The original data does not specify for all samples what part of a plant was used or how it was prepared for sampling, so we can not account for the wide variability shown for some of the individual fruits and vegetables.

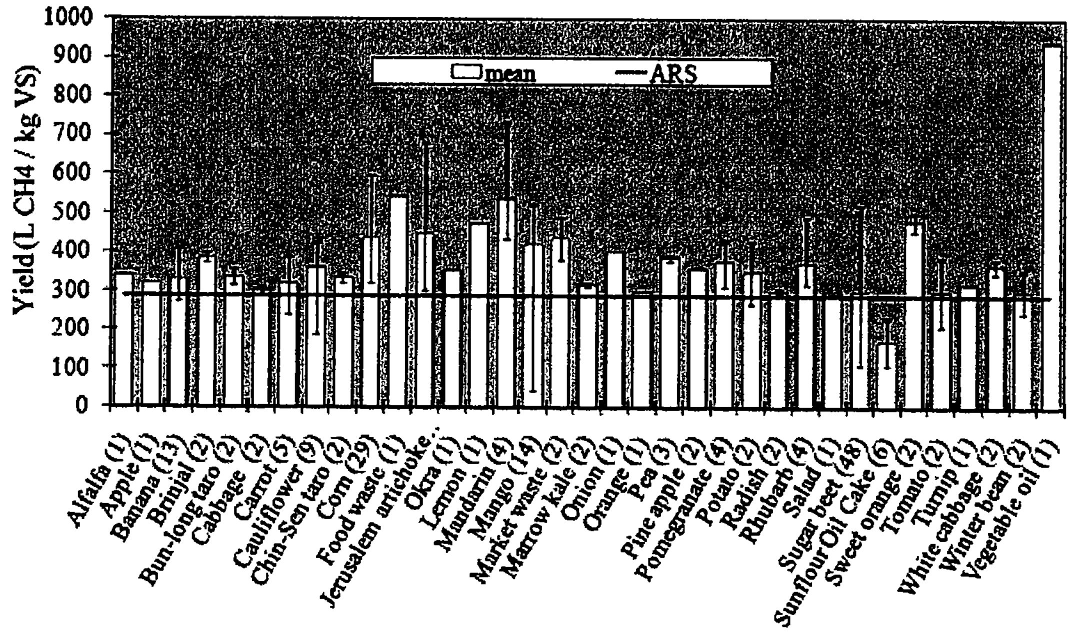


Figure 6. Summary of specific methane yield for fruit and vegetables (data from Cropgen 2007)
(number (n) of samples in parenthesis, error bars represent minimum and maximum values).

Bottom line: Food processor residue is available in substantial, if inconsistent, quantities and shows wide variability in type, content and methane yield. It can likely be had for free (or garner tipping fees) and has minimal contamination issues.

Glycerin

Crude glycerin (or glycerol), the main by-product from the production of biodiesel, contains some water and residual catalyst from the esterification process. Uncontaminated glycerin has some value to the medicinal, cosmetic, personal care and food industries but the market is limited and purification can be costly. As biofuel production increases, glycerin can become a liability. At full production, the SeQuential Biofuels biodiesel facility in south Salem will alone produce 30,000 gallons per month (~1800 tons/year) of glycerin.

Glycerin is well suited for collection and transportation. It has relatively high energy and low water content; it is easily stored with good shelf life; it is pumpable and originates from a single point source. Heating glycerin makes it easier to handle. Typical values for glycerin include TS of 82-92%, VS/TS of 92-97, pH of 5.7 and C:N of 274. Glycerin is rapidly biodegraded so care must be used not to add too much. Too much glycerin, or too high organic loading rate (OLR), will cause excessive volatile fatty acid production which will drop pH, inhibit methanogenesis and reduce methane production. Glycerin is especially synergistic when co-digesting with dairy manure: the manure contains the nutrients and the glycerin contains a readily available carbon source, so a slight addition enhances degradation of the manure and methane yields.

