Bio-Products Engineering Corp.

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Project Title:
Conversion of High Strength Volatile Fatty Acids to Methane Rich Biogas at Lab Scale to Establish Design and Operating Parameters of the Methane Phase in High Solids Two-Phase Anaerobic Digestion (HS2PAD™) Process

Project Type: Biogas

Project Abstract:
High Solids Two-Phase Anaerobic Digestion (HS2PAD™) is near commercial viability. The acid phase demo at commercial scale has been demonstrated in Milwaukee with moneys from private industry and the state of Wisconsin (DNR Grant #05-15 and Biobased Initiative contract no. 1039). This project will simulate the conversion of High Strength Volatile Fatty Acids to methane-rich biogas at lab scale to establish the design, cost analysis, and operating parameters of the methane phase at full scale. Lab results will give definitive information to complete the design and construction of the commercial scale demonstration methane phase unit. This short term project will give the necessary info to complete the HS2PAD™ system demonstration.

Project Description: The project description must be a self-contained narrative containing project title, the objectives of the project, a description of the project, the potential impact of the project (for example, benefits and outcomes), and major participants.

The development of the High Solids Two-Phase Anaerobic Digestion process (HS2PAD™) has been funded by the state of Wisconsin (DNR and DATCP) and private funds. The first steps of designing, building and operating a continuous flow high solids acid phase commercial scale reactor have been accomplished proving the viability of the continuous flow processing of food wastes and other high strength wet organics into high strength Volatile Fatty Acids (VFA). (Please see final report at DATCP project #1039, 2007/2008) Conventional digesters operate with VFA concentrates orders of magnitude less than expected operational levels in the HS2PAD™ process. Therefore, lab work is needed to establish design and operational procedures for the methane phase of the HS2PAD™ system. There is no conventional experience from which to obtain this information, as there are no systems of this kind operating in the world. Please note that the design part of our project is simply to establish the means by which existing technologies can be adapted to our purposes. We are not redesigning the entire process. A lab scale two-phase system will operate at UW-Green Bay for six months to establish norms and protocols for feeding high strength VFA to simulate conditions of full scale. On completion of this lab work Bio-Products Engineering will use the lab data to design the full scale commercial methane phase reactor to match the output from the existing demonstration acid phase reactor at Growing Power in Milwaukee. Funds will then be sought to build and operate the full scale commercial HS2PAD™ system.

Objectives:

1. Lab simulation of high strength VFA conversion to methane to establish design and operational standards for commercial sized reactor.
2. Design commercial sized methane phase reactor to match the existing acid phase commercial reactor in Milwaukee. (Please note that the design part of our project is simply to establish the means by which existing technologies can be adapted to our purposes. We are not redesigning the entire process.)
3. Establish cost estimate for full scale methane phase reactor and cost estimate to run the complete full-scale HS2PAD™ system in Milwaukee.

Potential Impacts:

1. Simplify a commercialization of the methane phase step in HS2PAD™ development.
2. Obtain accurate cost, and design information for the construction of the methane phase.
3. Obtain real world operating experience at high strength VFA levels never before done.
4. Once project finishes we can move to build the world's first complete commercial scale HS2PAD™ continuous flow system in Milwaukee with further development at food processing and waste water treatment plants in the state.

Participants:

Bio-Products Engineering Corp., Richland Center, WI commercial developer of the HS2PAD™ process;

Drs. John Katers and Mike Zorn, UW-Green Bay, professors in Natural and Applied Sciences, Engineering and Chemistry; highly regarded leaders in the state and region.

