TURNING WASTE INTO REVENUE THROUGH BIO-TRANSFORMATION

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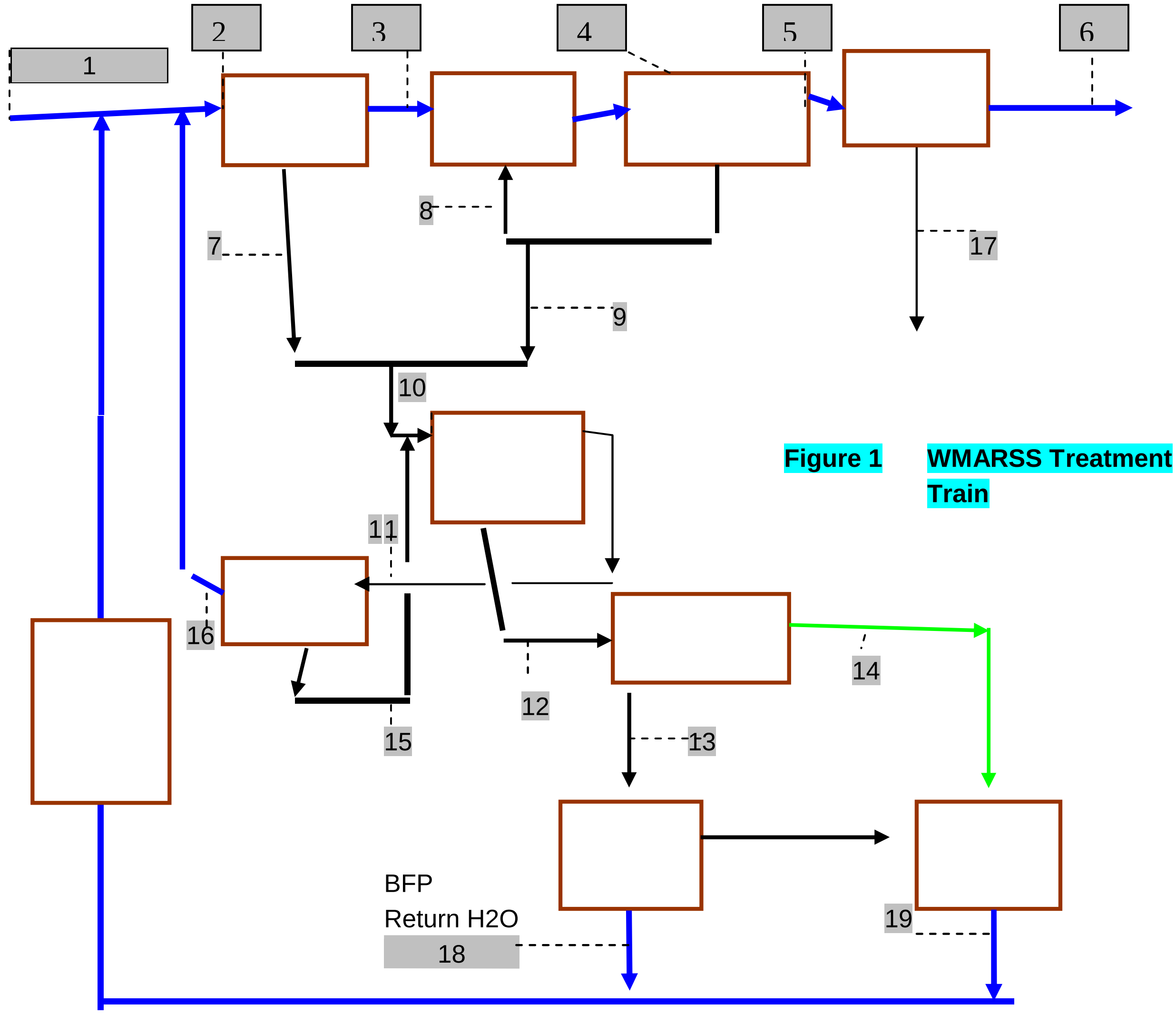
ABSTRACT