Fourteen day BMP trials of glycerin mixed with dairy manure with 0, 9 or 16 % glycerin yielded 140 L CH_4 / kg VS, 220 L CH_4 / kg VS and 310 L CH_4 / kg VS and VS reductions of 38%, 60% and 95% respectively. Subsequent continuous flow experiments showed stable digester performance with the 9% glycerin mix at OLR as high as 6 g VS /L/ day. The 16% glycerin had good methane yields with an ORL of 0.5 g VS /L/ day, but yields decreased if OLR was > than 0.5 g VS /L/ day.

Laboratory BMP tests were done with glycerin added at 3, 6, 8 and 15% to a base mixture of 31% maize silage, 15% corn and 54% swine manure. The control (without glycerin) had a methane yield of 335 L CH_4 / kg VS. The methane yield for 3, 6, 8 and 15% glycerin samples were 411, 440, 368 and 400 CH_4 / kg VS respectively. Adding more than 6% glycerin did not produce continually increasing methane yields. Even though this data is on swine manure and not dairy manure, the data suggests that low steady doses of glycerin will boost methane yields, but higher concentrations might cause digester instability and be a waste of a valuable anaerobic digester feedstock.

Bottom line: Glycerin has high degradability and attractive material handling qualities but also competing uses; with low moisture and high C:N, it is most suitable as a co-digestion substrate.

Fats, Oils, Greases (FOG)

A number of sources of FOG are available in the southern Willamette Valley as anaerobic digester feedstock. Recycled cooking oil ("yellow grease") from restaurants is currently collected by renderers, screened of impurities and used for animal feed or biodiesel production. While this entire grease stream would be very amenable to biogas production, it already has a beneficial, competitive use. However, the waste stream from the screening process also has biogas potential.

One renderer in the southern Willamette Valley has 50 – 60,000 gallons (~200-250 tons) of this stream available each month.

Another FOG source with no current beneficial end use is grease trap waste (GTW or "brown grease"). The free fatty acid content of GTW is generally too high for use in animal feeds or, currently, biodiesel production. Grease traps or interceptors are located in restaurant/store kitchens to separate grease from the wastewater stream to reduce clogging of sewer lines and front-end maintenance problems at municipal wastewater treatment plants.

Mobile waste haulers collect GTW, sometimes mixed with sewage from septic tanks, and dump it at permitted treatment facilities; the destination is driven by the tipping fee. For example, some mobile waste haulers were driven away from the Eugene-Springfield area treatment plant when the Metropolitan Wastewater Management Commission (MWMC) increased facility charges to over $0.15/gallon. Most haulers now dump at a local transfer site for a private wastewater treatment plant in Roseburg that has lower tipping fees. Haulers have the ability to segregate GTW from septage if there is a dedicated destination, such as a biogas plant, and the price is right. One of the 14 permitted haulers in Eugene estimates they can collect 6,000 gallons/month of GTW. A regional hauler estimates there are 1,000,000 gallons/year of GTW available in a 15 mile radius around each of the Eugene-Springfield and Salem-Keizer areas.

Characteristic ranges of typical brown grease include TS between 10-80%, BOD of 10,000 to 130,000 mg/L, pH of 4 to 5, VS/TS of 90 to 97%. VS reduction of brown grease via anaerobic digestion ranges from 80 – 90%. Fats, oils and greases have relatively high methane potentials compared to other more commonly used carbohydrate/vegetative feedstocks (Figure 7). Since brown grease quality varies greatly, energy content is often estimated as equivalent to soybean oil at 15,400 BTU / lb.

In one case study, two diary manure digesters added FOG at rates of 12 and 8% by weight which resulted in overall methane yields of 403 and 379 m3 CH4 / tonne VS, respectively (assuming 55% methane); significantly improved over typical manure-only yields of 200 or less. Addition of FOG also allowed for increased VS loading rates to the digesters, further improving methane production.

To avoid a grease slug from occurring in a digester, FOG should be introduced slowly. A grease holding tank with a mixer might help to ensure consistent addition of FOG. Unmixed, FOG may stratify. Additional insulation and heating to 75 F to 85 F helps reduce the viscosity and should promote better mixing. When FOG is used with sewage sludge, digesters maintain stability up to 30 % FOG additions, but start to have problems greater than 30 % FOG.