UW-Green Bay Research Summary

The principal investigators have shown that a pilot scale acid-phase anaerobic digester fed with food waste is capable of continuously producing a feed stream of VFAs (volatile fatty acids) at levels as high as 20,000 mg/L. The research proposed here will evaluate the ability of a methane-phase anaerobic digester to successfully handle a feed stream containing these elevated levels of VFAs. Bench-top experiments will be conducted using a bench top Armfield Limited Anaerobic Digester (Model W8), owned by UW-Green Bay. This digester is equipped with two 5 liter packed bed, upward flow reactors. Each reactor has variable flow rate pumping capabilities and gas sampling / collection capabilities. The feed flow rate to each reactor can be accurately and independently controlled to any temperature between ambient and 55°C, using 200W heating jackets. For these studies, only one reactor will be utilized, and it will be operated as a methane-phase digester. This reactor will be fed with a solution containing acetic acid as well as nutrients at an appropriate concentration to simulate the feed stream described above.

Bio-Products Engineering Corp.

Mark Heffernan, President, will supervise the designing of the methane phase reactor and cost analysis.

Project Readiness: Describe the project's readiness, including the percentage of necessary project capital that the Applicant has raised or has access to; whether the applicant has identified existing financial partners, the Applicant's ability to execute agreements, etc.

Bio-Products Engineering (BPE) has completed the first step of a three-step development plan. This is the second step and BPE has more than 50% of the money to finish this step. We have a long history of working with our partners at the UW-Green Bay. UW-Green Bay has state of the art lab equipment and experience and a grad student capable of doing the assigned work. The design and cost estimating part of this project conducted by Mr. Heffernan comes with already established business relationships in the

design and construction and operation of the acid phase. Mr. Heffernan will be able to capitalize one these relationships to complete the design and cost estimating in a timely and accurate fashion.

The third and final step for full scale demonstration of the HS2PAD™ process though not part of this grant application is also likely to move at a respectable pace, as political and industrial relationships in the city of Milwaukee are already established, and there is considerable interest on the part of industry to use the process once complete.

Project Deliverables: Identify the quantifiable metrics that will evaluate the Project outcomes.

1. Establish standards and operating protocols to process high strength VFA into methane rich biogas.

2. Design and cost estimate full-scale methane phase system to match the existing acid phase digester in Milwaukee. (Please note that the design part of our project is simply to establish the means by which existing technologies can be adapted to our purposes. We are not redesigning the entire process.)

3. We will then accumulate knowledge and experience to design and build and operate full-scale HS2PAD™ systems.

More than 800 food processing facilities, along with the state's restaurants and food service establishments generate over 400,000 tons of food waste per year. A conservative estimate of the energy potential in this waste is more than 100,000 Btu/hr/ton. The completion of this project will bring us to the last step in the development of the HS2PAD™ process so that the utilization of this clean abundant and reliable resource can be realized.

Project Leaders and Qualifications

Current Positions:

Mark Heffernan
President, CBT Wear Parts, Inc. (CBT)
CBT Wear Parts Inc. is a national manufacturer and distributor of industrial wear components, machinery, and equipment systems for material handling and size reduction equipment in the construction, composting, aggregate, waste processing, and recycling industries. CBT is also the manufacturer of the HS2PAD™ demonstration system for the conversion of wet biomass to energy and other bio-chemical products.

President, Bio-Products Engineering Corporation (BPE)
BPE is a cutting edge small business biotechnology firm specializing in renewable energy from wet biomass and the production of additional bio-chemicals from high moisture biomass feedstocks. The HS2PAD™ Acid Phase demonstration has completed in Milwaukee. BPE is currently working on the Methane Phase demonstration.

Education:
Ball State University, Bachelor of Science, Philosophy, 1982
Ball State University, Bachelor of Science, Psychology, 1982

Employment History:
As President of BPE, Mr. Heffernan has been supervising the commercial development of the innovative HS2PAD™ Process as a renewable energy and bio-products production technology for the conversion of high moisture biomass feedstocks to energy and other bio-chemical products. Mr. Heffernan is the co-designer and developer of the world's first commercial demonstration of the HS2PAD™ process installed in Milwaukee, WI. Mr. Heffernan has been involved with anaerobic digestion commercialization work since 1989.

