Title: Bioenergy Production from MSW by Solid State Anaerobic Digestion

PIs: Sarina J. Ergas, Professor & Daniel Yeh, Associate Professor

Contact information: Dept. Civil & Environmental Engineering, University of South Florida, 4202 E. Fowler Ave. ENB 118, Tampa FL 33620, Phone: 813-974-1119, Email: sergas@usf.edu

ABSTRACT

Solid-state anaerobic digestion (SS-AD) is a bioenergy production technology characterized by a high solids content (15-30% solids). It is widely used in Europe to produce biogas from the food and yard waste; however, to our knowledge only one commercial scale SS-AD facility is currently operating in the US. Advantages of SS-AD include faster waste degradation and higher biogas quality than conventional or bioreactor landfills, lower water use and leachate production than wet anaerobic digestion technologies and production of a nutrient rich fertilizer. The overall goals of this project are to evaluate the potential for SS-AD in Florida and to improve the rate of biogas production during co-digestion of the organic fraction of municipal solid waste (OFMSW). Specific objectives are to: 1) evaluate the most appropriate technologies for implementing SS-AD of OFMSW in Florida, 2) carry out fundamental research at bench- and pilot-scale to improve the biodegradability of lignocellulosic waste through co-digestion with pulp and paper waste sludge, 3) identify potential sites, collaborators and funding sources for a large scale SS-AD demonstration project in Florida. Results from this project will be disseminated widely to a variety of stakeholders including FDEP, USEPA and county regulators, county solid waste directors and their staff, private waste management companies and other associated industries, university and K-12 students, engineers, operators, scientists and community members.

INTRODUCTION AND OBJECTIVES

Energy recovery from municipal solid waste (MSW) is commonly practiced by collecting and utilizing landfill gas for heat, vehicle fuel or conversion to electricity using internal combustion engines or turbines (EPA, 2013). The current strategy in the US for enhancing landfill gas production is through recirculation of leachate through the entire waste stream. Many landfills in Europe; however, separate the organic fraction of MSW (OFMSW) for energy recovery through anaerobic digestion. This promotes faster degradation of the organic waste, a higher quality of biogas based on methane composition and production of a nutrient rich fertilizer. Depending on the total solids (TS) concentration of the waste material, anaerobic digestion can be applied under wet (≤ 10% TS), semi-dry (11-19% TS) or solid state (≥20%TS) conditions. Advantages of solid state anaerobic digestion (SS-AD) include water savings, elimination of wastewater disposal and greater potential to reuse the solid residues as fertilizer.

Europe has made great strides in capturing energy from the OFMSW using SS-AD. Within the last five years, 70% of the full-scale installed capacity for the digestion of food/yard waste in Europe is through SS-AD (De Baere, 2012). Numerous full-scale landfill operations either receive source-separated organics or separate the OFMSW using mechanical sorting systems and then digest the waste for energy and fertilizer production. By the end of 2014, it is expected that there will be 244 full-scale plants in Europe, with a combined capacity of 7.8 million tons of OFMSW per year (De Baere, 2012). This amounts to approximately 20% of the MSW stream in Europe. The US; however, has been slow to adopt AD-SS of MSW. One full-scale SS-AD system has recently been completed at the University of Wisconsin, Oshkosh Ohio

(http://www.uwosh.edu/sustainability/what-were-doing), which is operated using food and yard wastes. When fully operational, the system is expected to meet 10% of UW, Oshkosh's electricity needs. Pilot-scale SS-AD systems are under study at the Ohio State University (Li & Liew, 2011) and the University of California, Davis (Rapport et al., 2008).

The overall goal of the proposed project is to investigate the potential for biogas production in Florida from OFMSW using SS-AD. Our overall research approach and measures of success for each objective are detailed in Figure 1. The project is responsive to Hinkley FY 2014-15 research agenda items 16: *What new developments have been made in biological treatment technologies for MSW?* and 41: *What is available and working in terms of MSW conversion technologies?* Specific objectives of the proposed research are to:

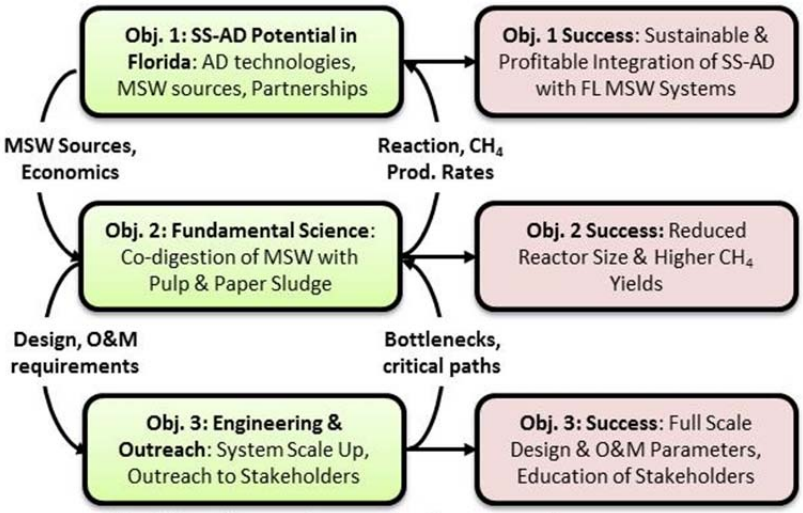

Fig. 1. Overall research approach and measures of success.

1. Evaluate the potential for energy and nutrient recovery from food and yard waste in Florida using SS-AD,
2. Determine an efficient co-digestion strategy for food and yard waste to promote both energy production and recovery of nutrients in the form of a high quality soil amendment and
3. Demonstrate SS-AD technology to stakeholders including FDEP, USEPA and county regulators, county solid waste directors and their staff, private waste management companies and other associated industries, operators, haulers, university and K-12 students, engineers and scientists and community members.

LITERATURE REVIEW

Food and yard waste make up approximately 25% of the overall MSW waste stream in the US. Co-digestion of food and yard waste is advantageous because food waste provides an abundance of nitrogen (N) and yard waste serves as an adequate carbon (C) source. The appropriate balance of C:N is essential for efficient digestion, with the ideal C:N ratio ranging from 25 to 35 (Demirbas, 2006; Hills & Roberts, 1981). Although food waste is easily degraded, the lignin in yard debris acts as a barrier to the microbial population that performs hydrolytic conversion of cellulose (Tong et al., 1990). The main factor that influences the slower anaerobic degradation of these wastes is the hydrolysis of cellulose, mainly due to its crystalline structure, the association of the cellulose and hemicellulose with the lignin and the low activity of the cellulose enzymes present in conventional digesters. Lignin; however, is considered the most important factor affecting the hydrolysis of the cellulose component in lignocellulosic material. The initial degradation step is difficult because the ligno-carbohydrate complexes create a barrier for microbial conversion. Thus degradation of yard waste requires thermal or chemical pretreatment or long retention times.

