Water Environment Research Foundation
Lauren Fillmore, Senior Program Director
635 Slaters Lane, Suite G110
Alexandria Virginia 22314
Email: lfillmore@werf.org Phone: 571 384-2107

Subject: **RFI DE-FOA-0000933 Waste Applications for Sustainable Technologies for Energy**

The Water Environment Research Foundation (WERF) is a leading independent scientific organization addressing research needs of wastewater treatment providers, including pioneering research to improve energy efficiency in treatment processes, reduce fugitive greenhouse gas emissions, and recover heat, energy and other resources previously wasted as constituents in treated effluents.

1 pound of dry biosolids has 8,000 BTUs 1 ft^3 biogas has 600-700 BTUs

The energy content embedded in wastewater (e.g., chemical, thermal, kinetic) is typically 2 - 4 times the energy needed to treat it (Tchobanoglous, 2009). In some cases, the energy content can be as high as ten times the energy for treatment (WERF, 2010). Treatment facilities, even those using best practices, currently produce only a fraction of the energy they require for their operations. If a self-sufficient operating paradigm is to be achieved, new practices, technologies and information must be developed and deployed; to do so will require substantial and immediate investment into research and demonstrations.

The wastewater sector is positioned to lead in this direction because our operations are presently significant energy users although wastewater contains opportunities to capture and reuse renewable energy. This paper is our response to questions in RFI CATEGORY 3 ***Community Scale Applications of Waste to Energy for Sustainable Production*** based on wastewater, biosolids and biogas. Our colleagues, NACWA and WEF, have submitted responses to Category 1 and 2 questions, respectively.

Anaerobic digestion (AD), the bioconversion of biosolids into biogas by microorganisms in the absence of oxygen, is a process utilized by approximately 10% of all U.S. WRRFs (water resource recovery facilities formerly known as wastewater treatment plants) (Beecher and Qi, 2013). Although AD is considered an established process (EPA 832-R-06-005), there are several innovative modifications to the original two-stage mesophilic (operated at ambient temperature) process to enable significantly more biogas recovery.

1) What innovative system approaches are available for AD to more effectively generate heat, power or fuel? These innovative AD processes improve methane yields: modify the temperature during operations (thermophilic or temperature phased), enhance mixing (e.g. linear motion mixers), improve the shape of the digester (egg-shaped instead of cylindrical tanks), and better control of the organic loading (high rate), pH (acid-phased) and alkalinity. In addition, there are several emerging processes that pretreat the renewable feed (biosolids removed from the wastewater) by heat, pressure, chemicals and physical means. The pre-treatment of biosolids using these processes (e.g. Cambi™, Microsludge™, ozonation) frequently increases the biogas (WERF,2010; 05-CTS-3).

WERF is aware of many examples of research into new AD processes. One example is Columbus Advanced Biosolids Flow-through Thermophilic Treatment (CBFT3). This process is a modification of thermophilic AD using a plug-flow reactor developed by Columbus (GA) Water Works. While improving pathogen reduction in biosolids, the process train generates biogas and incorporates advanced

reciprocating engines to produce electricity from that biogas which supplies 40-50% of the plant electricity needs. The overall energy efficiency of the process is 68-83%.

The co-digestion of organic waste with wastewater solids to improve production of biogas is another new approach applied at WRRFs. Non-municipal wastewater-derived organic waste is accepted by WRRFs to increase the production of biogas by digesting this waste with the wastewater solids. Common examples of waste co-digested include: fats, oils and grease (from restaurant grease traps and food processing), other organic wastes from industrial food manufacturing, waste glycerol from biodiesel production, and organic wastes (food scraps) separated from post-consumer and commercial sources. While this practice has taken off (examples include East Bay Municipal District, Oakland, CA, Sheboygan, WI, and Gloversville-Johnstown, NY,) it can lead to operational challenges and even AD upset. Questions that each WRRF needs to answer before proceeding with co-digestion is how much organic waste can be added and still have stable digestion. WERF is conducting research now that helps provide answers to those questions and develops operational metrics to ensure stable digestion when adding non-wastewater derived solids.

Some organic wastes require preparation to become a feedstock amenable to digestion. Digester mixing, especially with co-digestion of organic wastes, becomes critical and the impact of poor mixing is not fully understood. Co-digestion also has other operational issues, such as better control of foaming and altered characteristics of residual biosolids which need to be evaluated to optimize the potential of this practice.

There are additional ways to increase the productivity and efficiency of AD by improving better and more economical ways to utilize the biogas for energy recovery. Cheaper and easier ways to remove siloxanes and other contaminants from biogas enhance the potential for energy recovery. While there is ongoing research into new technologies, like fuel cells, to recovery energy from biogas, extensive biogas clean up requirements to prevent fouling in these newer technologies are economic barriers to their greater use. Given the ‘dirty’ nature of biogas, re-designed Stirling engines (external combustion engines) in a modular unit suitable to convert biogas to electric energy at WRRFs would be advantageous.