To decrease sludge management costs associated with treatment of domestic and industrial wastes, and promote resources recovery, the City of Waco Wastewater Treatment Plant (WWTP) also called WMARSS, operates a sludge pelleting process that converts traditional wastewater sludge into a marketable product for use as a nutrient and soil conditioner. Pelleting increases the bulk weight of the waste by a factor of up to 10, thus generating a product that is easier to transport and store for further treatment, e.g. recycling or combustion. This promotes controlled handling rather than local burning or dumping. Although this paper focuses on the bio-transformation revenue generation avenue and its optimization at the WWTP, it is important to understand that all bio-transformation side stream flows have to be controlled through continuous monitoring and treatment to be effective in accomplishing the plant's overall treatment mission.

The sludge pelletization process at the WWTP generates about 5,000 Tons/year of pellets from a WWTP (Activated Sludge) with an annual average wastewater influent of 29 mgd, influent BOD of approximately 225 mg/L and TSS of 265 mg/L. The retail value of these pellets range from $20/ton to $90/ton dependant upon the market demand. The average cash inflow through sale of this pelletized agricultural product can be as high as $275,000 if the marketing of this product is expanded statewide. Freeing up capacity at the landfill through bio-transformation is another significant benefit to the City in addition to the cash flow from sale of the pelletized product. The pelletization process is a direct drying, rotary drum process with air recirculation. The evaporation process in the direct dryer takes place within a triple-pass, rotating drum. The high-speed air within the drum pulls the material through the drum until it is dry enough and, therefore, light enough to be lifted and pneumatically conveyed out of the drum. The dryer drum consists of three concentric arranged cylinders, so that the material to be dried flows through the innermost cylinder, back through the middle cylinder, and finally out through the outer cylinder as a dried, pelletized product. Flights on the inner walls of the cylinders lift the material and cascade it into the hot air stream. The dried product is generally valued on its nitrogen content for use as a fertilizer amendment providing that it meets the required physical characteristics such as particle size, hardness, and density. The City of Waco is presently attempting to add a composting treatment train to diversify our bio-transformation alternatives and add a methane to electricity co-generation unit for the digested sludge in conjunction with heat recovery options. These diversification options will require high BTU sludge from industries to be transported directly to the anaerobic digestors thereby bypassing the collection and treatment systems. Other bio-recovery processes in consideration include generation of bio-diesel as a part of our Fats. Oils, and Grease program to eliminate unauthorized discharges to the sanitary sewer system and reduce the load on the WWTP.

A flow chart (Figure 1), depicts the WMARSS Treatment Train.



