids drying could be reconsidered if vehicle fuel prices increase significantly or Class A biosolids production becomes necessary. FRWRD has begun to implement the recommended 5-year capital improvement program, starting with covering biosolids storage areas and changes to the struvite control chemical feed system. Other short-term projects will include digester mixing and biogas handling systems improvements, and replacement of heating and ventilating systems in select buildings.

Town Branch WWTP Biogas Master Plan and Digestion Upgrades – Lexington-Fayette Urban County Government, KY

Contact Information	Planning Start Date	Design Start Date	Construction Completion Date
Tiffany Rank, P.E. 301 Lisle Industrial Avenue Lexington, Kentucky 40511 859-425-2506	April 2016	In Planning Phase	In Planning Phase

The 30-mgd Town Branch WWTP Primary Digester Facility was constructed approximately 30 years ago and, in general, nearly all of the original equipment is still in operation. Equipment age has impacted treatment efficiency and reliability, and Lexington-Fayette Urban County Government (LFUCG) is now required to upgrade the digestion facilities to serve its needs for the next 20 years. As part of this effort, LFUCG desired to evaluate options to better utilize digester gas produced in the digestion process.

Town Branch WWTP.

We were selected to provide preliminary engineering, design, bid-related, and construction-related services for this digestion improvements project, as well as master planning for future digester gas utilization. The project is currently in the planning and evaluation phase. The primary digester improvements project will result in an upgrade and renewal of the existing primary digester complex. The existing complex includes three primary digesters with Pearth mixing systems and floating covers. Ancillary equipment includes boilers/heat exchangers, pumps, digester gas safety equipment, gas flare, and electrical gear and controls. The project will begin with a condition assessment of the existing facilities and equipment, followed by an evaluation of upgrade alternatives for these processes and equipment.

The digester gas master planning evaluated the following:

- **Alternative 1:** Current and future digester gas production at the Town Branch WWTP
- **Alternative 2:** The potential to codigest HSW using available digester capacity to generate more digester gas, including the required facility upgrades to implement codigestion
- **Alternative 3:** The potential of using digester gas in: (a) a cogeneration facility to produce electricity and heat for use at the plant, (b) a compressed digester gas facility to produce vehicle fuel, and (c) boilers to provide digester and building heating

We have completed the Digester Gas Master Plan, and Alternatives 1 and 2 above both have reasonable paybacks and return on investment. We will work with LFUCG to select the most viable alternative based on business cases for each. LFUCG is currently constructing a CNG filling station near the plant and is already investing in

CNG-equipped vehicles. Supplementing or replacing CNG with bioCNG from the plant could be a very attractive option in the future, particularly if the renewable energy credits available through the U.S. EPA are aggregated and applied to the business case. EPA uses Renewable Identification Numbers (RINs) to track renewable transportation fuels. The RIN system allows EPA to monitor compliance with the Renewable Fuel Standard (RFS), a federal program that requires transportation fuels sold in the United States to contain minimum volumes of renewable fuels. A similar system is being implemented in Dubuque, Iowa, with our involvement, as well as other places across the country.

Qualifications of Team

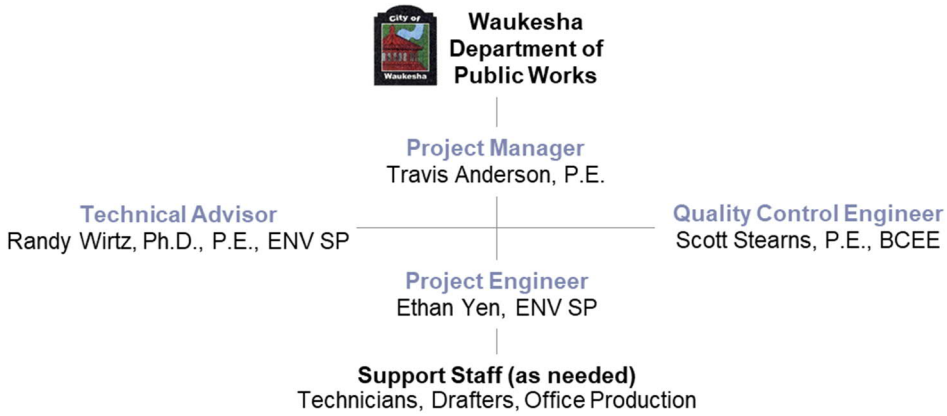
Providing All Services In-House Improves Project Coordination, Quality, and Efficiency

We are a consulting firm that delivers the right solutions to optimize our clients' investments and add value throughout the process. Our strength is our broad and deep expertise in plan development, design, and construction of solids management/handling systems, anaerobic digestion systems, and renewable energy systems, as well as all the ancillary processes and systems needed for a complete project.

