Final Summary Report: John Ball Zoological Garden Anaerobic Digestion Feasibility Study

Submitted by Norah B. Fletchall

Michigan Dept of Labor and Economic Growth
Grant #PLA-06-66

Grant Period: May 10, 2006 to April 9, 2007

Project Goals:

Currently more than 90% of waste produced by the John Ball Zoological Garden is moved offsite to landfill by a commercial waste management service. This includes all animal manure, spent food and bedding produced by the exotic animals in the collection; uneaten animal feed, and all solid food waste produced by the visitors and staff. A recycling program is in place for cardboard and paper products as well as other minor waste products (used motor oil and batteries). Manure and spent bedding from the zoo's small domestic animals in the Children's Zoo is composted in the summer months, however, this process is labor intensive and difficult to manage. In addition, significant amounts of waste water are produced in the process of animal care and operations. Currently this water is flushed into the City of Grand Rapids sanitary sewer system.

In addition to the zoo's goals of education and conservation there is a commitment on the part of zoo leadership to move towards "green practices" such as increased water conservation, LEED certified buildings, utilization of alternative energy sources, etc. in all aspects of our operations. An increase in operating costs (due in part to increased energy costs) coupled with budgetary constraints over the last several years have resulted in utility and waste management costs becoming an ever increasing portion of the zoos operating budget. In order to evaluate the potential advantages of moving towards incorporation of biomass energy practices into zoo operations an accurate determination of the types and amounts of wastes produced needed to be made. Also, an assessment of the best energy production technology for the zoo's site and resources was needed. Through completion of this project the JBZG now has data to help determine whether biomass resources are of sufficient quantity and type that energy production can take place on site thereby reducing our utility costs and conserving resources.

The project consisted of three primary components:

1. Quantification of types of waste produced at the zoo and amounts of those wastes
2. Analysis of the biomass energy potential of these wastes based upon laboratory analysis of aggregate waste streams from #1.
3. Development of a payback period for implementation of a biomass to energy system at the zoo. Included in this step is a recommendation from the PI's as to whether this system is practical given the anticipated capital and ongoing operating costs.

Role of Investigators and Partners

The Principal Investigators (PI) on the project worked closely with two primary partners to complete the work plan as outlined in the grant. Charles Gould of Michigan State University's Extension Office met with the PIs and representatives from AGRISA during AGRISA's site visit. Mr. Gould subsequently met and communicated with the PIs and AGRISA to prepare a study of the potential of developing a composting program on site to handle the waste and/or by products of the biomass energy generation process. Mr. Gould also submitted an alternative proposal to compost all applicable waste currently produced at JBZG (see attachment 3 of this report).

AGRISA principal Scott Pogue and his colleagues oversaw collection system design, sample collection, testing and analysis, determination of appropriate waste to energy system and potential costs associated with the system.

Quantification of Waste Streams

In order to accurately quantify the amounts and types of wastes produced through the operation of John Ball Zoo the principal investigators developed a system that allowed zoo keeping and maintenance staff to record waste streams by type and amount (see attachment 1of this report).

Although JBZG is open 364 days a year the bulk of our attendance takes place in the months of June through September. For this reason we chose to quantify our waste streams during August and September. A trial period to test this system was undertaken in mid-August. This approximate two week period tested the color coding system and the sorting/separation process. Zookeepers and maintenance staff received training in how to identify and separate waste streams. A color coded tagging system for bags was utilized as once waste was bagged and tagged by zookeepers weights were then obtained and recorded by maintenance staff. Subsequent to that the actual quantification process was carried out over a four week period.

Waste streams were quantified as closely as possible within the following categories:

1. Manure: Animal manure sorted as much as possible from bedding
2. Bedding: Animal bedding consisting of primarily straw taken from off exhibit animal holding areas.
3. Food waste: Includes both uneaten animal feed as well as uneaten human food from the zoo's concession stands.
4. "Everything": In some cases it was not possible to sort and/or distinguish between the three different types of waste. This is due to the fact that animal care staff typically cleans exhibits and holding areas by sweeping/raking materials into a pile and then putting the aggregate material into a plastic bag. So this category includes bags of waste that we could not practically sort.