Mr. Heffernan has been the owner of CBT Wear Parts, Inc. since 1990 -a company which specializes in mechanical parts and assemblies and systems components in the materials handling and size reduction aspects in the waste processing, recycling, composting, and soil products industries. CBT is also an industry leader in manufacturing of soil products processing and screening equipment. Prior to 1990 Mr. Heffernan worked as one of the leading parts sales persons for a company specializing in parts sales for heavy equipment in mining and construction. In these past 15+ years he has gained an invaluable amount of on the job experience in materials handling systems, materials of construction for mechanical parts, mechanical systems reliability, costs of production for parts and assemblies, and management of business. This experience has given Mr. Heffernan a very high level of understanding and ability to integrate the knowledge bases from a number of scientific disciplines to be able produce unique and innovative products and services. Most recently CBT has been the co-designer and manufacturer of the world's first demonstration of a commercial scale High Solids Two-Phase Anaer

CBT Wear Parts, Inc. President, Aftermarket company specializing in the manufacturing and marketing of machinery and wear products to the construction, composting, waste processing, recycling, and other industries. 1990-present

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Education
1997 Ph.D. in Environmental Chemistry and Technology (formerly Water Chemistry), UW-Madison.
1993 B.S. in Chemistry, UW-Green Bay.

Professional Experience
2001 - Present Assistant Professor of Natural and Applied Sciences, Chemistry, UWGB.
1993 - 2001 Research Assistant, Post-Doctoral Researcher, and Associate Researcher.
Water Chemistry Program, University of Wisconsin-Madison.

Relevant Funded Research
2003 - 2004 **Focus on Energy Renewable Energy Program**
Co-Principal Investigator with Dr. John Katers
Biogas Generation from a Wisconsin Dairy Farm Using Anaerobic Catalysis and/or Photocatalysis - $60,080

2002 - 2003 **Wisconsin Space Grant Consortium**
Principal Investigator
Photocatalytic Oxidation of Gas-Phase Compounds in Confined Areas - $10,042

Relevant Presentations
Davis, C.M.; Zorn, M.E.; Katers, J.F.; Anderson, M.A. Anaerobic photocatalysis as a secondary treatment following anaerobic digestion. Midwest Environmental Chemistry Workshop. October 17, 2004. Madison, WI.

Zorn, M.E. Photocatalytic methods for contaminant degradation. Northeast Wisconsin Local Section of the American Chemical Society: New Faculty Showcase. April 1, 2003. University of Wisconsin-Green Bay, Green Bay, WI.

Zorn, M.E. Applications of photocatalysis. Faculty Lecture Series. April 18, 2003. University of Wisconsin-Green Bay, Green Bay, WI.

Zorn, M.E. Degradation of gas-phase contaminants using photocatalytic oxidation. The 13th Annual Wisconsin Space Conference. August 14-15, 2003. University of Wisconsin-Green Bay, Green Bay, WI.

Zorn, M.E; Tompkins, D.T.; Zeltner, W.A.; Anderson M.A. Photocatalytic oxidation of acetone vapor on TiO_2 / ZrO_2 thin films. American Society for Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE). 1999. Seattle, Washington.

Selected Publications
Coronado, J.M.; Zorn, M.E; Tejedor-Tejedor, I.; Anderson, M.A. Photocatalytic oxidation of ketones in the gas phase over TiO_2 thin films. *Applied Catalysis B: Environmental* **2003**, 43 (4), 329-344.

Zorn, M.E. Photocatalytic Oxidation of Gas-Phase Compounds in Confined Areas. *13^{th} Annual Wisconsin Space Conference*. August 14-15, **2003**. Green Bay, WI. Wisconsin Space Grant Consortium.

John F. Katers, Ph.D.
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Education

1996 Ph.D. in Civil and Environmental Engineering, Marquette University, Milwaukee, WI.
1993 M.S. in Environmental Science and Policy, UW-Green Bay.
1991 B.S. in Environmental Science and Business Administration, UW-Green Bay.