We have assembled an experienced and qualified team to efficiently evaluate the range of potential projects and identify the best solutions for the City.

Our team is comprised of individuals with vast experience at the Waukesha CWP. This brings familiarity, consistency of communications and deliverables, and a team the City can trust. All of the project team members are located in our Madison, Wisconsin, office, further enhancing overall communication on this project.

The organization of our team is shown below. Experience summaries for each team member follow and detailed resumes are available upon request.



Project Manager

Travis J. Anderson, P.E., will serve as the Project Manager, providing direct contact between the overall project team and the City. Travis is a skilled wastewater engineer with more than 7 years of plan development, design, and construction-related experience on a wide array of projects in Wisconsin, Iowa, Illinois, and West Virginia. Travis played a critical role on Waukesha's $44.9 million CWP improvements, providing both engineering design and construction project management. He is currently Project Manager for phosphorus-related permit compliance services at Waukesha and developed the Final Compliance Alternatives Plan for the facility. He also served as the Project Engineer for the City of Ames' Biogas Utilization Study. Travis has designed biogas facilities at Whitewater, Manitowoc, Salem, the Kankakee River Metropolitan Agency (KRMA), the Fox River Water Reclamation District (FRWRD), and Ames. He has also developed air permit applications related to biogas utilization at Fond du Lac, Stoughton, Watertown, Salem, Racine, and Waukesha.

Travis' detailed knowledge of the Waukesha CWP will provide value for this project.

Quality Control Engineer

Scott W. Stearns, P.E., BCEE, Senior Associate, has more than 24 years of wastewater engineering experience. Scott is the coordinator of our wastewater group, a role that allows him to get involved in dozens of wastewater projects throughout our firm. This exposes Scott to a wide range of ideas, concepts, and technologies, which is perfect for his role as the key quality control engineer.

Scott's quality control review begins with a memorandum that establishes milestones for an independent review of the work products at various intervals.

Scott has been responsible for facilities plans, designs, and construction projects for wastewater treatment and conveyance facilities throughout Wisconsin, Illinois, Ohio, and West Virginia; serving populations of up to 300,000; and resulting in construction projects ranging to $78 million.

Scott recently served as project manager for the facilities plan, nutrient removal technical memo, and design services of Waukesha's CWP, and is involved with Waukesha's phosphorus compliance plan development. He is also the project manager for our membrane bioreactor (MBR) plan development, design, and construction project for the Morgantown Utility Board, Morgantown, West Virginia. Scott was project manager for Kankakee River Metropolitan Agency (KRMA) plan, design, and construction, which included biogas optimization in the form of HSW, significant biogas conditioning, including biological hydrogen sulfide removal and moisture removal, and biogas utilization in an engine powered generator with heat recovery. Scott's significant technical experience includes enhanced clarification processes and pilot testing, design, and successful implementation of filtration processes, including ultrafiltration membrane systems.

Technical Advisor

Randall A. Wirtz, Ph.D., P.E., ENV SP, Senior Associate, will serve as the Technical Advisor for this project. Randy has more than 22 years of experience with our firm in wastewater treatment studies, plan development, design, and construction projects. Randy has exceptional experience in all aspects of this project – anaerobic digestion, cogeneration and energy recovery, digester gas storage and management, and energy market analysis. His relevant experience includes the following similar projects:

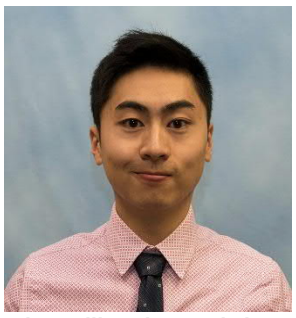
- Dubuque, IA – Codigestion, cogeneration, and biogas plan development, design, and construction
- Fond du Lac, WI – Codigestion, cogeneration, and biogas plan development, design, and construction
- Lexington Fayette Urban County Government, KY – Biogas Utilization Master Plan and codigestion analyses
- Fox River Water Reclamation District, IL – Biogas and Biosolids Master Plan (included HSW market analysis)
- Brookfield, WI – Biogas utilization codigestion plan development

Randy is one of our firm's most experienced process experts and was named the recipient of the 2016 Water Environment Federation Schroepfer Innovative Facility design Award.