Maintenance staff weighed and recorded weights by category for each separate waste stream (see Attachment 2 of this report). These weights were then aggregated by category to correspond with the laboratory samples submitted for analysis.

Representatives of AGRISA visited the zoo in September to assess the site, meet with the PIs and local officials and assure proper preparation and submission of laboratory samples for biogas production analysis. Aggregate samples of the various waste streams were collected by AGRISA representatives during their visit. In addition to the waste streams from zoo operations, a sample of the accumulated material from the bottom of the large pond in John Ball Park was taken for analysis. This was done to determine if this was a potential nitrogenous waste source that could be utilized in the biomass system. Each sample aliquot was weighed, labeled and sealed in a container. These containers were then shipped to Shaw Environmental Group for analysis of the following parameters: chemical oxygen demand, Total Solids, Volatile Solids, Biochemical Methane Potential, Total Nitrogen, Total Phosphorus and Total Potassium. Samples were prepared and analyzed over approximately 44 days (See Attachment 5 of this report).

Utilization of Waste Water

Throughout the quantification process several meetings took place concerning the potential use of waste water produced during the cleaning of animal exhibit and holding areas. It was quickly determined that although this water was of significant quantity it could not be used as a source of water for the biomass energy generation process as it typically contains enzymatic or quaternary based ammonia cleaners. These products would potentially kill the anaerobic bacteria necessary for energy generation. However, during the site visit AGRISA did attempt to quantify the amount of free flowing water onsite as a result of the fact that the zoo and park contain artesian wells that historically had been used as sources of drinking water by residents of Grand Rapids. Since waste water from cleaning could not be utilized as a source of water for the biomass process we did analyze the potential for use of this groundwater as well as water from one of the ponds in John Ball Park. Test results revealed that the water could potentially be utilized in the biomass process (see attachment 4 of this report). Additional research as to the feasibility of capturing this water as well as storm water run-off for use needs to be done and is beyond the scope of this grant.

Challenges with Waste Stream Quantification

We did encounter challenges with the quantification process. The amount of labor needed to actually sort, weigh and record the waste did impact our resources as it took considerably more time and effort to sort, bag and weigh the waste than we originally estimated. Operations and maintenance staff had to become very actively involved in separating and weighing the waste. On a typical day the zoo site might generate anywhere between 50 and 100 bags of trash, the vast majority of which had to be weighed. Each zoo staff member is responsible for bagging waste from their work areas and taking it to a centralized location where a maintenance worker then loads the bags into a truck, transports those bags to an area at the edge of our park and then again moves those bags into the dumpster. The separation and quantification process required for this project added one additional step for each staff member involved as they had to separate the waste, bag it and then tag/mark the bag. For the maintenance staff they then needed to weigh each bag and record it on the log sheet. From a practical standpoint should we decide to move forward with the creation of a biomass to energy facility our current waste removal system will have to be re-designed to be more efficient, accurate and less labor intensive.

Given the challenges encountered with quantifying the existing waste streams it became apparent that accurate estimates of future waste production as the zoo expands was beyond our capability at this juncture. Until we have a more detailed plan regarding taxa to be exhibited, as well as infrastructure and operational procedures for the proposed expansion the Principal Investigators cannot predict waste volumes. These details will only become available as each new exhibit or expansion project is undertaken.

Analysis of biomass to energy potential

Analysis of the results of the lab testing coupled with the waste stream production is outlined in the table below. Based upon test results and current utility costs to the zoo/park it appears that a waste to energy facility at John Ball Zoo could offset approximately $20,000 in natural gas purchases annually. It is the recommendation of AGRISA that we utilize the methane produced to offset natural gas costs versus utilization as a fuel to generate electricity (see AGRISA Executive Summary attached to this reporting Attachment 7 as well as completed AGRISA Final Study Report submitted). AGRISA's recommendation is based upon the inefficiencies that might result from needing to incur capital costs for a generator/engine and a potential expensive utility interface and relay protection.