A novel approach to overcome the lignin challenge in SS-AD is through co-digestion of OFMSW with sludge from anaerobic digesters treating waste from pulp and paper mills. This improves the biodegradability of lignocellulosic waste by integrating microorganisms that are acclimated to anaerobic degradation of lignocellulosic material. An advantage of this approach is that there is no need for a separate pretreatment step that requires chemical addition, high temperatures for thermal pretreatment or aerobic conditions for fungal pretreatment. Mussoline et al. (2013a) carried out pilot-scale SS-AD tests in digesters loaded with different mixtures of rice straw, swine wastewater and paper mill sludge. Paper mill sludge addition was found to accelerate volatile fatty acid (VFA) and methane production compared with a digester operated without paper mill sludge addition. The same specific methane yield (231 LCH_4/kg VS) was obtained in a 93-day digestion cycle in the digester containing the paper mill sludge compared with 189 days without the sludge (Mussoline et al., 2012; Mussoline et al., 2013a). In addition, only half of the swine wastewater was needed when paper mill sludge was added.

Additional experiments were recently conducted in our laboratory by Wendy Mussoline, a visiting doctoral student from the Erasmus Mundus in Environmental Technologies for Contaminated Soils, Solids and Sediments ($ETeCoS^3$) program, a cooperative program between three European universities. Rice straw and sugar cane bagasse were co-digested with swine waste, with and without paper mill sludge (Table 1). Swine waste was obtained from a pig farm in Hillsborough County. Paper mill sludge was obtained from a mesophilic upflow anaerobic sludge blanket (UASB) reactor treating wastewater from a pulp and paper mill. Experiments were conducted in 1L glass reactors at 35°C for 92 days. Methane yields (Table 1) from the digesters containing the paper mill sludge were significantly higher than from digesters with just the straw and bagasse feedstocks or those containing both feedstock and swine wastewater (Mussoline et al., 2013b). Specific methane yields in digesters operated with rice straw were higher than those attained with several pretreatment approaches reported in the literature (Ghosh & B.C., 1999; Lianhua et al., 2010; Zhang & Zhang, 1999) and were comparable to the theoretical value of methane production from rice straw (***i.e.*** 330 LCH_4/kgVS), indicating that complete degradation and conversion was accomplished. VFA results showed that hydrolysis of the straw occurred faster in digesters with higher fractions of sludge. The results showed that the microbial community and nutrients in the paper mill sludge were capable of overcoming the lignocellulosic challenge and accelerating the hydrolysis stage of the SS-AD process for both rice straw and sugar cane bagasse, thus maximizing the methane potential from these feedstocks.

Table 1. Specific methane yields for rice straw and sugar cane bagasse digested with varying amounts of pulp and paper (P&P) sludge.

Rice Straw Treatments	**Methane Yield (L CH_4/kgVS)[a]**	**Sugar Cane Bagasse Treatments**	**Methane Yield (L CH_4/kgVS)[a]**
100% Rice Straw	46	100% Sugar Cane Bagasse	4
67% Swine 33% Straw	BDL	67% Swine 33% Bagasse	BDL
67% P&P 33% Straw	340	67% P&P 33% Bagasse	326
33% Swine, 33% P&P, 33% Straw	335	33% Swine, 33% P&P, 33% Bagasse	279

[a] Values represent methane produced from feedstock only (gas produced from sludge blanks were subtracted); BDL = below detection limits.

SCIENTIFIC APPROACH

Food and yard waste have energy potential, yet the general practice in the US is to dispose of them in landfills. Europe has clearly demonstrated the applicability of SS-AD for the recovery of energy and nutrients from these wastes with numerous full-scale installations. The research team will evaluate the implementation of SS-AD to OFMSW in Florida to help divert unnecessary waste disposal in landfills. The applicability of the co-digestion approach using paper mill sludge will also be evaluated.

Task 1: Potential for SS-AD Implementation in Florida: This phase of the project will allow us to evaluate the most appropriate technologies for implementing SS-AD of MSW and to identify potential sites and collaborators for a large scale demonstration project in Florida. The results will also be used to provide data on the practical compositions of co-digestion mixtures for the bench- and pilot-scale tests described below, as well as the life cycle assessment (LCA) and life cycle cost analysis (LCCA) proposed for year two. A review of the published and grey literature will be conducted on SS-AD of the combined mixture of food and yard waste. Full-scale operations, specifically in the Netherlands, that utilize both batch and continuous flow reactors for digestion of food and yard waste will be researched and documented. SS-AD technologies for continuously-fed systems, such as Dranco, Valorga and Kompogas, will be evaluated to determine the most appropriate design for food and yard waste applications in the US (Lissens et al., 2001). In addition, staff from US MSW facilities, pulp and paper mills, and related industries will be interviewed regarding current practices for waste management, bioenergy and fertilizer production and marketing and perceived barriers to the implementation of SS-AD. Since Florida does not have a large swine industry, alternatives will sought for co-digestion substrates, such as dairy or poultry manure or municipal wastewater sludge.

Task 2: Increase the Biodegradability and Methane Yield of Lignocellulosic Waste: This phase of the project will allow us to assess whether addition of paper mill sludge or digestate from acclimated digesters will increase the biodegradability and methane production from lignocellulosic wastes. Bench-scale SS-AD reactors will be set up in 1-L glass bottles and incubated under mesophilic (35 °C) conditions in a controlled temperature room. The reactors will initially be set up with varying ratios of food waste, yard waste and paper mill sludge. Paper mill sludge will be obtained from Tembec, a Canadian based manufacturer of forest products. Food and yard waste will be obtained from local sources. The digesters will be set up in duplicate, with sludge blanks to correct for gas production by the paper mill sludge. An additional set of bottles will be assembled and sacrificed for intermediate analysis. Digesters will be monitored for biogas production, methane composition of the biogas, volatile solids (VS), pH, alkalinity, and concentrations of VFAs, total nitrogen (TN), total ammonia nitrogen (TAN) and total phosphorous (TP), as described below. Trace metals will be measured at the beginning and the end of the digestion cycle. The specific retention time for the reactors will be determined based on the growth and decline of biogas production, but the estimated digestion cycle is 60 days. A second round of bench-scale tests will be used to test the hypothesis that a portion of the digestate can be used to seed the digesters with acclimated microorganisms, thus avoiding paper mill waste addition after the first acclimation stage.