Randy is also our resident expert on renewable gas credits.

Project Engineer

Ethan T. Yen, E.I.T., ENV SP, will work closely with Travis to develop recommendations that best meet the needs of the project. Ethan has B.S. and M.S. degrees in environmental engineering from Cornell University and University of California -Berkeley, respectively. He is an exceptionally motivated and sharp young engineer, and is skilled at bringing innovative ideas to the projects on which he works. Ethan has played a critical role on several anaerobic digestion and digester gas utilization projects.



Ethan will assist Travis in efficiently evaluating alternatives to develop the best solutions for the City.

Ability to Meet Schedule

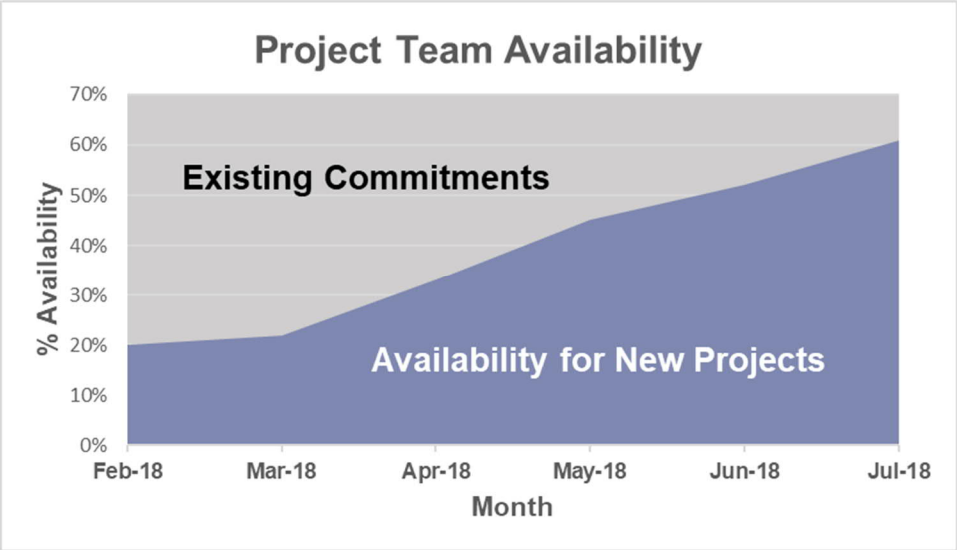
Internal, Corporate wide Scheduling System Results in Timely Project Delivery

We have developed an internal, customized, staff scheduling database for all of our employees, which serves as a tool to determine staff availability relative to project deadlines. At the start of every project, the Project Manager enters the associated hours assigned for each staff member for the duration of the project, starting with planning and continuing through the anticipated construction completion. All projects in the scheduling database are updated on a monthly basis, and staff availability is reviewed each month to schedule new workloads appropriately to those individuals who are the most available. This provides confidence that our team will not be overcommitted throughout the duration of the City's project.

Our scheduling system is an integral part of our project management system.

Our scheduling system is an integral part of our project management system, as it enables us to closely monitor the earned value of our progress in comparison to the remaining workload. Based on our scheduling system, we can confidently state that our staff's capacity and availability will support delivering the project within any reasonable schedule the City desires. The following graph shows the availability of staff throughout the duration of the project.

The engineering team proposed for this project has availability and is eager to serve the City.



Our proposed schedule was developed to meet the City's needs and complete the project in an efficient manner. A graphical representation of our schedule is presented in the *Supplemental Information* section of this proposal. The engineering team proposed for this project, which is anticipated to begin in March 2018, is available and eager to begin the project.

Pricing

Scope of Services is Based on Decades of Similar Biogas Projects

We have developed a scope of services with associated budget for the services requested. The individual tasks, anticipated man hours, and total cost per major task are provided in the attached spreadsheet. This effort/fee is based on our understanding of the project goals and deliverables.

