Assessing Heterogeneity in Organic Municipal Solid Waste Across City-Scales for Optimized Urban Biogas Production

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Hypothesis: Biogas projects have found success in supplying renewable energy for niche markets with homogenous waste streams, but are limited by heterogeneous waste streams at the urban scale. Disaggregating waste streams to homogenize anaerobic digestion feedstocks will aid stability of biogas production at the urban scale.

Introduction: Bangkok currently produces one of the highest municipal solid waste generation rates of megacities within the developing world, at over 11,000 tons per day[1]. The majority of Bangkok's organic fraction of municipal solid waste (OFMSW) is landfilled, with adverse impacts on both public health and the environment through degradation of water resources and large releases of the potent greenhouse gas methane. One commonly accepted method for management of the OFMSW is anaerobic digestion (AD). Anaerobic digestion of OFMSW has numerous benefits: voluminous production of biogas (a biogenic gas that may be combusted for electricity and heat production), reduction of landfilled waste volume, reduction of methane emissions, and production of a high-quality organic fertilizer by-product[2]. However, variations in biochemical composition of organic waste streams largely dictate the stability of biogas production, as heterogeneities in feedstocks can cause inhibition of the microbiological processes that produce biogas[3,4]. For example, significant differences in moisture content between two areas may necessitate the implementation of different AD technologies, such as wet, dry, or a wet-dry combination of AD. Additionally, OFMSW collection infrastructures can be complicated and expensive due to waste originating from numerous sources over large spatial areas. Understanding how generation of OFMSW varies over urban to exurban spatial scales will better inform strategic homogenization of AD feedstock waste streams, more effective collection infrastructure, and appropriate siting of future biogas production plants for the sustainable management of OFMSW.

Research Plan: My intended research will fundamentally address the following questions:

1. Do urban "pockets" exist in which municipal solid waste is predominantly composed of organic, digestible waste?
2. Can waste collection infrastructure and waste facility siting be restructured to better reflect spatial variations in OFMSW generation?

Methods: I will combine spatial mapping, waste-transport charts, and waste sampling to assess how generation of organic waste is distributed over Bangkok's urban environment.

1. *Delineate urban, suburban, and rural-urban fringe (RUF) zones.* I will use Geographic Information Systems (GIS) to demarcate urban, suburban, and RUF zones of Bangkok based on census data, land use maps, and aerial photography[5]. The demarcation of the three urban zones will inform my in-field waste sampling during the summer of 2015.
2. *Identify waste management plants/landfills that collect waste within each of the above-listed zones, and sample waste from May – August, 2015.* Municipal solid waste in Bangkok is not source separated, thus I will conduct a waste composition study under ISO 14001 standard[6]. Depending on the waste center, I will either collect samples from waste screens and grinding operations, or will hand sort the waste to collect samples of the organic fraction. I will then assess the waste sample for moisture content and biochemical composition through local university facilities[7]. I

will collect waste samples two times per day from ten replicates within each urban zone to best account for expected high variability in waste structure.

3. *Identify appropriate sites for siting of future AD facilities.* By comparing samples of organic waste with existing waste collection routes, inferences can be made as to whether or not organization of waste management facilities are appropriate for the waste composition originating from Bangkok. I expect that city areas with high densities of malls (often with large food courts) and food markets will have disproportionately high food waste suitable for AD.
4. *Model the potential biogas production based on computer simulation of biogas production, and scale the waste streams for their representative urban areas to the city scale.* I will input the elemental compositions of organic wastes into the Anaerobic Digestion Model 1 (ADM1) computer simulation to gain rough estimates of biogas productions[8]. I will then scale the production rates from each urban area type to its full city-wide extent to estimate Bangkok's biogas production potential.
5. *Model future urban development and its implications for organic waste based on the Bangkok Development Plan released in 2013.* Similar to step 4, I will use projections of future shifts in urban environment (e.g., from suburban to urban) to model future growth in urban waste/biogas.

Research collaborations: Through Yale University's Urban Resources Initiative (URI), I will conduct a pilot project to assess neighborhood-wide waste streams during the spring semester of 2015. Working with URI will give me valuable experience and insight into potential pitfalls that may arise during my summer data collection, and will allow me to extend my research to New Haven's local community. Additionally, my previous research collaborations through the Joint Graduate School of Energy and Environment in Bangkok will afford me access to university facilities for biochemical analyses and support from Thai professors currently involved with waste-to-energy projects.

Intellectual merit: My proposed research aims to bridge the gap between the use of AD technology in the developed and the developing world. Understanding how waste-streams respond to urban growth will allow city planners to best implement future waste management plans for developing urban environments in both the developing and developed world – such as the U.S. My intended research will contribute to the broader knowledge on waste management through the goal of a peer-reviewed publication by the end of my second year, as well as presentations of findings at university-based and international conferences.

Broader impacts: Capitalizing on OFMSW for production of biogas is a comprehensive sustainable development strategy that tackles the increasing challenges of managing waste, providing stable electricity, and mitigating greenhouse gas emissions. The findings of the research will be particularly valuable in developing urban environments, for example those in India or sub-Saharan Africa, in which putrefying organic waste directly contributes to public health concerns and ecological damage. Furthermore, generation of electricity from biogas may become significant for assisting intermittent renewable energies, such as wind and solar photovoltaics, in future provisioning of base load electricity supply. This work will directly aid local professors, students and urban planners, as few comprehensive waste-structure studies of Bangkok currently exist in the literature.

References: [1] Udomsri et al. 2011. *Energy for Sustainable Development* 15: 355-364. [2] Wellinger, A. *et al*. 2013. The Biogas Handbook. [3] Curry and Pillay. 2012. *Renewable Energy.* 41: 200-209. [4] Browne, J.D. *et al*. 2013. *Applied Energy* 128: 307-314. [5] Pryor, R.J. 1969. Geografiska Annaler. Series B, Human Geography. 51:33-38. [6] ISO 14001. 2004. Environmental Management. [7] Zhang, R. *et al*. 2007. *Bioresource Technology* 98: 929-935. [8] Batstone, D.J. *et al*. 2002. *Water Science Technology* 45: 65-73.