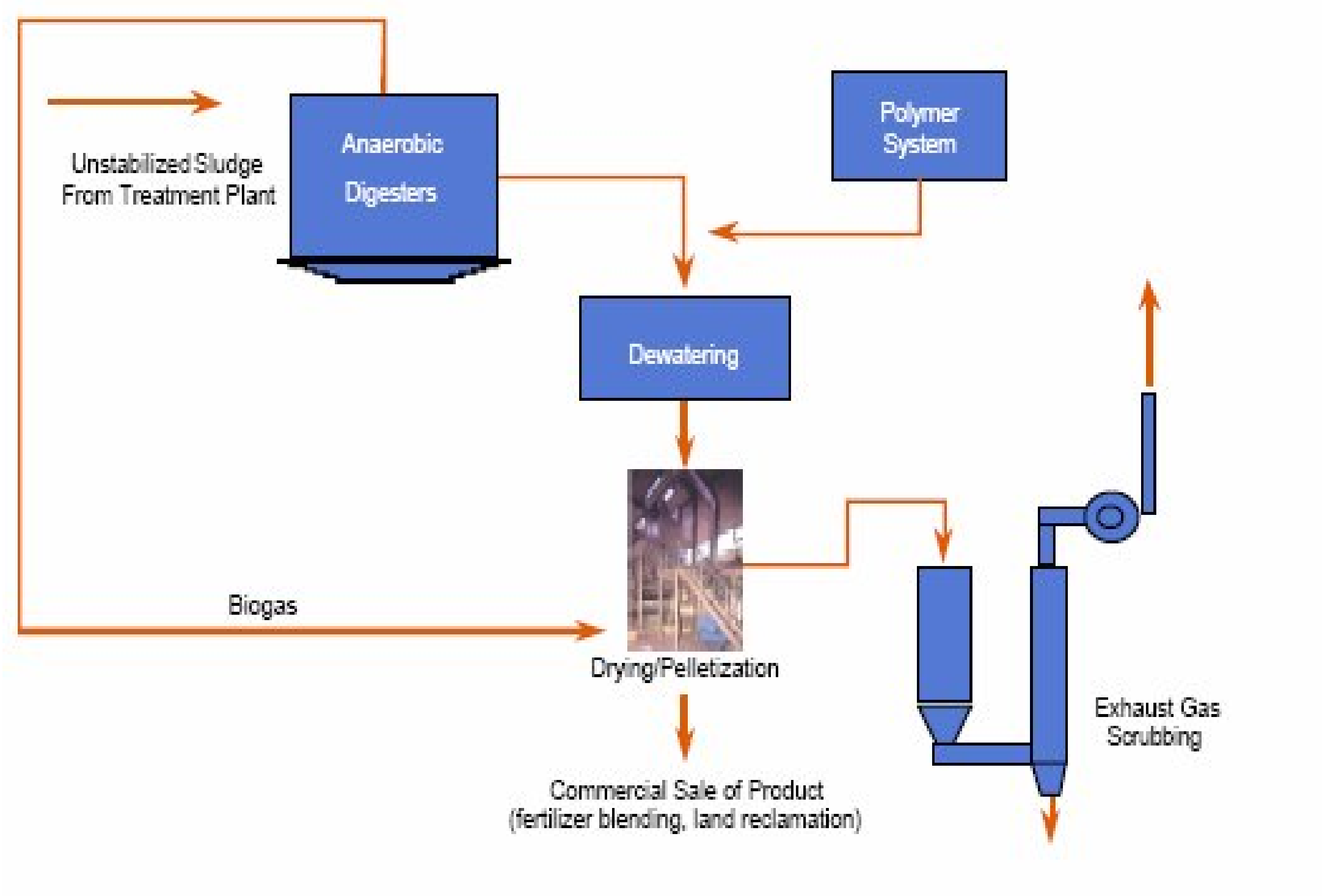
ID	Stream Name	Flow		TS	TSS	VSS	BOD
		[lbs/day]	[gal/day]	mg/l	[mg/l]	%	[mg/l]
1	Plant influent		24mgd	891	258	46	380
2	Primary settler inlet		8mgd	854	248	47	321
3	Primary settler outlet		8mgd	724	69	45	185
4	Secondary settler inlet		11mgd				
5	Secondary settler outlet		8mgd	535	8	25	1.54
6	Plant effluent		24mgd	524	1	18	1.27
7	Primary settler underflow		800gpm	8085		71	
8	WAS return		3mgd				
9	Secondary sludge to DAF		200gpm				
10	DAF inlet (sludge)		400gpm				
11	Final clarifier inlet		2000gpm	806		37	
12	Digester inlet		140gpm	45406		70	
13	Digester underflow		140gpm	19936		63	
14	Digester gas stream						
15	Final Clarifier underflow		100gpm	15642		68	
16	Final Clarifier overflow		2mgd				
17	Sand filters underflow		800gpm				
18	BFP return water		140gpm				
19	Dryer return water		400gpm				