Task 3: Demonstration SS-AD System: In this phase of the project, a pilot-scale reactor (approximately 1 m^3) will be constructed at the USF Botanical Gardens to demonstrate the application of SS-AD of combined food and yard waste with paper mill sludge addition. The Gardens (www.cas.usf.edu/garden/) are an integrated component of the School of Geosciences,

which serves the research needs of USF and also serves as a portal for the public. The unit will be operated with mixtures of substrates and sludge based on the bench-scale tests. The reactors will be equipped with an internal thermometer and external readout for temperature control and stabilization. A separate tank for excess liquid will be arranged so leachate can be continuously recirculated to provide homogenization and mixing. The duration of the pilot-scale experiments will depend on the digestion cycles determined by the bench-scale tests, but the anticipated time-frame is between 60 and 90 days. The reactor will be monitored for biogas production, biogas quality, and leachate quality and the final digestate will be characterized, as described above. Data from this system will also be combined with food and yard waste availability data to estimate the expected biogas production and power generation rates and quantity and quality of residuals produced for a full-scale system. The pilot system will also serve as a focal point for many of the outreach activities described below.

Analytical methods: *Standard Methods* (APHA, 2012) will be used to measure TN (4500-NO3– E and 4500-P E), TP (4500-P J), COD (5200 B), alkalinity (2320 B), VS, and TS (2540 G) concentrations. Total ammonia nitrogen will be measured using the method of Willis et al. (1996). VFA concentrations will be measured by using a Perkin Elmer GC equipped with an FID. Metals concentrations will be measured by ICP-MS in the Center for Geochemical Analysis at USF. Biogas volume will be measured by water displacement for the bench-scale assays and using wet tip gas meters (Wayne, PA) for the pilot system. CH_4 content of the biogas will be measured using a Gow Mac Instrument Co. gas chromatograph (GC) (Bethlehem, PA) equipped with a thermal conductivity detector.

TIMELINE AND MILESTONES

A summary of the project milestones and timeline for the project is shown in Table 2. Outreach activities are described in the Project Deliverables section.

Table 2. Milestones and timeline for project completion.

Quarter / Project Task	Q1	Q2	Q3	Q4
Literature review	■			
Industry Survey	■			
Bench scale reactor set up	■			
Round 1: Bench scale study		■	■	
Round 2: Bench scale study			■	■
Pilot construction		■		
Pilot study			■	■
Outreach activities	■	■	■	■
Quarterly reports	♦	♦	♦	
Journal Publications		♦		♦
Draft Report				♦
Final Report				♦

POTENTIAL YEAR TWO PROJECTS

If a second year of funding is granted from the Hinkley Center, we will design, construct and operate a continuously-fed SS-AD reactor to demonstrate the practical application for MSW facilities where waste is added on a daily basis. Operating parameters will be based on results of

the bench and pilot-scale reactor experiments described in this proposal and industry standards. Potential sites for this project include the USF campus or one of the Hillsborough County solid waste disposal facilities (e.g. South County Landfill or one of the Yard Waste Processing Centers). Screening level life cycle assessment (LCA) and life cycle cost analysis (LCCA) will also be conducted to identify the combinations of waste sources and SS-AD system designs that have low environmental impacts and total costs over the project life. For the LCA, the system boundary will be cradle-to-gate (MSW processing, transportation, conversion) and the functional unit will be 1 kg methane produced. The impact categories will include cumulative energy demand, greenhouse gas emissions, acidification and eutrophication.

PRACTICAL SPECIFIC BENEFITS FOR END USERS

SS-AD technology is particularly promising for Florida due to the high availability of food and yard waste, warm climate and high energy demands in urban areas. Benefits of SS-AD include diversion of waste from landfills and extended landfill life, higher bioenergy production rates than conventional landfills or landfill bioreactors, reduced greenhouse gas emissions, lower leachate production and the potential to produce a stabilized soil amendment that can be sold or used by municipal agencies or community members. Challenges associated with SS-AD involve slow start-up periods and the need for specialized equipment for handling, pumping and mixing the dry material.

PROJECT DISSEMINATION, STUDENT TRACKING AND DELIVERABLES

The PIs are fully committed to disseminating the results of the proposed research to a variety of stakeholders including FDEP, USEPA and county regulators, county solid waste directors and their staff, private waste management companies and other associated industries, university and K-12 students, engineers, operators, scientists and community members. Their past performance in this respect attests to this commitment. Deliverables for the project will include a project website (to be linked to http://usf-reclaim.org/), project abstract for the general public, quarterly progress reports, a draft and final technical report, TAG meeting videos and minutes posted on the project website, digital photos of faculty and students engaged in project activities, tracking information for faculty and students working on the project and other periodic updates, as requested. The PIs and/or students working on the project will travel to and attend project meetings with Hinkley Center staff and the FDEP as needed or requested by the Center Staff. Results will also be disseminated through presentations at regional and national meetings of professional associations, such as the Water Environment Federation (WEF) and the Solid Waste Association of North America (SWANA). We anticipate that two peer reviewed journal articles will result from this research, one on the results of the literature review and industry survey and one on the results of the bench- and pilot-scale studies.

The co-PIs will also integrate the research into ongoing outreach activities at local public schools, including Middleton Magnet High School for Science Engineering and Technology and Learning Gate Community School. Middle and high school teachers will also be integrated into the project through the NSF funded Research Experience for Teachers (RET) program described below. Past hands-on educational activities at Learning Gate have led to curricula developed for TeachEngineering.org, including topics on waste biorecycling (http://www.teachengineering.org/view_lesson.php?url=collection/usf_/lessons/usf_biorecycling/usf_biorecycling_lesson01.xml) and closed-system thinking (http://www.teachengineering.org/view_lesson.php?url=collection/usf_/lessons/usf_dome/usf_do

me_lesson01.xml). We will use these and new lessons developed as platforms for teaching teachers and K-12 students about our SS-AD research.

Additional outreach and dissemination activities will include outreach at a variety of events. The pilot-scale reactor will be located at the USF Botanical Gardens, which serves as a portal for the public, with over 30,000 visitors annually. The gardens sponsor a large number of well attended events, including Earth Day Tampa Bay and Native Plant sales, where the PIs and their students have showcased their bioenergy related research. The PIs and their students also regularly showcase their research at USF's Engineering Expo (http://expo.eng.usf.edu/), the Florida Water Festival (http://www.fwea.org/water_festival.php) and other similar events. The research will also be integrated into courses taught by the PIs, including Biological Principles in Environmental Engineering, Environmental Biotechnology, Water Quality and Treatment and Green Infrastructure.

DETAILED BUDGET & JUSTIFICATION

A budget for this project is shown in Table 3. A small amount of summer salary (15% of a month) is requested for Drs. Ergas and Yeh. Funds are requested for one full time doctoral student (20 hr/week; $20,020/yr) and one half time masters student (10 hr/week; $8,00/yr), who will carry out the day-to-day work on this project. It is expected that graduate research assistants working on this project will partially derive their dissertation or thesis from the results. Benefits include fringe benefits, health insurance and graduate student tuition (36 credits @ $504/credits). Materials & Supplies are requested for carrying out the bench and pilot-scale studies include materials for reactor construction, chemicals, laboratory gases, glassware and other supplies needed for chemical and microbial analysis of reactor samples. Travel funds are requested for carrying out the industry survey, attending meetings and disseminating results. Additional funds for Drs. Ergas and Yeh and unrecovered indirect costs will be provided as matching by the USF College of Engineering. A cost share letter of commitment is provided as an attachment to this proposal.

