Our Bets are on Co-Processing of Fecal Sludge and Municipal Solid Waste as the Next Important Trend in Urban Sanitation

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Background

In the absence of safe and reliable sewage treatment systems, liquid waste needs to go somewhere, and it does. It leeches out of septic tanks and latrines and into groundwater, it's surreptitiously dumped into open drains or onto agricultural fields, it's dug out of pit latrines and re-buried in shallow pits. The irony? While treatment is now, finally, seen as critical to achieving the health benefits of sanitation, the highly dispersed disposal practices for fecal sludge mean that it's often hard to access enough waste to make treatment financially viable.

The prevalence of such "informal" collection and dumping practices, or an abundance of on-site sanitation systems that get sealed upon filling, can make it difficult to access large and reliable volumes of waste, even in sub-Saharan Africa's most populous cities. Take for example, Kigali, Rwanda. With a population of over 1 million, less than 100 m^3 of fecal sludge are collected and dumped at the landfill everyday – a volume equivalent to waste generated by a population 5% the size.

Municipal solid waste (MSW), on the other hand, is adeptly collected across the city and across income brackets. Kigali's MSW collection rates are particularly impressive due to government-mandated services, and tiered fees for different income brackets. However, it's easy to see why MSW, almost universally, is more effectively collected than FS. Unlike FS, MSW is hard to make "disappear" – it piles up, and piles of trash are political suicide. On a practical note, collecting trash requires two things that are in abundance in Africa: unskilled labor and flat bed trucks; collecting FS requires less common commodities: vacuum trucks and reliable pit emptying services.

But collection is only one aspect of MSW management; disposal is the other. And in Kigali, a mountain 14 km from the city center serves as a poorly managed repository for the city's efficiently collected waste. The city has tried to install a MSW-fueled electrical generation facility to tackle the problem. However, a project typically requires 1000 t MSW per day to be bankable[1] compared to the approximately 300 t generated in Kigali.

Liquid and solid waste management are huge and unsolved challenges in many developing cities. ***This article makes the case that co-processing FS and MSW could help: 1) Tackle the public and environmental health disasters associated with inadequate urban waste management; and 2) Improve the operating economics of FS management.***

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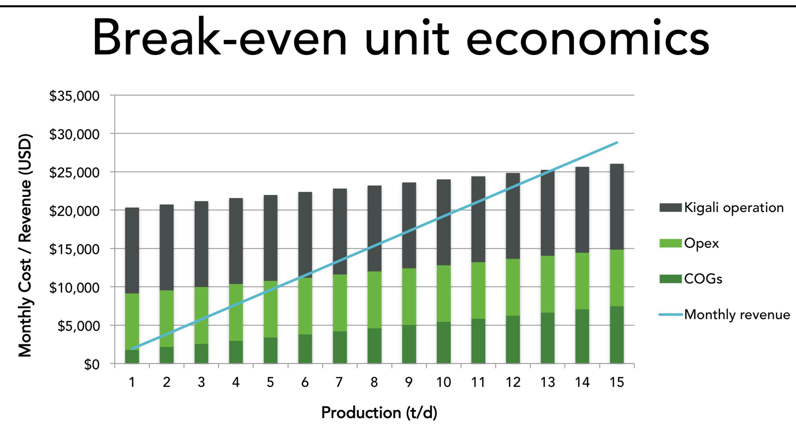
[1] Rodriguez, M. E., Themelis, N. J. (2011). Cost-Benefit Analysis of a Waste to Energy Plant for Montevideo; And Waste to Energy in Small Islands. *Department of Earth and Environmental Engineering,* Columbia University

MSW and FS Derived Fuels

Like with MSW, a reuse-focused liquid waste treatment plant needs sufficient volumes of FS for its operation to be economically viable. Poor FS collection infrastructure inhibits the capacity for developing reliable treatment systems and, in turn, sustainable businesses that operate those systems.

At our previous company Pivot, we designed and demonstrated a process for extracting solids from FS and converting them to a combustible fuel for industry. The demonstration plant in Kigali received a maximum 100 m^3 FS per day with less than 1% total solids, yielding a daily average fuel production of 0.5 t. The figure below presents the break-even unit economics for cost of goods sold (COGs), COGs plus direct operating costs at the factory, and for the entire Kigali operation, amounting to <1 t, 6 t, and 13 t per day, respectively. In some cities in sub-Saharan Africa, like Kampala and Accra, these production volumes are readily achievable with the amount of FS currently being collected. Indeed, it is possible to install FS processing factories that fully pay for their running costs where upwards of 600 m^3 per day FS (depending on solids content) are being collected. ***But how do we build reliable, affordable and productive waste treatment facilities in cities with smaller volumes? One answer, we believe, is co-processing FS with MSW.***



Break-even points	
COGs	<1 tpd
Production (COGs+OPEX)	6 tpd
Kigali operation (Production + General Admin)	13 tpd

1

Figure 1. Break-even unit economics for a fecal sludge-to-fuel plant that operated in Kigali, Rwanda. At 6 tons per day, direct operating costs of the facility can be fully covered.