John Ball Zoological Garden Potential Biogas Yield from Waste Streams

Samples submitted	total of weekly averages (lbs)	% moisture	% Total Solids	Total Solids (lbs)	% Volatile Solids	Volatile Solids (lbs)	Maximum Biogas Yield (SCF/lb VS)	Total Gas Produced per week (SCF)	Total Annual Estimated Biogas Yield (SCF)
Sample 1 (TDL 10808)-Animal Groups	1587	68.50	31.50	499.97	85.20	426.00	2.40	1022.40	53164.80
Sample 2 (TDL 10809)-Uneaten Food	180	84.70	15.30	27.57	84.50	23.27	8.60	200.12	10406.24
Sample 3 (TDL 10810) Ruminant Manure	1473	71.10	28.80	425.81	45.80	195.00	6.40	1248.00	64896.00
Sample 4 (TDL 10811) Moist Bedding	944	63.40	36.60	345.37	97.00	335.14	4.20	1407.59	73194.68
Sample 5 (TDL 10812) Pond Sludge	NA	32.00	68.00	NA	0.0094	NA	<1.0	NA	NA
Totals	4184			1298.72		979.41		3878.11	201661.72

Currently the zoo purchases all of its utility and waste disposal support as follows:

Utility and Waste Disposal charges JBZ (2005 rates)			
	Cost	Unit	total annual cost
Electric-Consumers (park areas)	$ 0.14	per KWH	$ 197,113
Electric-City of GR Street lighting	$ 0.08	per KWH	$ 142,766
Gas-DTE	$ 0.86	per CCF	
Water City of GR	$ 1.28	per HCF	$ 227,413
Sewer City of GR	$ 1.89	per HCF	
Waste Disposal (contractor)			$ 21,600
Totals			$ 588,892

One of the recommendations made by AGRISA was purchase of natural gas via a long term contract as this could stabilize the purchase price as well as result in cost savings (AGRISA Final report p. 15). This possibility was explored through the zoo's purchasing department. Unfortunately, the zoo and the park do not use natural gas in large enough quantity to make these bulk purchases possible. As the zoo grows we will continue to monitor our usage and may re-visit the bulk purchase possibility.

Composting

There is a potential for utilization of a large component of the waste produced by the zoo in a compost operation. Also, the by-product of the waste to energy process could be composted. The compost produced from either system has the potential for revenue generation if sold to the community and/or it could be utilized in the zoo and park by horticultural staff. Charles Gould analyzed the use of all potential waste products in a composting operation (see attachment 3 of this report).

However, if the waste to energy system recommended by AGRISA is utilized on site composting of by products will need to be incorporated into the project. Initiation of a waste to energy system without the composting of materials would not be practical as non-compostable materials and the by products of the Anaerobic Digestion system (AD) would still need to be moved offsite. This transport would incur costs similar to what we now pay in waste hauling.

Given the large footprint that a composting operation would need (anywhere from 7,000 to 13,000 square feet depending upon volume) finding a suitable location within John Ball Zoo/Park will be difficult. As the AD system would need to be located adjacent to the composting system the potential area needed for the total operation is 9,000 to 15,000 square feet. Adjacency is critical to avoid incurring costs of transporting waste and compost to/from the AD system site. Currently the only practical location within the park that has this much area available is the upper hill area adjacent to the zoo's hospital. Future plans for this area may include an education facility. Locating a waste to energy facility to help power the education campus would be an excellent opportunity to help educate the local community and school groups concerning the value of anaerobic digestion and composting as a conservation tool.

Alternatively AGRISA recommends locating a composting facility off site. The practicality of this option must be considered as this would require contracting with a company to haul the waste to the composting site. This would incur additional costs that could be similar to the current costs we now pay to have all of our waste hauled off site thereby resulting in no net savings.

Capital costs associated with a composting system are outlined in detail in Charles Gould's report (see Attachment 3 of this report). The in vessel composting system appears to be the best suited for our site given the potentially smaller footprint required. Total capital investment required for this system is $188,195. Revenues generated from the sale of compost could offset the cost of the capital investment. The assumption in Charles Gould's report is to sell the compost at $10 per 10 pound bag. This price point seems rather high. It might be more realistic to expect to sell a 40 lb bag for $10. At this price point utilizing the potential of production of 4,560 cubic feet (approximately 182,400 lbs) of compost every 5 months could result in revenues of approximately $109,400 per year from the sale of compost.