Table 3: Project budget.

Budget Item	**Hinkley Center**	**Cost Share**
Ergas Summer	$1,899	$6,329
Yeh Summer	1,683	5,611
Graduate Students	28,020	0
Fringe Benefits	688	1,921
Health Insurance	2,012	1,269
Domestic Travel	3,469	0
Materials and Supplies	4,000	0
Tuition	18,133	0
Total Direct Costs	**$59,904**	**$15,130**
Indirect Costs	0	20,676
Total Project	**$59,904**	**$35,806**

PLAN FOR SEEKING FUNDING

Additional funding sources for this research include DoE, NSF, USEPA, USDA, USAID, the Environmental Research and Education Foundation (EREF) and private industry. Potential research directions include: 1) further investigation of enhanced biomethane production,

including fungal, thermal and/or chemical pretreatment of MSW, 2) investigation of the availability and biodegradability of other Florida waste biomass resources, such as bagasse and sugar cane waste, citrus pulp, forest residues and invasive trees and plants, 3) application of SS-AD in developing countries, 4) development of integrated life cycle assessment-economic assessment tools to assist in SS-AD decision making. In addition, we will apply to USF's Student Green Energy Fund for funding to implement a full-scale SS-AD system on the USF Tampa campus (http://psgs.usf.edu/usf-office-of-sustainability/green-energy-fund/).

RESULTS FROM PRIOR HINKLEY CENTER SUPPORT

Dr. Yeh has previously received Center funding, including projects related to anaerobic membrane bioreactor for treatment of landfill leachate. Center funds supported two graduate students (Dr. Anh Do and David Starman) and contributed to successful funding from the Bill & Melinda Gates Foundation for additional work in this area. Dr. Anh Do is presently a Researcher with the Climate Change Research Center at the Institute of Meteorology Hydrology and Environment, Hanoi, Vietnam (atdo@imh.ac.vn). Mr. David Starman is presently Operations Regional Manager with Seven Seas Water, US Virgin Islands (stars2man@yahoo.com).

TECHNICAL AWARENESS GROUP

We have identified a TAG of individuals knowledgeable in areas related to SS-AD who are willing to serve as advisors to the PIs to ensure project success (Table 4). All have agreed to attend at least two TAG meetings per year (see attached letters of support). The PIs will facilitate this by making remote participation of TAG meetings possible.

Table 4. Technical Awareness Group (TAG) members.

TAG member	Affiliation	Title	Email
Steven G. Morgan	Florida Department of Environmental Protection	Waste Permitting, Environ. Services Section, SW Dist.	Steve.Morgan@dep.state.fl.us
Wendy Mussoline	UF, Dept. Soil & Water Science	Postdoc, Environ. Biotechnology Lab	wmussoli@mail.usf.edu
Juan R. Oquendo	Gresham, Smith & Partners	Sr. Environ. Engineer & Waste to Energy Leader	juan_oquendo@gspnet.com
Debra R. Reinhart	UCF, Dept. Civil, Environ. & Construction Eng.	Professor & Assistant Vice President	Debra.Reinhart@ucf.edu
Larry Ruiz	Hillsborough County	Landfill Operations Section Manager	RuizLE@HillsboroughCounty.ORG
Adrie Veekan	Attero, the Netherlands	Bio-based Products Business Developer	adrie.veeken@attero.nl
Shawn Veltman	CHA Consultants	Director of Technical Services, Water & Wastewater	SVeltman@chacompanies.com

Mr. Steven G. Morgan is an Environmental Scientists in the Waste Permitting Environmental Services Section of the Southwest District Office of the Florida Department of Environmental Protection. His participation in the TAG was arranged through the Hinkley Center as someone from FDEP whose "experience and knowledge will bring value to the process."

Dr. Wendy Mussoline is a postdoctoral researcher in Dr. Ann Wilkie's laboratory at UF. She has a BS and MS in Environmental Engineering from UF and a PhD from three European universities as part of the Erasmus Mundus in Environmental Technologies for Contaminated Soils, Solids and Sediments (ETeCoS^3). Dr. Mussoline carried out the research described above on enhanced methane production from lignocellulosic materials using SS-AD.

Mr. Juan Oquendo is an Environmental Engineering consultant who specializes in the biosolids practice area. He earned a BS in Civil Engineering from the Univ. of Puerto Rico and is a PE in Florida and Georgia. Juan has managed a number of waste-to-energy projects including food co-digestion and AD facilities in Miami and Baton Rouge.

Dr. Debra Reinhart has been conducting research in the field of MSW management, including the degradation of organic matter in landfills, for over 27 years. She is an Associate Editor for the *Waste Management Journal*. She is a registered PE in Florida and Georgia, a Board Certified Environmental Engineer, and Fellow of the ASCE and the AAAS.

Mr. Larry Ruiz has over 25 years of environmental project and waste management experience, including landfill siting and design, landfill operation, leachate monitoring and treatment system design and operation, landfill gas collection and control system design and solid waste facility environmental assessment.

Dr. Adrie Veekan is a bio-based product business developer with Attero, the Netherlands. He has 25 years of experience in organic waste treatment, including design and operation of full-scale AD facilities in the Netherlands where the treatment of organic waste via AD is widely established.

Dr. Shawn Veltman is the Director of Technical Services in the Water and Wastewater Division of CHA. Dr. Veltman has worked on dozens of traditional and high rate AD projects in the US and Canada to treat a wide range of substrates. CHA has completed multiple biogas to energy projects with electric power generation of up to 12 MW using internal combustion engines, microturbines, Stirling engines, and Organic Rankine Cycle technology.

RESEARCH COLLABORATION

Drs. Ergas and Yeh will be responsible for project administration, overseeing report writing, and recruiting and advising qualified USF Civil & Environmental Engineering graduate students who will carry out the day-to-day work on this project. Dr. Sarina J. Ergas is a professor and graduate program director in the Department of Civil & Environmental Engineering at the University of South Florida and a registered professional engineer in the Commonwealth of Massachusetts. Dr. Ergas has over 20 years of experience conducting laboratory and pilot-scale studies of biological treatment processes including wastewater treatment, bioremediation and waste-to-energy technologies. Dr. Daniel Yeh is an associate professor of Civil & Environmental Engineering and research fellow with the Patel Center of Global Solutions at the University of South Florida (http://mbr.eng.usf.edu/). He is a registered professional engineer in Georgia and a LEED Accredited Professional (Green Building Certification Institute). Dr. Yeh's research and teaching interested are related to water treatment, wastewater reuse and recovery of embedded energy and nutrients from wastes using membrane technologies and biological processes.