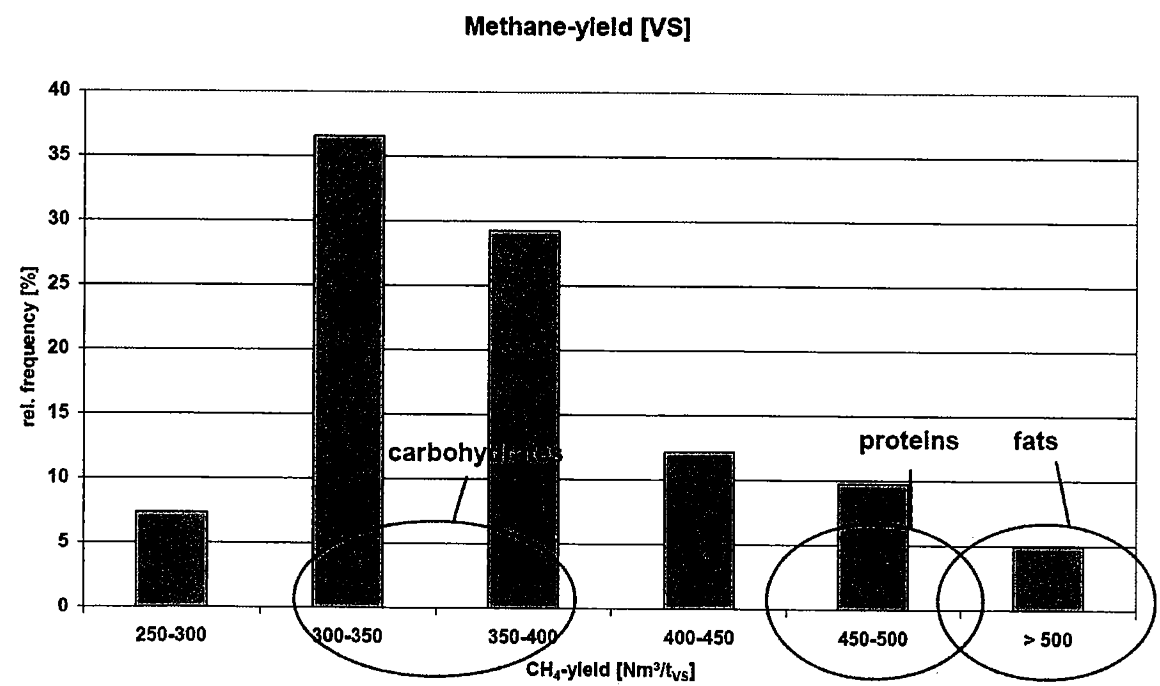


Figure 7. Frequency of use of feedstocks with various methane yields.
(x-axis is relative frequency of use, y-axis is methane yield per volatile solid)

Bottom line: FOG, like glycerin, would be an excellent additive to a co-digestion biogas plant by significantly enhancing biogas output when used in small quantities; quality and end-use vary by source.

"Green" (Yard/Garden) Waste

"Green" waste is a mixture of grass clippings, leaves, garden waste, brush/shrubbery, branches and tree cuttings and other vegetative matter. Composition varies by season, climate, community, source and collection method. Some cities, such as Eugene, mandate curbside residential pickup of yard debris by licensed haulers. Others, such as Springfield, offer voluntary participation via their contract hauler. In either case, backyard composting likely reduces the amount available for collection. Seasonal variability in composition and volume can be extreme; spring-time curbside tonnage in Eugene is more than double winter-time collection. Commercial landscape companies and rural residents in unincorporated areas of Lane County may self-haul yard waste to some County-owned transfer stations or a privately-owned composting operation, for a volumetric fee.

According to hauler records, there was 13,500 tons of residential yard debris collected at curbside in Eugene for 2008.

A feasibility study by Sacramento Municipal Utility District (SMUD) suggested that the hurdles to overcome for digestion of garden waste were seasonal variability of waste, maintaining consistent nutrient composition, low energy yields of some garden waste substrates, poor or slow degradation of woody biomass and controlling digester temperature. It concluded that anaerobic digestion of garden waste is technically feasible, but produces a comparatively lower energy yield than other materials such as food, paper and animal manures.