Professional Experience

2004 - Present Associate Prof. of Natural and Applied Sciences, Engineering, UWGB.
1999 - 2004 Assistant Prof. of Natural and Applied Sciences, Engineering, UWGB.
1995-99 Industrial Recycling Specialist, University of Wisconsin Extension - Solid and Hazardous Waste Education Center, Green Bay, Wisconsin.

Awards

2004 - 2005 Named as a 2004-05 University of Wisconsin System Ideas Fellow
100 Faculty members from UW System were honored by the University of Wisconsin System Board of Regents in recognition of public service contributions to the state that help further job creation in Wisconsin

Relevant Funded Research

2004 - 2005 **UW System Applied Research Grant**
Co-investigator with Dr. Michael Zorn
Biogas Generation from a Wisconsin Dairy Farm Using Gas-phased Anaerobic Photocatalysis - $44,796

2003 - 2004 **Focus on Energy Renewable Energy Program**
Co-Principal Investigator with Dr. Michael Zorn
Biogas Generation from a Wisconsin Dairy Farm Using Anaerobic Catalysis and/or Photocatalysis - $60,080

2002 - 2003 **Wisconsin Department of Administration**
Principal Investigator
Evaluation of a Temperature-phased Anaerobic Digestion System for the Dairy Industry - $44,000

2001 - 2002 **UW System Applied Research Program**
Principal Investigator
Evaluation of a Temperature-phased Anaerobic Digestion System for the Dairy Industry - $44,424

Relevant Presentations

Katers, J. Temperature Phased Anaerobic Digestion of Dairy Manure." Anaerobic Treatment of High-Strength Industrial and Agricultural Wastes. Marquette University. Milwaukee, WI. 2003

Katers, J.; Drew, D. Energy and Resource Recovery from Agricultural and Food Wastes. 32nd Annual Conference on Environmental Engineering in the Food Processing Industry. Vancouver, Canada. 2002.

Scientific Support: Describe how the project is supported by established science, include (where available) prototype information, beta testing, pilot project demonstrations, laboratory testing, scientific modeling, or other established means of support for the project.

Bio-Products Engineering Corp. has established the first step of the High Solids Two-Phase Anaerobic Digestion process at commercial scale with a demonstration unit installed in Milwaukee. With moneys from state programs (info here DNR and DATCP) and its own resources BPE has established that a continuous operation conversion of high solids food wastes to high strength VFAs is commercially viable at the tonnage generated by industry. We also proved that these high strength VFAs can be stored and shipped and can be produced at concentrations higher than expected. This next step will establish protocols for conversion of these VFAs to methane rich biogas at feeding rates considerably higher than industry norms. Our feed rate will be at a VFA concentration two times what we produced in our acid phase demonstration, as we anticipate the ability to increase the VFA concentration at full scale operation of an HS2PAD™ system.

Intellectual Property: List any existing or pending patent (or other intellectual property) owned or licensed by applicant relevant to the project.

All I.P. resides with Bio-Products Engineering Corp. All associates are currently constrained by confidentiality agreements. Know-how has been and will be protected, and process patents will be applied for. The system design will also be patented.

Project Potential

1. **Describe how the project involves the commercialization, production, and use of new renewable energy products and services**

HS2PAD™ is a newly developed method of anaerobic digestion which allows for the processing of higher solids content organic biomass materials into energy and other biobased products. This allows materials now discarded or land applied or land filled i.e., food wastes to be converted into energy and other products. Separation of the acid phase from the methane phase in anaerobic digestion allows for more materials to be considered as likely feedstocks with the major cost of methane generation shared by a number of small volume generators who would not on their own be able to absorb the cost of a full system. Production and storage of VFAs allows for a timed energy production even at a different location with no loss of energy potential. Higher net energy per ton of biomass is achieved due to the increased performance of both phases of the process.