The proposed Year 2 LCA studies will be led by Dr. Qiong Zhang. Dr. Zhang is an assistant professor in the Department of Civil and Environmental Engineering at USF. She worked for the Sustainable Futures Institute at Michigan Tech as the operation manager before she joined USF.

Her research includes embodied energy modeling, life cycle assessment of bio-energy systems, and sustainability engineering education.

The project will leverage NSF funded Research Experience for Undergraduates (http://reu-tier.net/) and Research Experience for Teachers (http://www.wareret.net/) programs in the Department of Civil & Environmental Engineering at USF. The programs bring talented undergraduates from all over the US and local middle and high school science teachers to USF over the summer months to participate in ongoing environmental engineering research projects. Graduate student mentors are given specific training in mentoring novice researchers in order to make these research internships productive. Teachers continue to work with their student and faculty mentors during the academic year to translate their research into classroom projects at local secondary schools. Drs. Ergas, Yeh and Zhang are all active participants in the REU and RET programs and Ergas is a co-PI on the REU grant. We anticipate that each graduate student working on the project will be assigned to mentor either an REU or an RET during each summer of Hinkley center funding.

The project will also leverage a USF collaboration on Biological Waste-to-Energy Technologies (BioWET) with two European partners through a European Commission-funded project that supports faculty and graduate student mobility from UNESCO-IHE (Delft, The Netherlands) and Institute of Chemical Technology (ICT, Czech Republic) to USF. In particular, ICT has a long-term experience in SS-AD and will send a graduate student to USF for six months to work to improve methane yields from solid organic materials (see attached letter of support).

PERTINENT LITERATURE

De Baere L., B., M. 2012. Anaerobic digestion of the organic fraction of municipal solid waste in Europe - Status, experience and prospects in: *Waste Management, Vol 3: Recycling and Recovery*, Vol. 3, TK, pp. 517-526.

Demirbas, A. 2006. Biogas potential of manure and straw mixtures. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, **28**(1), 71-8.

EPA. 2013. Landfill Methane Outreach Program, http://www.epa.gov/lmop/basic-info/index.html#http://www.epa.gov/lmop/documents/pdfs/generating.pdfa03.

Ghosh, A., B.C., B. 1999. Biomethanation of white rotted and brown rotted rice straw. *Bioprocess Engineering*, **20**, 297-302.

Hills, D.J., Roberts, D.W. 1981. Anaerobic digestion of dairy manure and field crop residues. *Agricultural Wastes*, **3**, 179-89.

Li, Y., Liew, L.N. 2011. Solid-state anaerobic digestion for energy production from organic wastes, The Ohio State University Extension Agriculture and Natural Resources Fact Sheet (AEX-653-11), The Ohio State University, Columbus, OH.

Lianhua, L., Dong, L., Yongming, S., Longlong, M., Zhenhong, Y., Xiaoying, K. 2010. Effect of temperature and solid concentration on anaerobic digestion of rice straw in South China. *Int J of Hydrogen Energy*, **35**, 7261-6.

Lissens, G., Vandevivere, P., De Baere, L., Biey, E.M., Verstrae, W. 2001. Solid waste digestors: process performance and practice for municipal solid waste digestion. *Water Sci Technol*, **44**(8), 91-102.

Mussoline, W. 2012. Personal communication. VAR Site Visit, Wilp, The Netherlands.

Mussoline, W., Esposito, G., Lens, P., Garuti, G., Giordano, A. 2012. Design considerations for a farm-scale biogas plant based on pilot-scale anaerobic digesters loaded with rice straw and piggery wastewater. *Biomass and Bioenergy*, **46**, 469-78.

Mussoline, W., Esposito, G., Lens, P., Giordano, A. 2013a. Enhanced methane production from pilot-scale anaerobic digester loaded with rice straw. *The Open Environmental Engineering Journal*, **6**, 32-39.

Mussoline, W., Esposito, G., Lens, P., Spagni, A., Giordano, A. 2013b. Enhanced methane production from rice straw co-digested with anaerobic sludge from pulp and paper mill treatment process. *Bioresour Technol*, **148**, 135-143.

Rapport, J., Zhang, R., Jenkins, B.M., Williams, R.B. 2008. Current Anaerobic Digestion Technologies Used for Treatment of Municipal Organic Solid Waste. University of California, Davis.

Tong, X., Smith, L.H., McCarty, P.L. 1990. Methane fermentation of selected lignocellulosic materials. *Biomass*, **21**, 239-55.

Zhang, R., Zhang, Z. 1999. Biogasification of rice straw with an anaerobic-phased solids digester system *Bioresour Technol*, **65**, 235-45.

SARINA J. ERGAS, PhD, PE, BCEE

Professor and Graduate Program Director
Phone: (813) 974-1119, Fax: (813) 974-2957
Email: sergas@eng.usf.edu

Dept. Civil & Environmental Engineering
University of South Florida
4202 E Fowler Avenue, ENB 118
Tampa, FL 33620

Professional Registration

Professional Engineer, Commonwealth of Massachusetts, Civil Engineering, 1995-present
Board Certified Environ. Engineer, Specialization: Water Supply/Wastewater Engineering, 2012-present

Professional Preparation

Humboldt State Univ., Arcata, CA	Environmental Engineering	B.S.	1988
University of California, Davis, CA	Civil Engineering,	M.S.	1990
University of California, Davis, CA	Civil & Environmental Engineering	Ph.D.	1993

Academic Appointments

2011-present	Professor	Civil & Environ. Engineering., Univ. South Florida
2009-2011	Assoc. Professor	Civil & Environ. Engineering., Univ. South Florida
2009-2010	Professor	Civil & Environ. Engineering, Univ. Massachusetts, Amherst
2000-2009	Assoc. Professor	Civil & Environ. Engineering, Univ. Massachusetts, Amherst
1994-2000	Asst. Professor	Civil & Environ. Engineering, Univ. Massachusetts, Amherst
2007-2008	Fulbright Fellow	Civil, Environ. & Ag. Engr., Technion Israel Inst. Technol.

Selected Publications

Kinyua, M.N., Cunningham, J., Ergas, S.J. (2014) Effect of Solids Retention Time on the Bioavailability of Organic Carbon in Anaerobically Digested Swine Waste, *Bioresource Technology*, in press.

Udom, I., Zaribaf, B.H.; Halfhide, T.; Gillie, B.; Dalrymple, O.; Zhang, Q.; Ergas, S.J. (2013) Harvesting Microalgae Grown on Wastewater, *Bioresource Technology*, 139: 101-106.

Baek, K., McKeever, K., Rieber, K., Sheppard, D., Park, C., Ergas, S.J., Nüsslein, K. (2012) Molecular approach to evaluate of biostimulation of 1,2-dibromoethane in contaminated groundwater, *Bioresource Technology*, 123:207-213..