One study showed that turf grass, oak leaves and oak branches had specific methane yields (BMP) of 0.209, 0.123, and 0.134 m_3 CH_4 / kg VS. When blended together in a 1:1:1 ratio the value for the mixture was 0.143 m_3 CH_4 / kg VS. The woody fraction of yard waste presents a problem for anaerobic digestion. Wood is generally refractory to anaerobic degradation due to low moisture and high lignin content. In studies, woody biomass has shown biphasic methane production with simple, non-structural carbohydrates degrading relatively quickly and cellulosic components producing biogas later.

A review of other BMP testing on woody biomass showed higher values for poplar and sycamore (0.32 m_3 CH_4 / kg VS) than other biomass. Eucalyptus, pine and fir had the lowest values at 0.014, 0.063 and 0.042 m_3 CH_4 / kg VS respectively. Pretreatments such as reduced particle size and sodium chlorite treatment did improve yields, but all yields were less than 0.33 m_3 CH_4 / kg VS.

The variable nature of woody biomass is graphically displayed in Figure 8.

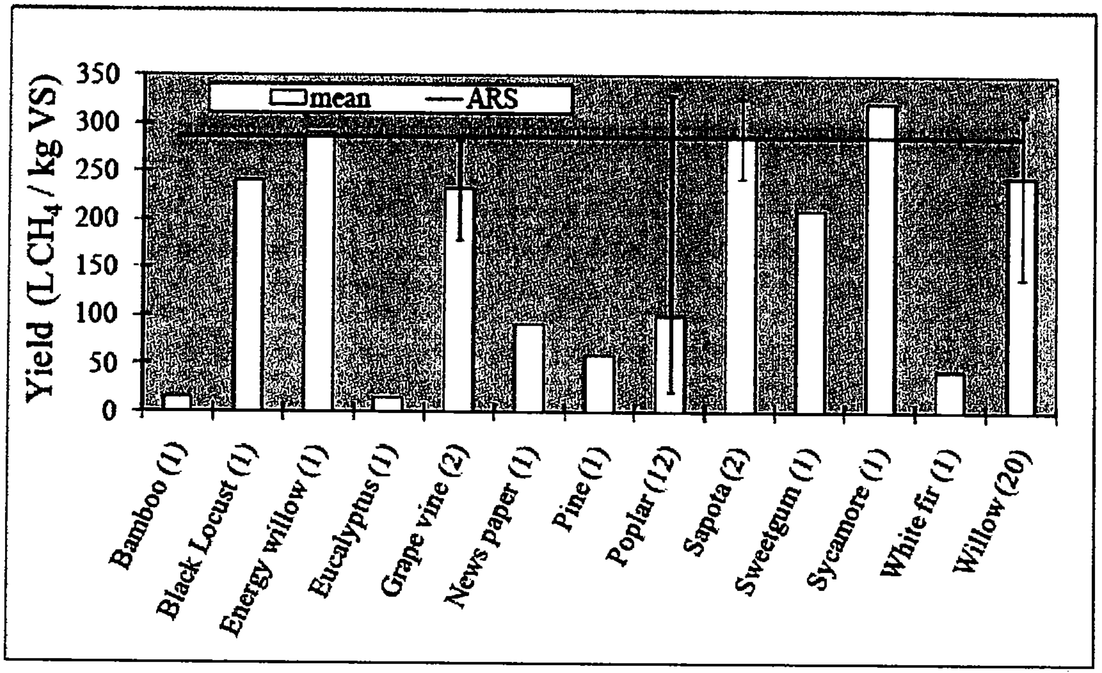


Figure 8. Summary of specific methane yield for woody biomass (data from Cropgen 2007) ***(number (n) of samples in parenthesis, error bars represent min and max values)***

The high variability of the garden waste mix combined with extended HRT and some extremely low BMP values makes this option less viable than others. Using yard/garden waste requires constant nutrient management assessment that would entail mixing garden waste, testing the chemical composition of the mix and having another feedstock available to get the right balance. Additionally woody biomass would probably need a pretreatment to reduce the biphasic nature and speed up the rate of degradation.

Essentially, garden waste is a low energy value feedstock that may require longer HRT and larger digester. It may not be feasible to control mesophilic temperatures with such a low energy feedstock. Other readily available feedstocks that don't require pretreatment and have balanced nutrient compositions without high seasonal variability would be better choices than yard/garden wastes if optimizing energy production and financial returns are high priority. In addition, yard/garden wastes have another competitive, beneficial use as a compost material.