However, this $109,400 would only be applicable if we composted all of our waste and did not incorporate an anaerobic digestion system. Based upon the AGRISA composting Action Plan (Section 12.2 in the AGRISA Final report) we could produce 57,000 lbs of compostable material after "washing" to remove the digestible volatile solids. This material could then be composted via the in vessel system to produce approximately 118 lbs (157 lbs of bedding daily reduced by 25% due to in vessel composting) of material per day to be windrowed. This translates into 43,070 lbs of compost annually sold at $10 per 40 lb bag. This would generate $10,768 in annual revenue.

Pay back Period Determination

Significant capital costs would need to be incurred in order to implement a waste to energy facility at John Ball Zoo/Park. A detailed Capital Budget Estimate is included in the AGRISA final report and totals approximately $95,200. Location of the system on the site will require approximately 2000 square feet exclusive of composting. Given the topography and layout of the zoo there are three potentially feasible areas where the waste to energy facility (exclusive of a composting site) could be located. These areas are outlined in the AGRISA report. Final location of the facility would depend upon several factors including: proximity to the public and surrounding residential areas (odors), accessibility for transport and holding of waste components to be placed into digester, ease of incorporation into building infrastructure, potential for unit to be viewed by the public.

However, it should again be emphasized that it is not practical to locate the AD system site at a different location than the composting site. As a result the only practical site for location of the system is in the park area near the Zoo's hospital.

In addition to the capital costs incurred to locate a waste to energy facility there will be ongoing operation and maintenance costs. Annual operating costs for the AD system alone are outlined below and total $62,000. Annual estimated operating costs for a composting system would add an additional $19,000 to this figure (based upon 10% of capital costs).

- Operations and maintenance based at 10% of capital costs = $9520
- One full time maintenance worker to operate system and maintain compost operation = $50,000 (wages and benefits).

Payback period for the cost of capital for the waste to energy Anaerobic Digester is approximately 32 months as calculated by AGRISA. However, significant operating and capital costs will need to be incurred to implement a composting operation. A significant portion of these costs will need to be incurred regardless of whether or not all waste is composted or only the portion that is available as a result of the AD process. If only a portion is composted we will still incur costs to transport other waste streams offsite for disposal. Anticipated capital costs for implementation of a composting system push the payback period for recovery of capital investments to 5.5 years. In addition, due to the anticipated need for a full time staff person to oversee the AD and composting operation it is anticipated there will be no net savings and operating costs will actually increase if we implement a waste to energy system (see Attachment 6 of this report).

Recommendations

Contained within the AGRISA report are recommendations and suggested next steps (see pp. 25-28 of AGRISA report). As per the original grant proposal the criteria utilized to evaluate the potential use of biomass resources are: quantity of waste streams, ROI on and additional operating costs, location of waste to energy project. Application of these criteria to the study results reveals the following:

- There are sufficient waste stream available currently to power a waste to energy system
- Payback period and potential increased overall operational cost of implementing an Anaerobic Digestion system at John Ball Zoo is not cost effective due to anticipated increased costs of operations and significant capital investment required.
- Given the large footprint required to house and maintain an AD system and composting operation there is only one potential area on site that is large enough.

Several steps could be taken to investigate opportunities to reduce the operating cost of an AD system. These steps are outlined below. It is the recommendation of the Principal Investigators that these options/issues be fully explored before ruling out the implementation of a waste to energy system at John Ball Zoo. However, until these issues can be resolved we do not recommend moving forward with implementing a waste to energy system.

Next Steps

1. Analyze current waste collecting procedures with the goal of streamlining and increasing efficiencies such that additional staff would not have to be hired to operate the AD/Compost system. Implementation of new procedures might require acquisition of new equipment and/or supplies which must be taken into consideration when calculating operating costs.
2. Quantify the disadvantages of utilizing methane gas to power electrical engine/generator. As the majority of our natural gas needs occur in the winter months direct utilization of methane gas might not be as efficient as first thought. In addition, electric conversion might provide more flexibility and ease of use thereby broadening the potential areas for use on site.
3. Explore the potential cost savings and reduced water consumption by capturing available underground water and storm water run off on site.
4. Investigate incorporation of AD system in Education facility proposed for the future.