Bailey, K.L., Tilton, F., Jansik, D.P., Ergas, S.J., Marshall, M.J., Miracle, A.L., Wellman, D.M. (2012) Growth Inhibition and Stimulation of *Shewanella oneidensis* MR-1 by Surfactants and Calcium 1 Polysulfide, *J. Ecotoxicology Environmental Safety,* 80: 195-202.

McKeever, R., Sheppard, D., Nüsslein, K., Baek, K-H, Rieberb, K., Ergas, S.J., Forbes, R., Hilyard, M., Park, C. (2012) Biodegradation of Ethylene Dibromide (1,2-Dibromoethane [EDB]) in Microcosms Simulating *In Situ* and Biostimulated Conditions, *J. Hazardous Materials*, 209:92-98.

Yuan, X., Wang, M., Park, C., Sahu, A.K., Ergas, S.J. (2012) Microalgae Growth Using High Strength Wastewater Followed by Anaerobic Co-digestion, *Water Environ. Research*, 84(5):396-404.

Coggon, M., Becerra, C.A., Nusslein, K., Miller, K., Yuretich, R., Ergas, S.J. (2012) Bioavailability of jarosite to iron reducing bacteria from an acid mine drainage site, *Geoch. Cosmoch. Acta*, 78: 65-76.

Boles, A., Conneely, T., McKeever, R., Nixon, P., Nüsslein, K., Ergas, S.J. (2012) Performance of a Pilot-Scale Packed Bed Reactor for Perchlorate Reduction Using a Sulfur Oxidizing Bacterial Consortium, *Biotechnology & Bioengineering*, 109(3): 637-646.

Yuan, X., Kumar, A., Sahu, A.K., Ergas, S.J. (2011) Impact of Ammonia Concentration on *Spirulina platensis* Growth in an Airlift Photobioreactor, *Bioresource Technology,* 102(3): 3234-3239.

Ergas, S.J., Sengupta, S., Siegel, R., Yao, Y., Pandit, A., Yuan, X. (2010) Denitrifying bioretention systems for control of non-point nitrogen sources, *J. Envir. Eng.-ASCE,* 136(10):1105-1112.

Sahu, A.K., Sengupta, S., Ergas, S.J. (2009) Onsite hydrogenotrophic wastewater denitrification using a hollow fiber membrane biofilm reactor, *Water Environment Research*, 81(7): 680-686.

Sahu, A.K., Conneely, T., Nüsslein, K., Ergas, S.J. (2009) Biological perchlorate reduction in packed bed reactors using elemental sulfur, *Environmental Science & Technology*, 43(12):4466–4471.

Daniel H. Yeh, Ph.D., P.E., LEED AP BD+C
Associate Professor, Dept. of Civil & Environmental Engineering, University of South Florida
4202 E. Fowler Ave., ENB 118, Tampa, FL 33620-5350 USA
(813) 974-4746 (TEL) (813) 974-2957 (FAX) dhyeh@usf.edu http://mbr.eng.usf.edu

PROFESSIONAL PREPARATION

The University of Michigan – Ann Arbor, MI	Civil Engin.	BSE, 1991
The University of Michigan – Ann Arbor, MI	Natural Resources	BS, 1991
Manhattan College – Riverdale, NY	Environmental Engin.	Grad courses, 1991-92
The University of Michigan – Ann Arbor, MI	Environmental Engin.	MSE, 1993
Georgia Institute of Technology – Atlanta, GA	Environmental Engin.	PhD, 2000

APPOINTMENTS

2011-present	Associate Professor, Dept. Civil & Environ. Engg, Univ. South Florida, Tampa, FL.
2009-present	Faculty (courtesy appt.), Dept. Global Health, Univ. South Florida, Tampa, FL.
2008-2011	Faculty Research Fellow, Patel Center for Global Solutions, U. So. Florida, Tampa, FL.
2005-2011	Assistant Professor, Dept. Civil & Environ. Engg, Univ. South Florida, Tampa, FL.
2002-04	Postdoctoral Research Fellow, Department of Civil & Environmental Engineering, Stanford University, Stanford, CA, and NSF STC WaterCAMPWS.
2000-02	Manager, Product & Technology Development, Wei Ming Pharma., Taipei, Taiwan
1994-99	Graduate Research Assistant, School of Civil & Environmental Engineering, Georgia Institute of Technology, Atlanta, GA
1993-94	Research Engineer, Scientific Research Lab, Ford Motor Company, Dearborn, MI.
1991-92	Environmental Engineer, HydroQual, Inc., Mahwah, NJ

PUBLICATIONS

Drexler, I., A. Prieto, R. Bair, C. Joustra, D.H. Yeh. 2014. AlgaeSim: A model for integrated algal biofuel production and wastewater treatment. *Water Environ. Res.* (in press)

Kijjanapanich, P., A.T. Do, A.P. Annachhatre, G. Esposito, D.H. Yeh, P.N.L. Lens. 2013. Biological sulfate removal from construction and demolition debris leachate: Effect of bioreactor configuration. *J. Hazardous Materials* (in press)

Qiao, Y. A.T. Do, D.H. Yeh and M.J. Watts. 2013. A bench-scale assessment of ozone pre-tretments for landfill leachates. Environ. Technol. 35:145-153, DOI:10.1080/09593330.2013.821141

Prieto, A.L., H. Futselaar, P. Lens, R. Bair and D.H. Yeh. 2013. Gas-lift anaerobic membrane bioreactor (GL-AnMBR) for conversion of sewage to energy, water and nutrients. *J. Memb. Sci.* 441:158-167.

Cruz Espinoza, L., D. Yeh, B. Vinneras, L. Rajaram, L. Whiteford, J. Corvin and R. Izurieta. 2012. Inactivation of *Ascaris Suum* by ammonia in feces simulating the parameters of the solar toilet. *J. Appl. Sci. Environ. Sanitation* 7:173-182.

Fox, D., T. Pichler, D.H. Yeh and A. Alcantar. 2012. Removing heavy metals in water: The interaction of cactus mucilage and arsenate (As(V)). *Environ. Sci. Technol.* 46 (8), 4553–4559

Gao, D.-W., T. Zhang, C.-Y. Tang, W.-M. Wu, C.-Y. Wong, Y.H. Lee, D.H. Yeh, C.S. Criddle. 2010. Membrane fouling in an anaerobic membrane bioreactor: differences in relative abundance of bacterial species in the membrane foulant layer and in suspension, *J. Membrane Sci.,* doi:10.1016/j.memsci.2010.08.031.