Bio-Products Engineering Corp. will offer full service design, build, own, operate services to users of the process so that they can concentrate on their core business and still get the maximum benefit from what is now currently a waste product to them.

2. **If the Project involves Applicant's development, commercialization, and production of a specific product, describe the overall market size, the market potential of the product, the expected market growth of the product within 1-3 years, and whether the product growth is expected to exceed the industry average**

Market Size: There are more than 800 food processing plants in the state of Wisconsin. We have interest from as well as letters of endorsement from the major food processing corporations within the state as well as the region's food processing association. Additionally the state of Wisconsin has an interest to remove food waste from landfill disposal. These wastes constitute 10-15% of the volume going to landfill. Municipal wastewater treatment plants have expressed interest in the HS2PAD™

technology. Conventional wastewater digesters operate at very low solids loading rates and are energy inefficient. Additionally, conventional digester technologies do not allow additional high strength and or high solids loads. BPE with its HS2PAD™ process will offer all of these markets another option. Our demonstration of the acid phase has been in conjunction with a group in Milwaukee called Growing Power focused on agricultural production in urban environments. The HS2PAD™ process gives the urban ag producer a means to utilize urban organic wastes for both energy production and nutrient utilization. We expect to have our first full scale HS2PAD™ system in operation within 3 years after this project completes. Subsequent installations of the process are expected to proceed at a rate of about one every 2 to 3 years in the food processing industry as these projects take a long time to initiate and complete. Growth in the wastewater treatment field is expected first at locations where there are food processors on small rural systems and larger installations to follow.

3. Provide a timeline of major milestones and a schedule of time to commercialization

In the next eighteen months we expect to complete the bench scale demonstration of converting high strength VFA to methane rich biogas and to complete the design and operating standards for the methane reactor. By the third year we should build and operate a full scale HS2PAD™ system and then run that system for a period of about one year to perfect integrated systems and material handling. By year five we expect to be under contract and building the first full-scale commercial HS2PAD™ system for the food processing industry.

4. In addition to jobs created directly by this project, describe the potential direct and indirect economic development benefits to Wisconsin that may accrue from the project, such as related industry and supplier support and agglomeration, increase to tax base, reduced energy cost to consumers, etc

The HS2PAD™ process development has been almost completely developed with Wisconsin-based suppliers, vendors, researchers, contractors, and manufacturers. Bio-Products Engineering Corp. is a Wisconsin-based company dedicated to the commercialization and distribution of the HS2PAD™ process. We are working directly with the University of Wisconsin system, UW-Green Bay. Our systems have been and will continue to be manufactured in Wisconsin using Wisconsin-based suppliers and craftsmen, and where at all possible, using Wisconsin-manufactured peripheral equipment. Our demonstration project is located in Milwaukee, and we expect our collaboration with Growing Power to assist in their efforts to build the world's first urban agricultural production and processing center. The HS2PAD™ process contributes significantly to the ability of a region to capture and utilize diverse and otherwise small volumes of organic biomass resources that would go either to landfill or go unused. The process offers symbiotic business collaborations for food processing, food production, waste conversion to energy, municipal waste water systems, and other biobased renewable energy methods. The HS2PAD™ system brings to the food processing industry an ability to utilize as an energy source what is currently handled as a waste product. Additionally, the process allows for nutrient removal and sale when further development of the process is completed. This benefit gets to the core regulatory considerations for both the food processing industry and municipal waste water treatment plants and is a benefit that no conventional anaerobic digestion process can offer.

Statutory Considerations

Describe how and to the extent the Project involves one or more of the following:

1. A new process, practice or technology.

The HS2PAD™ process is not done anywhere in the world on a continuous flow basis. Ours is an extremely innovative change in anaerobic digestion methods that allows many more sources of biomass to be utilized at their original solids contents and with any combination of biomass feedstocks.