INTRODUCTION, METHODOLOGY, DISCUSSION AND RESULTS

WMARSS is currently utilizing methane produced at the anaerobic digestors, to generate approximately 208,000 KWH of electric energy/month, which offsets the electric energy purchased from the electric market. The dryer/pelletization facility which converts the digested sludge to a beneficial agricultural product currently utilizes digestor gas (methane) in combination with natural gas to minimize the purchase of natural gas from the natural gas company. Future plans are being considered to enhance the dryer to produce enough methane for 4.3 MW of electric power. This would facilitate production of most of the electric energy for on-site use and sell the rest to the electric grid. Cement and power plants have expressed interest in utilizing pellets or sludge produced at the plant as possible additional fuel sources. The savings to the City of Waco based on current energy prices is approximately $17,380/month for electric energy being offset by in-house generation and $14,700/month for natural gas offset by utilizing the methane in the dryer. The benefits are the conversion of waste products to energy and reduction in the City's electric and natural gas costs.

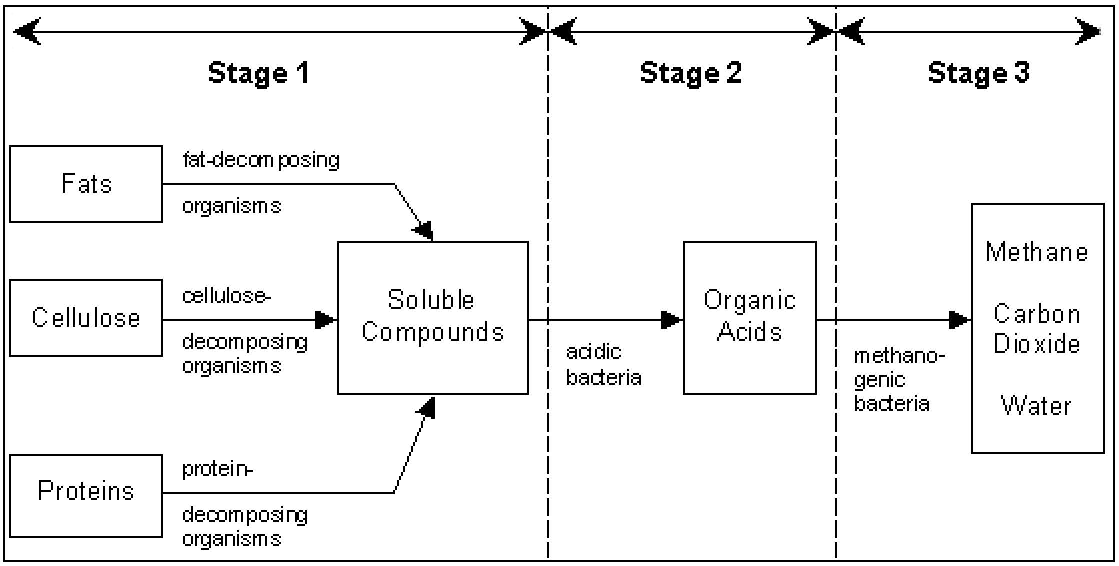
Below (Figure 2) is a schematic of how the sludge is stabilized in anaerobic digestors and dewatered in belt filter press for further drying and pelletization to market it as an agricultural product.

Figure 2 – Anaerobic Digestion and Sludge Pelletization to Create a Soil Enhancer of Significant Agricultural Value



Anaerobic digestion is used to stabilize primary (from primary settling tank) and waste activated sludge (from aeration/final clarifier) that is thickened in gravity and dissolved air flotation (DAF) units. The anaerobic digestor provides an oxygen free environment for processing of sludge by anaerobic bacteria. In the anaerobic digestor, 30 to 60% of organic compounds measured as volatile solids are converted to carbon-dioxide, ammonia and methane (Figure 3).