MSW is routinely converted to a refuse derived fuel (RDF) or fluff MSW for use in industrial kilns, especially in cement manufacturing. The return on investment for traditional waste-to-energy (i.e., electricity) facilities is rarely positive in developing countries. Numerous factors impact the economics of these facilities; however, as noted above, it takes about 1000 tons per day of MSW for WTE to be economical, and that's in developed countries. In developing economies, the composition of MSW streams has far less plastic and more wet organics, which decreases the overall energy density, and thus increases the MSW volumes needed to hit the breakeven threshold.

Producing a MSW-derived industrial fuel is a fairly simple matter of sorting (to exclude inert or hazardous materials) and shredding, and thus has a much lower breakeven threshold than waste-to-energy plants that produce electricity. Additionally, capital costs are minimized by co-treatment with FS, and sharing resources and facilities for the two sanitation systems. Table 1 provides an overview of the magnitudes of cost and impacts of different city-scale sanitation options for MSW and FS, separately and together.

Table 1. Financial and environmental impact matrix of potential FS and MSW sanitation systems.

Facility	CAPEX	OPEX	Potential Revenue	Sourcing Infrastructure	Personnel	Environmental impact
Landfill (MSW + FS)	Low	Low	Negligible	Negligible	Negligible	High
Waste-to-Energy (electricity)	Very High	High	High	Moderate	High	Low
FS Treatment Plant	Moderate	Low	Low	High	Moderate	Low
MSW + FS Co-Treatment	High	Moderate	Moderate	Moderate	Moderate	Low

Landfilling in the context presented in Table 1 refers to a make-shift dumping ground and not a designed "sanitary" landfill. Additionally, while city dumps officially employ few people, these sites becomes a magnet for scavenger communities, which have large health and safety impacts that are solved by implementing alternative systems. Capital expense for co-treatment can be considered "high", however it incorporates two treatment systems and the per-system cost is less than for individually committed FS and MSW treatment. Additionally, through co-treatment, cities with poor FS collection infrastructure can effectively cross-subsidize FS treatment with MSW processing and fuel revenue, and can be incentivized to expand FS collection as a means of increasing potential fuel revenues.

At the Kigali facility, Pivot demonstrated that ***mixed MSW can be sorted and shredded, and easily incorporated into FS-derived solid fuel***. Pivot used an industrial waste shredder. ***The blended product was energy dense and can be used in the same industrial applications as pure FS-derived fuel. This co-treatment approach is advantageous in that it leverages the relative simplicity of MSW collection and cost effectiveness of processing to solve broader sanitation issues within growing urban areas throughout the developing world.***

RDF emissions controls

Concerns about emissions from the incineration of MSW-derived fuels can easily be addressed with basic emission controls and routine monitoring. The cement industry is a particularly attractive end-user because the combination of high temperature (flame = 2000°C, material = 1400°C), long residence time, and oxygen-rich environment in cement kilns means that organic materials and residues undergo complete combustion.[2] Table 2 shows emissions of concern at cement plants and the relative impact of waste-derived fuels on their levels.

Table 2. Results of meta-review on emissions impacts of using waste-derived fuel.

Sulphur	Concentrations in alternative fuels is usually much lower than reference level in fossil fuels (0.1-0.2% vs 3-5%, respectively)
NO_x	Concentrations in alternative fuels are usually lower than reference levels in fossil fuels. In fact, if nitrogen is present in the form of ammonia NH_3, NO_x emissions can be reduced as a result of a reduction reaction between NH_3 and NO that results in the formation and release of the nitrogen as N_2.
Chlorine	Concentrations should be kept below 0.3-0.5% to prevent excess in emissions.
Heavy metals	Non-volatile metals are retained very well in the finished product, so not a major concern. Concentrations of volatile metals such as Hg and Cd, which should be limited to 10 ppm and 440 ppm, respectively. Concentrations below the limit are controlled by scrubbers.
Dioxins and furans	PCDD/PCDFs may form if chlorine is present in the fuel but this is usually repressed due to high temperature and long residence times (see below). Feeding waste into the main firing system – as opposed to secondary firing system – is the best way to ensure that the temperature and retention requirements are achieved.