2. The development, production, processing or distribution of renewable energy.

The HS2PAD™ process is a new way of doing anaerobic digestion that separates acid production from methane production. This allows for energy storing and shipping at its full energy potential which no other renewable energy process allows. It also allows for a timed energy production to meet the optimal needs of the energy consumer. These are advances that some other renewable energy technologies cannot make because they are unable to delay energy production and cannot store energy with no net energy loss.

3. The use of existing surplus or by-products of natural resources in the state.

The HS2PAD™ process uses food wastes and urban wastes that are either land-applied or landfilled and therefore go un-utilized. The process also allows for Waste Water Treatment Plants (WWTP) to thicken their sludges to a much higher level and allows the possibility that low flow WWTPs without digesters can combine their sludges and effectively utilize the energy potential therein. Additionally, WWTPs can consider an operation that combines much thicker sludge with food wastes to create more energy and an overall more efficient system.

4. The conversion waste or by-products into renewable energy.

The HS2PAD™ process uses food wastes and urban wastes that are either land-applied or landfilled and therefore go un-utilized. The process also allows for Waste Water Treatment Plants (WWTP) to thicken their sludges to a much higher level and allows the possibility that low flow WWTPs without digesters can combine their sludges and effectively utilize the energy potential therein. Additionally, WWTPs can consider an operation that combines much thicker sludge with food wastes to create more energy and an overall more efficient system.

5. **Products or services that will be commercialized or manufactured in Wisconsin.**

Bio-Products Engineering Corp. is a Wisconsin-based company dedicated to the commercialization and distribution of the HS2PAD™ process. We are working directly with the University of Wisconsin system, UW-Green Bay. Our systems have been and will continue to be manufactured in Wisconsin using Wisconsin-based suppliers and craftsmen, and where at all possible, using Wisconsin-manufactured peripheral equipment. For example, Waukesha and Marathon Engines are Wisconsin companies whose engines will burn our biogas.

6. Utilization of renewable energy sources by Wisconsin manufacturers.

The food processing plants themselves are likely to use the energy they produce. These companies have very high energy demand and can meet that demand oftentimes producing a surplus of electricity. Same

as the case for WWTPs. And urban agricultural operations will benefit from both the energy product and the nutrient utilization of an HS2PAD™ system. Siting an HS2PAD™ system in conjunction with ethanol or biodiesel facilities improves their net energy balance.

Describe any special attributes the reviewers should know about. For example, does the project have other environmental/energy or social benefits, complements existing industries, etc.

Siting an HS2PAD™ system in conjunction with ethanol or biodiesel facilities improves their net energy balance. We ran our demonstration acid phase digester on mostly spent grain from a brewery and yielded very high VFA production. One can expect the same result from corn discharge from an ethanol plant. Biodiesel creates an excess of glycerin that will eventually become a significant waste issue for the industry. Glycerin will digest in the HS2PAD™ process.

Our collaboration with Growing Power and its development of urban agricultural production and processing facilities demonstrates the utility of the HS2PAD™ process. These kinds of facilities will benefit from the energy and the nutrients that come off of the HS2PAD™ process, and the HS2PAD™ process will take directly back any organic wastes generated at the urban ag facilities. These would include plant materials and fish or other food processing wastes.

By synergistically combining HS2PAD™ with these other industrial operations waste from one becomes a resource for another and environmental responsibilities are not only met but converted to assets. Subsequent work with a development of HS2PAD™ will be the removal of nutrients in a dry form to be marketed as another revenue stream.

Job creation from the development of HS2PAD™ involves both high tech and low tech long term jobs that will remain in the local region and not be exported to foreign countries. Examples of the areas of interest for job creation are: biochemistry, chemistry, microbiology, renewable energy, energy systems, hydroponics, aquaponics, nutrient management, process engineering, transportation systems, architecture, construction, fabrication, automation controls, etc.