2) Increasing the effectiveness of the microbial consortia, what characterization methods and laboratory techniques have had the most success? WERF, by supporting research efforts led by Dr. Kartik Chandran, Columbia University, is furthering the understanding of microbial metabolic pathways and characterizing the structure and function of communities in full-scale wastewater systems using high-throughput meta-nomic techniques, such meta-genomics, transcriptomics and proteomics. While this ongoing WERF study is not to investigate methanogens, a similar study conducted on the microbial consortia in digesters could yield valuable results and advance our ability to improve and stabilize digester operations yielding more efficient conversion of organics to biogas. The rate-limiting step in AD is the conversion by methanogens to methane (M&E, 2007). Further microbial research into the metabolic pathways, understanding inhibition and conditions promoting conversion to methane would be the most beneficial to optimize biogas production.

Metabolic Pathways of AD

1. Hydrolysis: performed by hydrolytic fermentative bacteria
2. Acidogenesis - fermentative bacteria
3. Acetogenesis – acetogenic bacteria
4. Methanogenesis – methanogenic bacteria

3) Modular waste to energy conversion systems: Municipal WRRFs are a reliable, consistent source of organic waste materials with high energy content amenable to recovery. Modular waste to energy systems have advantages such as the ability to scale-up or scale-down operations if the waste source is not consistent, and would have specific application at regional facilities where the contributions from participating plants vary over time in quantity and characteristics. Also modular units are appealing for small plants (2008 USEPA CWNS estimates 11,257 WRRFs are under 1 mgd size).

Principle technical barriers against utilizing biosolids as an energy resource include: overcoming the high water content to achieve net energy production; air quality issues; negative public perception and high capital cost with limited funding alternatives for new technologies and investments not mandated by regulatory requirements. The issue of water content does not apply to AD but is a concern for thermal oxidation processes such as gasification and pyrolysis.

> "Limitation of capital funds is a major barrier. Maintaining the District's mission takes priority. This issue could not be overcome by 20-30 year paybacks for biogas projects"
> ***Carrie Clement, WLSSD (MN)*** *Uses biogas for heat*

Other more significant barriers to advancing energy recovery from wastewater stem from legacy electric utility regulations and electric utility practices: A WERF study into barriers to energy recovery from biogas noted that it was electric utility practice in many places to charge penalties for reduced electric power purchase offsetting any cost savings. Other disincentives include a lack of recognition of biosolids as a renewable resource in state renewable portfolio standards, lack of national standards for returning distributed power back to grid, and obsolete regulatory provisions. (i.e. 49 states ban use of private lines across public roads to power satellite facilities, such as pump stations). As a result of this study, WERF prepared outreach materials to reframe the economics of energy recovery projects at WRRFs to build better business cases by considering the time value of money and life-cycle economics.

> A $8.4-million energy recovery project was made "practical" by $6.5 million in ARRA grants"
> ***Tyler Richards, Gwinnett County (GA)*** *Uses biogas for engine-based CHP*

> "We would like to generate power onsite. However, the power company has stated that using the power onsite would mean we would lose eligibility for lower power rates and rebate programs."
> ***Jackie Jarrell, Charlotte Mecklenburg Utilities (NC)*** *Uses biogas for AD process only*

4) Which community-scale applications of WTE will have the greatest environmental benefit based on life cycle analyses of these options? WERF studies investigated the life-cycle economics and implications of AD with co-digestion to common waste disposal options with resource recovery such as landfilling with methane capture and at a Mixed Materials Recovery facility (MRF). From a carbon footprint comparison, AD with co-digestion had the lowest carbon dioxide equivalent (CO2e) emissions compared to the other alternatives. The predicted negative emissions from the AD with co-digestion alternative were due primarily to the offset from electricity generation from the biogas produced from the digesters. This production offset is greater than similar production offsets in the landfill, and mixed MRF alternatives.

The USEPA estimates that there are close to 15,000 publicly-owned facilities that treat the domestic wastewater produced by 80% of the nation's population living in sewered areas. The 518 largest WRRFs (source USEPA CWNS, 2008) sized at or greater than 10 million gallons per day treat 66% of the nation's wastewater. These facilities are designed to protect human health and return clean water to the nation's waterways, yet the wastewater managed by these community-scale facilities contains chemical, heat and kinetic energy which can be recovered. The energy potential contained in our nation's wastewater and biosolids exceeds by ten times the energy used to treat it, and can potentially meet up to 12% of the national electricity demand (as given by EIA, 2009). That's enough to power New York City, Houston, Dallas and Chicago annually. The only deterrents to implementing energy recovery on this scale is a lack of funds into research and for investment into the known, proven and pioneering technologies available to make this happen. Further, updating regulations to promote the use of smart-grid technology and to use renewable energy from domestic wastewater to complement other source of renewable energy is necessary to enable this transition.