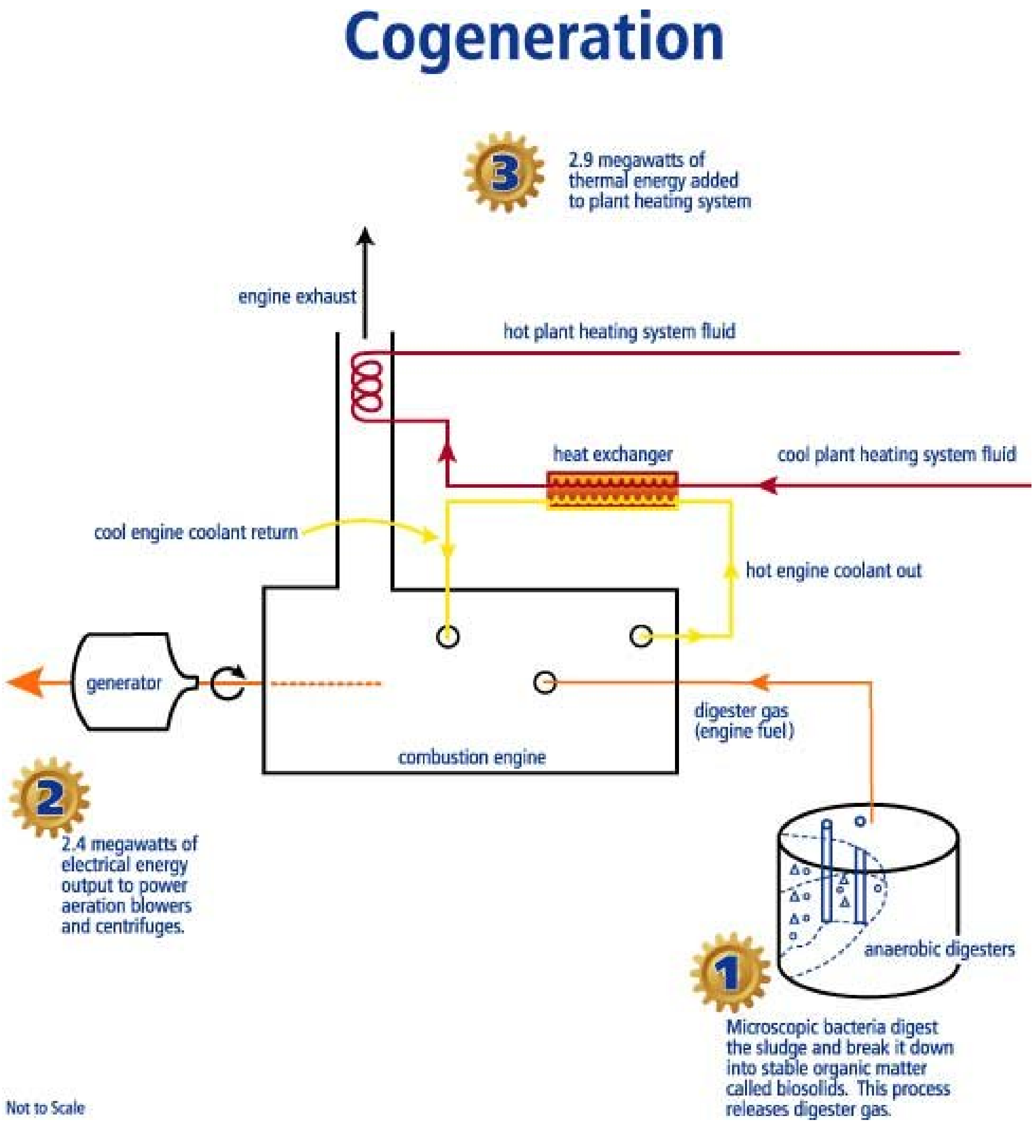
Figure 3 – The Three Stages of Anaerobic Digestion