We will use our recent similar experience and understanding of the CWP to provide unmatched value to the City.

Our Culture of Cost Control Results in Low Change Orders

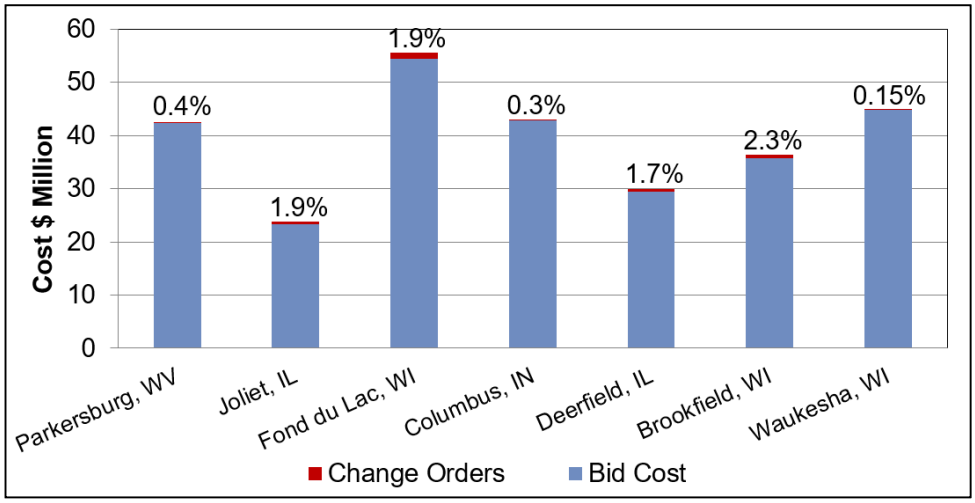
Controlling project costs, including engineering and construction costs, is one of the most important aspects of project management and cost control is truly part of our culture. Engineering cost tracking is a continuous process for every project. We understand that engineering fee adjustments can be difficult to justify, and, therefore, we are careful to establish a fair fee up front and then commit to getting the engineering project done for that fee. Timesheets are completed daily, and project reports are reviewed each week to compare engineering effort expended to the value of services accomplished in that week. Adjustments can then be made to maintain the overall project engineering budget.

Our construction cost development starts during the planning phase of the project when budgets are first calculated.

Our construction cost development starts during the planning phase of the project when budgets are first calculated. The first project budget is developed after the project's requirements are defined and are based on actual equipment quotes, basic take-offs, past project experience, and our internal cost database of hundreds of projects. That first budget is typically developed with a 20 percent contingency to account for undefined elements of the project. During the design phase, the project budget will be updated at the 30, 60, and 90 percent completion stages of the design, which coincides with our typical detailed design review meetings.

Change orders are a measure of an engineer's design accuracy, understanding of construction, and cost control in all phases of a capital project. Generally, a low ratio of change-order-dollars to bid-dollars indicates a high level of planning and design accuracy, which improves cost control on the project. The following graphic depicts the overall change order percentage on wastewater projects we have designed. Each of these projects represents multimillion-dollar investments. We are pleased that total construction costs exceed the actual bid price, on average, by only 0.40 percent, whereas the industry standard is approximately 5 percent. We believe this is truly indicative of the engineering performance the City should expect from its consultant and the level of commitment we are prepared to provide.

Our holistic approach is centered on maximizing the City's return on investment.