Guest, J. S.; Skerlos, S. J.; Barnard, J. L.; Beck, M. B.; Daigger, G. T.; Hilger, H.; Jackson, S. J.; Karvazy, K.; Kelly, L.; Macpherson, L.; Mihelcic, J. R.; Pramanik, A.; Raskin, L.; van Loosdrecht, M. C. M.; Yeh, D.; Love, N. G. 2009. A new planning and design paradigm to achieve sustainable resource recovery from wastewater. *Environ. Sci. Technol.,* 43(16), doi:10.1021/es9010515.

Ferlita, R.R., D. Phipps, J. Safarik and D.H. Yeh. 2008. Cryo-snap: A simple modified freeze-fracture method for SEM imaging of membrane cross sections. *Environ. Progress.* 27:204-209.

O. Dalrymple, D. H. Yeh and M.A. Trotz. 2007. Removing Pharmaceuticals and Endocrine Disrupting Compounds from Wastewater by Photocatalysis: Review. *J. Chem. Tech. & Biotech.* 82:121-134.

UNIVERSITY OF
SOUTH FLORIDA
COLLEGE OF ENGINEERING

April 3, 2014

John D. Schert, Executive Director
Hinkley Center for Solid and Hazardous Waste Management
P. O. Box 116016
Gainesville, FL 32611

Dear Mr. Schert:

The College of Engineering at the University of South Florida enthusiastically endorses the submission of Dr. Ergas' proposal entitled *Bioenergy Production from MSW by Solid State Anaerobic Digestion* which is being submitted to the Hinkley Center for Solid and Hazardous Waste Management. To show our support, the College of Engineering will provide cost share as shown below:

Salary of 0.50 month per year (Dr. Ergas)	6,329
Salary of 0.50 month per year (Dr. Yeh)	5,611
Fringe and insurance	3,190
Unrecovered IDC	20,676
Total	$35,806

Thank you for your consideration of this proposal. We appreciate this exciting opportunity.

Sincerely,

Jose L. Zayas-Castro
Associate Dean for Research
College of Engineering, USF

COLLEGE OF ENGINEERING
University of South Florida • 4202 East Fowler Avenue, ENB 118 • Tampa, Florida 33620-5350
(813) 974-5589 • FAX (813) 974-0460

INSTITUTE OF CHEMICAL TECHNOLOGY, PRAGUE
Faculty of Environmental Technology
Department of Water Technology and Environmental Engineering

27-March, 2014

Re: Support for Hinkley Center project, Bioenergy Production from MSW by Solid State Anaerobic Digestion

Dear Sarina,

I am writing in support of the proposal being submitted to the Hinkley Center for Solid and Hazardous Waste Management entitled "Bioenergy Production from MSW by Solid State Anaerobic Digestion." The proposed project provides an opportunity for professors and students at Prague ICT to collaborate with students and faculty at USF to study innovative and sustainable approaches to solid-state anaerobic digestion (SS-AD) using MSW from Florida facilities. The SS-AD project also fits well with our recently funded international research staff exchange scheme (IRSES) grant entitled Biological Waste-to-Energy-Technologies (BioWET), which was funded by the European Commission and is focused on bioenergy production (with total budget of 249 900 €). As you know, the research includes international exchanges of students, faculty and staff between USF, ICT Prague and UNESCO-IHE in Delft, The Netherlands. Students and faculty will work on a range of projects, including anaerobic digestion, bio-hydrogen production from food waste, SS-AD of municipal solid waste, sediment microbial fuel cells and sustainable algal biofuel production. Two doctoral students (in total 18 months) and several faculty (in total 3 to 6 months) from ICT Prague will conduct research on SS-AD at USF as part of this grant. The IRSES grant pays for travel, housing and other mobility expenses while students from ICT Prague work with USF faculty and graduate students involved in this project. This will enhance knowledge sharing and create knowledge flow between our two countries (U.S. and the Czech Republic).

We look forward to working with you on this project that builds on our relationship with USF. Please contact me at Jan.Bartacek@vscht.cz if you have any other questions regarding this project.

Sincerely,

Jan Bartacek,
Assistant Professor, Dept. Water Technology and Environmental Engineering
Institute of Chemical Technology Prague

Phone: +420 220 444374, e-mail: Jan.Bartacek@vscht.cz, www.vscht.cz
Technická 5, 166 28 Prague 6 - Dejvice, Czech Republic

April 4, 2014

Dr. Sarina Ergas
Dept. Civil & Environmental Engineering
University of South Florida
4202 East Fowler Ave., ENB 118
Tampa FL 33620

Dear Sarina,

I am writing in support of your proposal to the Hinkley Center for Solid and Hazardous Waste Management entitled "Bioenergy Production from MSW by Solid State Anaerobic Digestion." I would be happy to serve on the Technical Awareness Group (TAG) for this project. I understand that TAG members must be willing to attend a minimum of two TAG meetings per year, and give advice and suggestions to you, Dr. Yeh and the USF students working on this project regarding the proposed research project.

I am a recent graduate of the European Erasmus Mundus Joint PhD program and am currently a post-doctorate research at the University of Florida working on biogas potential of wastes associated with the eTuber™ industry. I received a joint PhD from the University of Cassino (Italy), UNESCO-IHE (The Netherlands) and University of Paris East (France) and conducted her PhD research on biogas production from lignocellulosic waste residues. I introduced an innovative co-digestion approach to enhance methane production from rice straw, and worked to optimize this approach in lab, pilot and a full-scale system located in Northern Italy. I am well acquainted with the tasks associated with the Hinkley 2014-2015 proposal and will be glad to provide professional expertise on this project as a professional courtesy.

I look forward to working with you on this exciting project.

Sincerely,
Wendy Mussoline, PE, PhD

Hillsborough County
Florida

Office of the County Administrator
Michael S. Merrill

March 18, 2014

Dr. Sarina Ergas
Dept. Civil & Environmental Engineering
University of South Florida
4202 East Fowler Ave., ENB 118
Tampa, FL 33620

Dear Sarina,

I am writing in support of your proposal to the Hinkley Center for Solid and Hazardous Waste Management entitled "Bioenergy Production from MSW by Solid State Anaerobic Digestion." I would be happy to serve on the Technical Awareness Group (TAG) for this project. I understand that TAG members must be willing to attend a minimum of two TAG meetings per year, and give advice and suggestions to you, Dr. Yeh and the USF students working on this project regarding the proposed research project.

I have over 25 years of environmental project experience, with particular emphasis in the solid waste management field including landfill siting and design, landfill operations, landfill closure plans, landfill leachate monitoring and treatment system design, landfill gas collection and control systems design, and Solid Waste Facilities environmental assessment. I currently serve as Landfill Operations Section Manager for Hillsborough County, Florida. I believe that my technical and operational experience can be of value to this research project.

I look forward to working with you on this exciting project.

Sincerely,

Larry E. Ruiz

Larry E. Ruiz
Manager Landfill Operations
Public Works Department,
Solid Waste Management Division

Hi Sarina,

I would be honored to participate as a member of the TAG. Thanks for considering me. Please keep me posted of the schedule and additional details as your proposal progresses. Let me know if you need additional assistance.