Anaerobic digestion, which takes place in three stages inside an airtight container, produces biogas (methane). Different kinds of micro-organisms are responsible for the processes that characterize each stage. Digestion is also referred to as stabilization since at the end of this process only limited potential exists for further biological activity. A significant volume of biogas (methane) is generated during this process which is used to generate electricity at WMARSS. Shown in Figure 4 is a typical process for co-generation of electricity with biogas, which is the same principle now being used at WMARSS. Presently, about 420 KWs of electricity (one-third of the plant's energy requirement) is being generated at WMARSS. Digester gas from the anaerobic digesters is piped and burned by a running combustion engine located in the cogeneration facility. Two other generators are used for emergency power on natural gas. The digester gas serves as fuel for the engines that drive the generators, producing the electricity. Circulating coolant runs through cavities in each engine body. As the digester gas combusts, excess heat raises the coolant temperature to approximately 150°F. Hot coolant is channeled to a heat exchanger where the heat is transferred to the plant heating system to heat the digestors. Process modifications are being made currently to increase coolant temperature to 175°F by using the heat from the exhaust gas which leaves the engine at much higher temperatures. To allow anaerobic digestion at 98^{o}F, heat from generation of electricity is recycled to the digestors to further conserve energy.

After digestion, the sludge is in a liquid, slurry form with a solids content of 2 to 5%. Following dewatering at the dryer building, the solids content rises to 20 to 30%. The dewatered sludge is then pelletized to a commercial product (process described Figure 5).

Figure 4 – Typical Cogeneration of Electricity with Methane (biogas)



Following tables show the savings from co-generation of electricity using one-reciprocating engine at WMARSS (**Short-term Option A**).

Existing Equipment:

- 4 Conventional Digesters
- Emergency Generators (3, use 1 for co-generation, 2 for emergency)
- Heat Exchangers

Using methane from conventional digesters to generate electricity while heating conventional digesters with heat exchanger. The following tables show the reduction in natural gas and electricity purchase after co-generation of electricity at the WMARSS Plant. Electricity purchase (electricity meter 1) is predicted to drop by 50% with no natural gas purchase (gas meter 1). Significant savings have already been realized.

Table 1 – 50% Drop in Electricity and no Gas Needed at Meter 1 with Co-generation

Existing Energy Usage Fiscal 2005

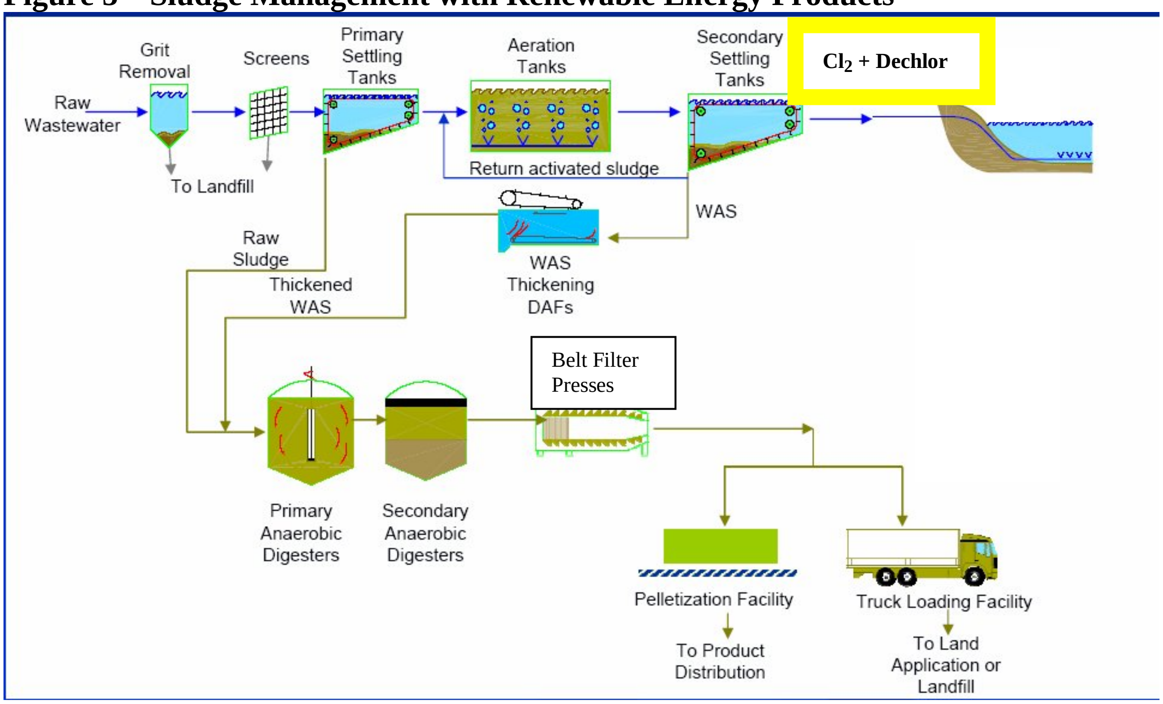
Meter	Electricity, kwh	N. Gas mmbtu
1	6,513,695	15,079
2	5,403,831	54,265