WAUKESHA BIOGAS BENEFICIAL UTILIZATION PROPOSAL
TABLE OF FEE FOR ENGINEERING SERVICES

TASKS	Project Manager Travis Anderson		Project Engineer Ethan Yen		QC Engineer Scott Stearns		Technical Expert Randy Wirtz		Secretarial		TOTAL HRS	LABOR COSTS	TOTAL EXPENSE	TOTAL FEE
	Rate	$ 114	Rate	$ 94	Rate	$ 221	Rate	$ 229	Rate	$ 87				
	Hrs.	Labor	Hrs.	Labor	Hrs.	Labor	Hrs.	Labor	Hrs.	Labor				
1. Project Administration	2	$ 228							2	$ 174	4	$ 400	$ 40	$ 440
2. Kickoff Meeting	4	$ 457									4	$ 460	$ 150	$ 610
3. Review of existing and Future Biogas Productions and Demands	2	$ 228	8	$ 752							10	$ 980	$ 100	$ 1,080
4. Evaluate Feasible Biogas Utilization Alternatives	12	$ 1,370	40	$ 3,762	4	$ 884	6	$ 1,376			62	$ 7,390	$ 740	$ 8,130
5. Mid-Course Review Meeting with City	4	$ 457									4	$ 460	$ 150	$ 610
6. Develop Draft Report for City Review	6	$ 685	40	$ 3,762	4	$ 884	4	$ 917	4	$ 348	58	$ 6,600	$ 660	$ 7,260
7. Present Recommendations to City	4	$ 457									4	$ 460	$ 50	$ 510
8. Finalize Report	2	$ 228	6	$ 564					2	$ 174	10	$ 970	$ 210	$ 1,180
TOTAL	**36**	**$ 4,109**	**94**	**$ 8,841**	**8**	**$ 1,768**	**10**	**$2,293**	**8**	**$ 696**	**156**	**$ 17,720**	**$ 2,100**	**$ 19,820**

Supporting Documentation for Focus on Energy Grant Application

Executive Summary

The City of Waukesha recently completed a major renovation project at the CWP that included a complete rehabilitation of the existing anaerobic digestion complex. Prior to the renovation, the complex consisted of four primary digesters, two 90-foot-diameter and two 55-foot-diameter, that were fed in series in proportion to their volume. Digested sludge flowed by gravity to a digested sludge storage tank prior to dewatering using belt filter presses. The new digestion process at the facility uses a newly constructed 1.1-million-gallon, egg-shaped primary digester. Partially-digested sludge flows from the egg-shaped digester to one of the existing 90-foot digesters, now being used as a secondary digester, which is equipped with a floating gas-holding digester cover. The other existing 90-foot digester has been equipped with a membrane gas holding cover with a capacity of 166,000 cubic feet of digester gas. This digester can also serve as a secondary digester, but, to-date, has just been used for gas storage. One of the existing 55-foot digester was converted to a centrate equalization tank and the other was removed to allow construction of the egg-shape digester. Currently, biogas is used only to heat the digestion process using two, dual-fuel boilers. Biogas in excess of that required for digester heating is flared.

The new digestion facilities are likely to improve digestion efficiency and biogas production because of the increased mixing capabilities of the egg-shaped digester. The potential for increased biogas production and increased gas storage volume gained with installation of the membrane gas holding cover provides the City with an opportunity to utilize the excess biogas more easily and for greater benefit. This study will evaluate several options for beneficial use of the biogas, including use of the biogas for electrical generation using engines or other means, cleaning of the biogas to pipeline quality for sale to the utility, use of the biogas as vehicle fuel, and use of the biogas for drying of the biosolids to produce a class A product.

Use of the biogas to generate electricity to offset electrical use at the facility will be evaluated and potential savings will be assessed at current electric rates as determined from Utility billings. Seasonal variation in biogas availability will be considered in this evaluation. The impact to demand charges that may be gained by on-site generation of electricity will also be included.

Sale of pipeline quality gas and the economic value of renewable identification numbers (RINs) and low carbon fuel standard credits has substantial benefits that make it a viability alternative to study. Gas conditioning costs are higher, but there is no cost for an engine for electrical generation. This alternative will be evaluated for both use of just the excess biogas and all of the biogas with purchase of natural gas for heating of the digesters.

Disposal of biosolids is becoming more expensive and availability of land for disposal is constantly decreasing. Drying of the biosolids to produce class A biosolids would provide the facility with increased opportunities for biosolids disposal.

These evaluations will include capital costs, including those for gas conditioning and operating costs. The projected annual energy production and use of each alternative, in kW, kWh, and/or therms, will be included in the analysis, as will the projected annual economic benefits.

The results of the evaluations and our recommendations will be presented to City staff to enable them to make informed decisions regarding the modifications to the existing biogas handling strategy.

Scope of Work

Task 1 – Project Kickoff Meeting and Data Analysis

Request and review plant operational data, reports, and related documents. We will also schedule a kickoff meeting with City staff to discuss the work plan (scope, schedule, and other details) for the project and the key issues. At the kickoff meeting, we will present a PowerPoint presentation to show the City the types of equipment and evaluations that we plan to conduct for this project, along with photos from our similar projects. After the kickoff meeting is completed, we will prepare meeting minutes, including decisions and action items, and distribute them to those in attendance.