Source: Hasanbeigi, A., Lu, H., Williams, C., Price, L. (2012). International Best Practices for Pre- Processing and Co-Processing Municipal Solid Waste and Sewage Sludge in the Cement Industry. *Ernest Orlando Lawrence Berkeley National Laboratory*, U.S. Department of Energy.

Designing Co-Processing Systems

Based on years of field experience, 30 degrees believes that co-processing FS and MSW to produce solid fuel is a compelling sanitation option for many developing cities. ***Co-processing can change the economics of FS management in cities where collection rates of FS are not sufficient for treatment and resource recovery to be financially self-sustaining on its own.*** How?

- Supplementing FS feedstock with MSW drives down the unit cost of fuel production and therefore the cost of waste treatment (this is somewhat intuitive given that the solids fraction of MSW is >60% compared to +/- 1% for FS);
- Productive utilization of trash excavated from pit latrines and septic tanks converts a cost center for FS treatment plants into a revenue stream
    - As FS collection services expand across cities, safe disposal of the fecal contaminated waste will be an increasingly expensive challenge;
- Higher fuel production volumes drive greater demand for fuel
    - Energy intense industries want large, reliable volumes of fuel; they will pay more per ton for 100 t/d than for 5 t/d.

To efficiently design co-treatment systems requires a detailed understanding of how to optimize footprint, equipment, and labor between processes. The following concepts are additional lessons from field experience in co-treatment.

- <u>Source sorting is high risk and advanced sorting systems may be cost prohibitive</u>. Where there is not already a culture of trash sorting at the household level (most countries), the quickest most

[2] Karstensen, K.H., Kinh, N.K., Thang, L.B., Viet, P.H., Tuan, N.D., Toi, D.T., Hung, N.H., Quan, T.M., Hanh, L.D., Thang, D.H. (2006). Environmentally sound destruction of obsolete pesticides in developing countries using cement kilns. *Environ. Sci. Policy,* Vol. 9: 577–586.

efficient path to scale is centralized sorting. Metals, batteries, and some glass and ceramics among other inerts must be removed before MSW can be processed for incineration. Large, capital-intensive sorting systems can be procured; however these additions are among the reasons WTE isn't cost-effective at smaller scales. A few key equipment additions and a small, well-trained team can function with equal efficacy and a fraction of the cost.

- Designing for growth. With widespread population growth estimated for the majority of Africa and a similar trend in most other developing economies, it is important to design systems with either the capacity to handle increased flows of MSW and FS or pre-designed "bolt-on" components that can be added to the facility when volumes increase. This design method presents an opportunity to eventually incorporate a few of the higher CAPEX sorting components, as both MSW volumes and the associated sales revenues increase. This approach was successfully implemented in Kigali with Pivot. Moreover, "bolt-on" retrofits and designing-for-growth are two areas where 30 degrees has significant experience and can help interested firms or municipalities in implementation.
- MSW introduction at a co-processing plant will generally occur after mechanical dewatering of the sludge. Accurate characterization of the MSW and FS streams is necessary prior to plant design. Depending on the volume of wet organics in the MSW stream, combination may need to occur during solar drying. More commonly the FS will be incorporated in the final processing stage as MSW volumes will likely be much greater than the FS volumes and can be used to maintain a consistent energy density.
- Monitoring the composition of the composite fuel is necessary for quality control. The calorific value of a fuel product can vary significantly with highly mixed MSW streams. Fuel customers demand a consistent product that has a predictable behavior in their kilns or boilers. Thus, it is essential to monitor the waste stream and may be necessary to occasionally warehouse certain fuel components for future incorporation in order to maintain steady calorific value.
- It is critical to understand industry preferences for fuel form factor. Form factor requirements vary widely with limited standardization within industries. We've worked with textile producers that required pulverized coal analogs that could be blown into the furnace while receiving exactly the opposite feedback from their competitors who desired briquetted fuel. An efficient treatment plant will have some tolerance to modify form factor, but clear guidance before finalizing plant design is the best practice. This requires in-depth market research at the outset of project development.

Designing facilities for co-processing fecal solids with municipal solid waste is a cost-effective and space-efficient option for cities in need of solutions for both sanitation challenges. Effective implementation of this novel approach requires careful planning around equipment sizing and selection, process flow, and product characteristics. 30 degrees has years of experience successfully developing and deploying low capex, design-for-reuse, co-processing facilities. 30 degrees is available to assist on all aspects of design, from initial process consultation and feasibility studies to design, implementation, and commissioning.