New Energy Usage with Electricity Cogeneration

Meter	Electricity, kwh	N. Gas mmbtu
1	3,518,495	0
2	5,403,831	54,265

Although the methane gas generated at the digestors is being used to run the dryer (Figure 5) for transformation of waste sludge to soil-conditioning pellets, meter 2 numbers/savings will not be recalculated until short-term option A has been completed.

Figure 5 – Sludge Management with Renewable Energy Products



***Short*-term goal (Option A)** described above is to *maximize* utilization of *existing infrastructure* to produce renewable energy to address budget shortfall. Other waste to energy bio-transformation goals being considered include the following:

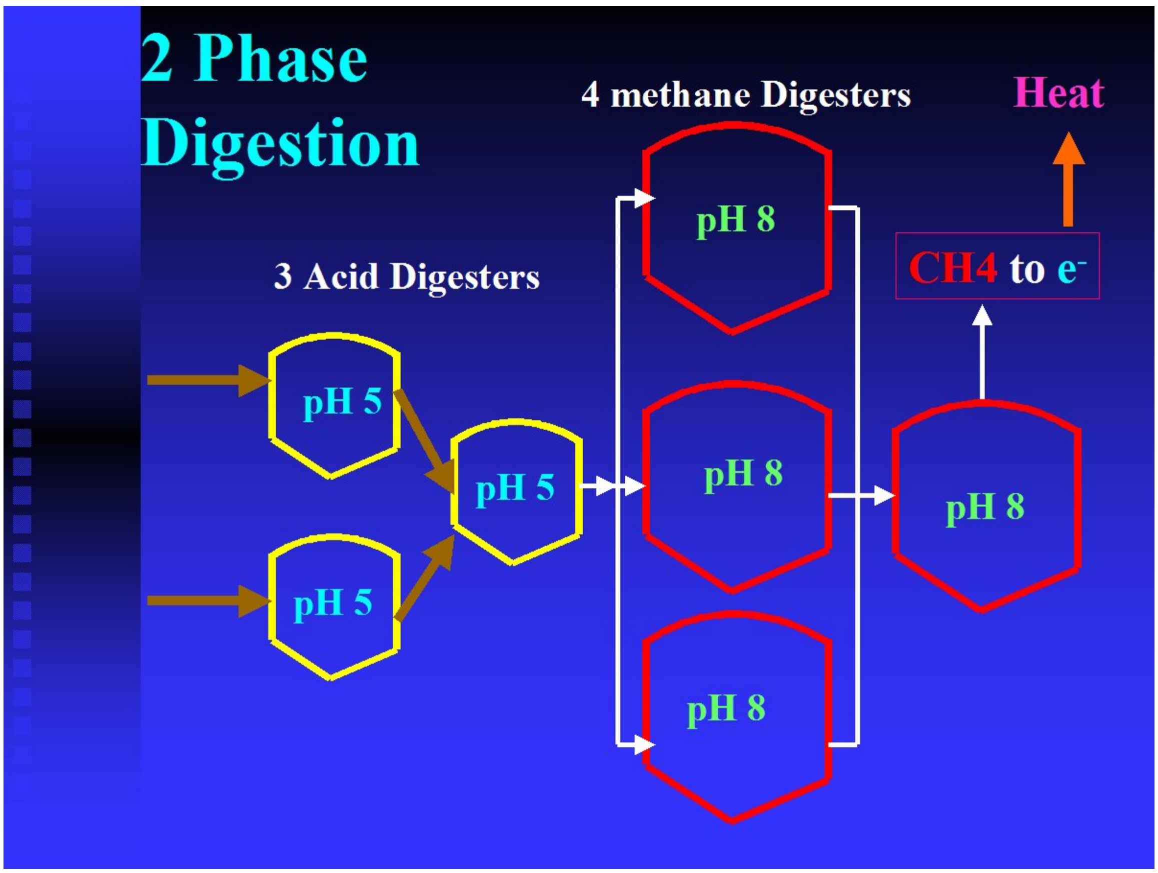
Mid-term goal (Option A-B) is to enhance existing infrastructure to improve the quality and amount of renewable energy produced:

Existing Equipment:

- 4 Conventional to Methane (CH_4)Digesters
- 3 Acid Phase Digesters (old units)
- Electricity (e^-) Generation Units
- Heat Exchangers

New Process Needed:
2 Phase Digestion (Figure 6) to produce cleaner, more & higher btu methane than conventional digesters to maximize electricity generation & minimize natural gas usage

Figure 6 – Two-Phase Digestion



The attached table (Table 2) shows energy savings with this mid-term option A-B.

More significant savings is realized with this option over option A, due to 75% Drop in Electricity and no Gas Needed at Meter 1 with Co-generation, plus 50% Drop in Natural Gas Usage at Meter 2 as depicted in the table.

Table 2 – 75% Drop in Electricity and no Gas Needed at Meter 1 with Co-generation Plus 50% Drop in Natural Gas Usage at Meter 2

Existing Energy Usage Fiscal 2005

Meter	Electricity, kwh	N. Gas mmbtu
1	6,513,695	15,079
2	5,403,831	54,265

Meter	Electricity, kwh	N. Gas mmbtu
1	1,520,495	0
2	5,403,831	21,706

Long-term goal (Option A-B-C) is to *complete utilization* of renewable energy produced from *existing and new infrastructure* enhancements:

Existing Equipment:

- 2 Phase Digestion Units
- Electricity Generation Units + new
- Heat Exchangers + new

Further reduce dependency on outside energy sources by purchasing new Electricity Generating Unit and installing at the Dryer building for electricity generation with methane

- provides heat to existing dryer units
- increases electricity production so power can be sold back to the grid after plant utilization (note significant decrease (Table 3) in electricity purchase at meter 2 with surplus at plant)

Table 3 – 75% Drop in Electricity and no Gas Needed at Meter 1 with Co-generation Plus 50% Drop in Natural Gas Usage at Meter 2 Plus Electricity Surplus

Existing Energy Usage Fiscal 2005

Meter	Electricity, kwh	N. Gas mmbtu
1	6,513,695	15,079
2	5,403,831	54,265

New Energy Usage with Electricity Cogeneration and 2 Phase Digestion + New Cogeneration Unit @ Dryer

Meter	Electricity, kwh	N. Gas mmbtu
1	1,520,495	0
2	-1,604,169	21,706

CONCLUSION

Waste to energy has been found to be a viable alternative for WMARSS to offset rising energy costs. The pelletization and methane to electrical energy with heat re-cycling have already provided significant savings to offset budget deficits. Further progression to mid-term and long-term alternatives are bound to yield significant cost-benefits. When combined with composting options being evaluated, this provides product diversification while consistently meeting the treatment goals for wastewater at WMARSS. In ordet to transition into mid-term and long-term alternatives, more methane generation is essential. This is being addressed with a pilot study to evaluate the increase in methane production using high btu wastes from local industries. Enhancing methane production with high btu wastes will be the subject of a separate paper at the conclusion of this study.

KEYWORDS

Cogeneration, pelletization, biogas, renewable energy, biosolids management, sludge management, waste to energy, two-phase digestion, composting, anaerobic digestion.

ACKNOWLEDGEMENTS

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REFERENCES

WMARSS Operation and Maintenance Manual, January 1985