Task 2 – Review of Existing and Future Biogas Production and Energy Demands

We will develop a detailed analysis of historical energy use using information provided from Utility billings, as well as trending information from the supervisory control and data acquisition (SCADA) system. This information will be used to determine the current average and peak energy demands at the facility and establish the baseline for energy use to compare against proposed biogas utilization improvements. The review of existing conditions will also include a summary of the design specifications of the existing digestion and gas handling equipment. The future loadings, digester gas production, and related parameters will be projected using the forecasted CWP loadings developed in the 2011 Facilities Plan.

Task 3 – Review Feasible Biogas Utilization Alternatives

This portion of the study will include identification and high-level evaluation screening of alternatives to meet both near- and long-term challenges. This task will identify several potential alternatives, screen these alternatives based on high-level costs and nonmonetary evaluations, and then develop a shortlist for more detailed analyses. A summary of the various biogas alternatives to be evaluated is shown in *Figure 1* (located at the end of this section).

Included below is a summary of the main process alternatives that we anticipate evaluating. These evaluations will include development of an energy and solids balance through the solids processing facilities to assist in sizing the potential digester gas end-use options. For each of these options, we will include a base case using current loadings, a mid-level case using the projected future loadings, and a high-level case assuming loading the digesters to their maximum capacity. The following options will be considered:

- Combined heat and power system using one or more new engines
- Combined heat and power system using microturbines
- Production of pipeline quality gas or compressed natural gas (bioCNG)
- Dual-fuel boiler for digester heating (with and without cogeneration)
- Biosolids drying

The evaluation of alternatives will include energy and mass balances; digester gas storage requirements; digester gas conditioning requirements; capital costs; operating costs, including purchase of natural gas for digester heating in alternatives that divert the biogas from this purpose; maintenance costs; future equipment replacement costs; and salvage costs over the 20-year life of the project. The various costs will be included in a present-worth evaluation to better compare the various alternatives on an equal monetary basis.

The evaluation of the use of the biogas for pipeline quality natural gas will include analysis of the anticipated revenues from gas sales, RINs, and low carbon fuel standard credits. This evaluation will also consider the potential for involvement of a third party to provide the gas conditioning equipment and purchase the rights to the digester gas as part of a long-term contract. This analysis will include the following:

- Review the feedstock makeup
- Review the planned end use and conversion processes
- Conduct the Renewable Fuel Standard RIN valuation, including feedstock implications regarding D3/D5 RINs
- Conduct the Low Carbon Fuel Standard credit valuation, including the carbon intensity estimate
- Review of capital and O&M opinions of probable cost, as well as potential revenue

If desired by the City, the evaluation will include the potential for increased digestion efficiency through an add-on process to increase digestion of the waste activated sludge (WAS).

Task 4 – Review Meeting with City

We will meet with the City to discuss the project progress and the results of the evaluations to-date. The meeting will present the current status of the project evaluations, project budget, and schedule.

Task 5 – Develop Draft Report for City Review

The draft report will be developed summarizing the results of Tasks 1 through 4. Additional implementation considerations such as potential funding, including Focus on Energy grants or incentives, and project delivery will be summarized in a final section, and we will submit the draft report for review. The project schedule enables ample time for City review and detailed discussion, as needed.

Task 6 – Finalize Report

Following City review and a teleconference for discussion of the City's comments, a final version of the report will be prepared and provided in both paper and electronic format. The report will be completed, assuming approval of the agreement approximately March 9, 2018, by July 6, 2018.

Listing of Deliverables

Deliverables for this project will include the following:

- Agenda, PowerPoint presentation, and minutes for the project kickoff meeting.
- Draft Report including:
  - A detailed analysis of historical utility billing information over at least the previous year or longer time period, as necessary, to demonstrate representative normal and peak energy use trends and to define current baseline energy use.
  - A plan for implementation of the recommended biogas utilization measures, including an explanation of how and where the biogas will be used.
  - An analysis of the proposed biogas project with supporting calculations for estimated annual energy production and utilization (kWh, kW, and therms).
  - Design specifications and current operating parameters for major equipment components of the digester system.
  - Cost estimate for purchase and installation of measures suggested for implementation, including design services.
  - Calculation of the simple payback for each of the proposed measures to be implemented.
  - A methodology to verify and quantify the actual magnitude of renewable energy production.
- PowerPoint presentation describing the biogas utilization evaluations and recommendations.
- Final Report including revisions incorporating comments from the City and Focus on Energy, as appropriate.