Best regards,

Juan R. Oquendo, PE

GRESHAM, SMITH AND PARTNERS
[P] 813.251.6838
[D] 813.769.8931
[M] 813.440.1413

Sarina:

I would be happy to serve on your TAG for this research project. Let me know how I can be of assistance.

Please feel free to e-mail or call me if you have any further questions. Please note the recent changes in the Southwest District office number and my phone and extension in the signature block below.

Steven G. Morgan, Waste Permitting
Environmental Services Section
Florida Department of Environmental Protection
Southwest District Office
13051 North Telecom Parkway
Temple Terrace, FL 33637-0926

office phone #: (813) 470-5700 ext 45754
direct phone #: (813) 470-5754
fax - (813) (813) 470-5996
e-mail - steve.morgan@dep.state.fl.us

University of Central Florida

Office of Research & Commercialization

February 25, 2014

Dr. Sarina Ergas
Dept. Civil & Environmental Engineering
University of South Florida
4202 East Fowler Ave., ENB 118
Tampa FL 33620

Dear Sarina,

I am writing in support of your proposal to the Hinkley Center for Solid and Hazardous Waste Management entitled "Bioenergy Production from MSW by Solid State Anaerobic Digestion." I would be happy to serve on the Technical Awareness Group (TAG) for this project. I understand that TAG members must be willing to attend a minimum of two TAG meetings per year, and give advice and suggestions to you, Dr. Yeh and the USF students working on this project regarding the proposed research project.

As you know, I have been conducting research in the solid waste management field for over 27 years. In particular, I have been studying the breakdown of organic matter in landfills. Further, I am an Associate Editor for the *Waste Management Journal*, a member of the Managing Board of the IWWG, and a member of the Environmental Research and Education Foundation board. I am a registered professional engineer in Florida and Georgia, a Board Certified Environmental Engineer, and Fellow of the American Society of Civil Engineers and the American Association for the Advancement of Science.

I look forward to working with you on this exciting project.

Sincerely,

Debra R. Reinhart

Debra R. Reinhart, PhD, PE, BCEE
Assistant Vice President
Pegasus Professor

4000 Central Florida Blvd• Millican Hall Room 243 • Orlando, FL 32816
(407) 823-2315 • FAX (407) 882-2819 • reinhart@mail.ucf.edu

Attero NV

Dr. Sarina Ergas
Dept. Civil & Environmental Engineering
University of South Florida
4202 East Fowler Ave., ENB 118
Tampa FL 33620

ons kenmerk		**contactpersoon**	Dr. Adrie Veeken
uw kenmerk		**telefoon**	+31 6 11 39 42 68
datum	10 March 2014	**e-mail**	adrie.veeken@attero.nl
onderwerp	Technical Awareness Group		

Dear Sarina,

I am writing in support of your proposal to the Hinkley Center for Solid and Hazardous Waste Management entitled “Bioenergy Production from MSW by Solid State Anaerobic Digestion”. I would be happy to serve on the Technical Awareness Group (TAG) for this project. I understand that TAG members must be willing to attend a minimum of two TAG meetings per year, and give advice and suggestions to you, Dr. Yeh and the USF students working on this project regarding the proposed research project.

I’m active in the field of organic waste treatment for 25 years in academics, consultancy, government and business. After my MSc studies in Chemistry and Environmental Sciences I started with my PhD at Wageningen University in 1990. I have been working as a researcher and assistant professor until 2004 in Environmental Technology and Urban Environmental Management. From 2004-2007 I was a consultant at LeAF as head of the Biogas group and the laboratory activities. In 2008, I joined the Waste Management Department of the Dutch government, involved in various international waste management projects. From 2011, I’m working for the waste company Attero where I started as a process engineer and at present I am a business developer of Bio-based products. So I have extensive experience in various aspects of organic waste recycling, AD and composting. I have written various scientific papers on AD as a researcher and at Attero I have had experiences with various types of full-scale AD facilities and types of AD technology. In the Netherlands, the treatment of organic waste via AD is widely established and we have a lot of experiences on the do and don’t’s of AD.

I look forward to working with you on this exciting project.

Sincerely,

Dr. Adrie Veeken
Business developer Bio-based products
Attero
The Netherlands

Roermondseweg 53
6081 NT HAELEN
Postbus 4114
6080 AC HAELEN

Telefoon: (088) 550 10 00
Telefax: (088) 550 23 54
E-mail: info@attero.nl
Internet: www.attero.nl

ING 66.94.41.376
IBAN NL47 ING B 0669 441376
BIC INGBNL2A
KvK: 18034173
BTW nr: NL800318444B01

March 5, 2014

Dr. Sarina Ergas
Professor and Graduate Program Coordinator
Dept. Civil & Environmental Engineering
University of South Florida
East Fowler Ave., ENB 118
Tampa FL 33620

Re: Letter of Support for Research Proposal on Solid State Anaerobic Digestion

Dear Dr. Ergas:

I would like to confirm my interest and support for your research proposal to the Hinkley Center for Solid and Hazardous Waste Management on "Solid State Anaerobic Digestion". I would be happy to serve on the Technical Awareness Group (TAG) for this project.

CHA is a full-service engineering company with approximately 1,400 staff located in more than 35 domestic and international offices. As you know, our firm serves clients in the Aviation, Power & Energy, Water & Wastewater, Manufacturing, Pulp & Paper, and Solid Waste markets. We are a Flex-Tech service provider for the New York State Energy & Development Authority (NYSERDA). We have developed dozens of traditional (low solids, low rate) anaerobic digestion projects and several high rate anaerobic digesters in the United States and Canada to treat a wide range of primary and secondary (co-digestion) substrates. Our firm was the first to utilize anaerobic treatment to treat aircraft deicing waste and we have completed multiple biogas to energy projects with electric generation capacities of up to 12 MW using internal combustion engines, microturbines, Stirling engines, and Organic Rankine Cycle technology.

Growing interest in the production of renewable energy and bans on the disposal of organic wastes in landfills has stimulated a great deal of interest in solid state anaerobic digestion, particularly in the northeast where our business is centered. We applaud your efforts to advance the technology needed to effectively digest semi-solid substrates including lignocellulosic biomass.

CHA is prepared commit the following in support of your research:

- My time and travel costs to attend a minimum of two TAG meetings per year to give advice and suggestions to you, Dr. Yeh, and the USF students working on this project regarding the proposed research project;
- Data sharing, testing results, and data we have collected from various digester and biogas to energy projects; and
- Engineering technical advice.

I look forward to the opportunity to work with you and your colleagues on this worthwhile effort.

Sincerely,

Shawn H. Veltman, PhD, P.E.
Director of Technical Services –
Water & Wastewater

SHV/egl