Bottom line: Yard/garden waste is a plentiful, variable, seasonal feedstock with a high woody content that is resistant to anaerobic degradation. Its dry nature, relatively low methane potential, contamination issues and currently beneficial end-use make yard/garden waste less desirable for co-digestion.

Digester Technology Options

Digester technology has been developed with a multitude of different approaches. The feedstock can be mixed or unmixed. The vessel can be a pond or tank of varying sizes, shape, and orientation. Operating temperatures range from psychrophilic (ground temperature) to mesophilic (37 to 41 °C) to thermophilic (50 to 52 °C). The amount of total solids that can be processed by different technologies varies. Hydraulic residence time (HRT) and solids residence time (SRT) vary and can be coupled or decoupled. The following section describes the types of digesters commonly in use.

Digester Types

Traditional Digesters:

Anaerobic Lagoons are essentially covered ponds, which can be mixed or not mixed. Lagoons operate at psychrophilic temperature, leading to seasonal production variability. They generally have poor bacteria to substrate contact, hence a very low processing rate (high residence time) and large footprint are required. Sludge will accumulate over time so ponds must be dredged. Anaerobic lagoons have low capital and operational costs.

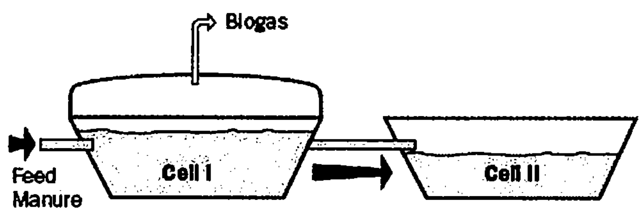


Figure 9. Anaerobic lagoon (Source: Unknown)

Plug flow digesters are linear (horizontal or vertical) shaped reactors. Influent enters on one end and effluent exits on the other. They are typically not mixed; substrate moves through the reactor in a "slug" and HRT = SRT. Plugflow digesters have a narrow solids range (11 - 14% TS) to avoid stratification or obstruction. They have moderate capital and operational costs and require periodic cleaning of the system which incurs downtime.

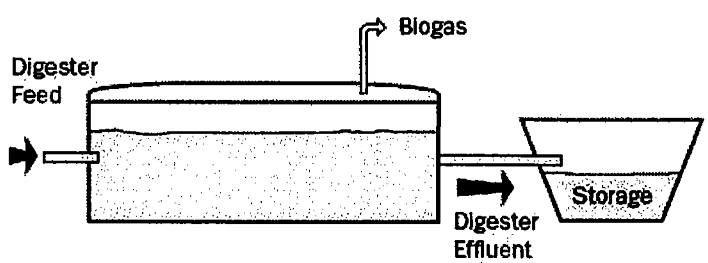


Figure 10. Plug flow digester (Source: Unknown)

Complete Mix or continuous stirred tank reactor (CSTR), a common digester type, are typically concrete or metal cylinders with low height:diameter ratio. They can be operated at mesophilic or thermophilic temperatures; mixing can be mechanical, hydraulic or via gas injection. Complete mix can accommodate a wide range of solids and, generally, HRT

= SRT. Higher capital and operational costs are balanced against the stability of the system and reliability of energy production.

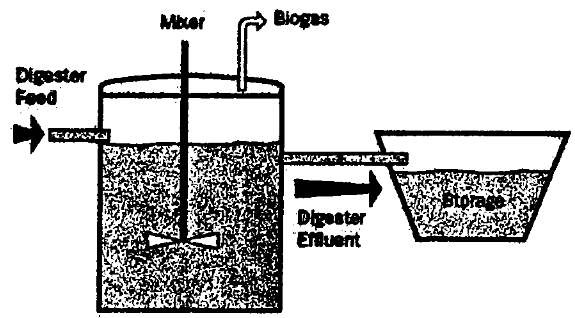


Figure 11. Complete mix (CSTR) (Source: Unknown)

High Rate Digesters:
Upflow Anaerobic Sludge Blanket (UASB): Granulated sludge remains fixed in the base of the reactor, as effluent is passed upwards through the sludge bed. UASB is considered very high rate and as such has a small footprint, however it is only applicable to waste streams with low solids content.