Estimate of Study Cost

The total projected cost for this project is $19,820. This cost includes 156 total labor hours. The labor rates and titles for staff intended to be involved in the study are listed in the table below.

Staff	Title	Labor Rate
Travis Anderson	Project Manager	$114
Scott Stearns	Quality Control Engineer	$221
Randy Wirtz	Technical Advisor	$229
Ethan Yen	Project Engineer	$94
Support Staff	Office Production	$87

Estimate of Potential Energy Savings or Production

The average biogas production in 2017 at the Waukesha CWP was approximately 131,000 cubic feet per day (cf/day). Biogas is currently used in the boilers for heating the digesters with excess gas flared at the waste gas burner. In 2017, only 27 percent (35,000 cf/day) of the total gas production was used in the boilers, resulting in 93,000 cf/day being flared. This data is based on flow meters located throughout the biogas piping system.

A cogeneration system would enable the CWP to utilize nearly all biogas produced. The total gas production of 131,000 CF/day has a power value of 78.6 million BTU/day (MMBTU/day), assuming a typical digester gas energy content of 600 BTU/cf. Converting 78.6 MMBTU/day results in 964 kW of power before efficiency factors are applied.

New engines have an electrical efficiency of approximately 36 percent. Therefore, a new engine generator could produce approximately 350 kW of electrical power at the CWP at the current digester gas production. Assuming continuous operation, this results in approximately 3,000,000 kWh/year of energy production with a value of $249,000 per year at the CWP blended electrical rate of $0.083/kWh. This does not include the cost of operation and maintenance associated with the cogeneration and gas conditioning systems.

New cogeneration systems have a thermal efficiency of approximately 43 percent. Therefore, a new cogeneration system could provide a heat output of approximately 33.4 MMBTU/day, or 334 therms/day. The value associated with this output is $62,000/year at the current CWP gas charge of $0.51/therm. As noted previously, the CWP currently uses 27 percent of the current biogas production for heating the digesters. The waste heat from the engines will likely be sufficient to heat the digestion process under most conditions. As previously discussed, detailed monetary evaluations will be included in the report for each alternative.

B0-1: Cell Lysing
Cell lysing systems will be evaluated and may improve VS destruction, digester gas production, and solids dewaterability.

B0-2: High Strength Waste
The digester system has adequate capacity to receive additional loadings. The addition of high strength waste will be evaluated to determine the potential benefits of increased gas production.

BC-1: Gas Conditioning
Most alternatives require removal of siloxanes and hydrogen sulfide from the digester gas. Locating this equipment outdoors allows access for media replacement.

BU-2 – Biosolids Drying
Biosolids drying will be evaluated and may be combined with other alternatives. There appears to be adequate space in the Centrifuge Room of Structure 430 for the new drying equipment.

BU-1a: Engine Cogeneration
Structure 510 has space available for an engine generator and is in close proximity to the digestion complex.

BU-3: Vehicle Fueling Station
We will evaluate the opportunity for producing bioCNG for use as fuel in the City's vehicle fleet. The close proximity of the Municipal Garage provides an opportunity for partnership and beneficial reuse of biogas within the City.

BU-1b: Microturbine Cogeneration
Microturbines are more efficient when located outdoors. The microturbine units could be located south of Structure 510.

BC-2: Pipeline Quality Gas
Pipeline quality gas requires removal of carbon dioxide through a membrane or pressure swing adsorption system.

BU-0: Boilers
Continued use of the current dual fuel boilers will be evaluated both with and without implementation of cogeneration.

Biogas Optimization	Biogas Conditioning	Biogas Utilization
B0-O: No optimization	BC-0: No conditioning	BU-0: Boilers & Flare
B0-1: Cell lysing	BC-1: H_2S, siloxane, & moisture removal	BU-1: Cogeneration (engines or microturbines)
B0-2: High strength waste	BC-2: CO_2 removal (pipeline quality gas)	BU-2: Biosolids drying
		BU-3: BioCNG/Vehicle fuel

Figure 1: Biogas Alternatives