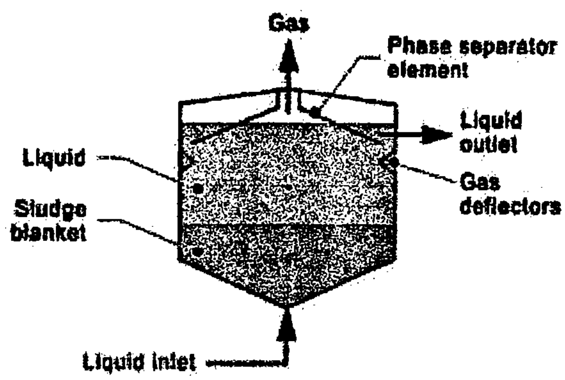


Figure 12. Upflow Anaerobic Sludge Blanket (Source: Unknown)

Fixed Film (or Anaerobic Filter): bacteria are retained in digester, attached to a media with high surface area (sand, beads, matrix, etc); also high rate (HRT as low as hours) with a small footprint. Fixed film systems are very efficient at degrading soluble constituents, but not particulates (i.e., only suitable for very low solids).

Contact Digesters:
Contact digesters retain biomass in the system, reduce the loss of microbial mass and increase residence time of solids (greater SRT). Since raw material and energy are not expended to replace bacteria that have been flushed from the system, more feedstock can be converted to methane.

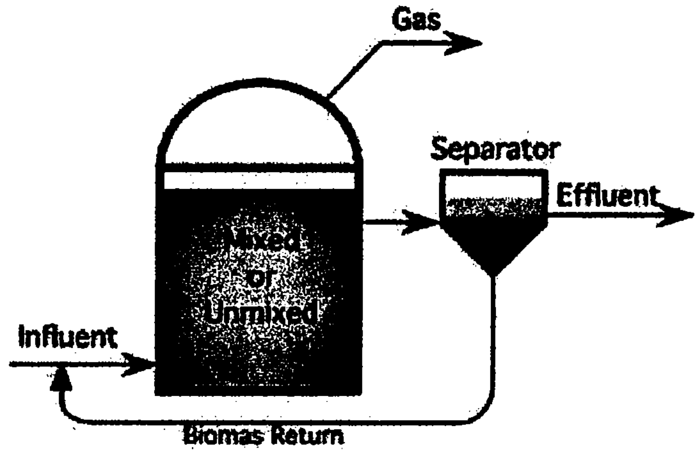


Figure 13. Contact Reactor (Source: Burke, 2001)

Anaerobic Contact Process (ACP): After digestion, effluent is degassed and settled in a separator (gravity tank); solids are returned to the main digester for further degradation. Mechanical methods (centrifuges, presses, membranes) have been used to speed the separation process.

Anoxic Gas Flotation (AGF): Separation is performed by bubbling effluent with anoxic gas – degassing is not necessary – and solids are skimmed off the top. AGF vendors claim the technology is physically gentler on the bacterial colony than mechanical separation allowing for greater productivity.

Sequencing Batch Reactor (SBR): The same tank is used for digestion and separation. Multiple tanks are operated in batch mode: feed, stir, settle, decant. Different feedstocks may be routed to smaller, parallel tanks to accommodate varying degradability. Tanks may be taken off-line when not needed.

Phased (multi-stage) Digesters:
Acid Phased: The hydrolysis/acidification step (high rate, short HRT) is performed in a separate reactor than the acetogenesis/methanogenesis step (low rate, long HRT) allowing for smaller overall footprint and shorter retention time. Theoretically, this improves biological stability and buffers feeding by avoiding over-production of volatile fatty acids (VFAS) in the methanogen tank; however this has yet to be consistently documented on a commercial scale.

Temperature Phased: A thermophilic first phase gives way to a second, mesophilic "polishing" phase. Rationale is the same as in the acid phased approach: to lower footprint and retention time, while getting more complete destruction of volatiles. Thermophilic digestion has a number of inherent drawbacks, including a narrower optimal temperature band, lower biological stability (increased "crash" potential) and higher parasitic heat demand.

Dry Digestion:
Engineered anaerobic digestion, unless otherwise specified, is a wet process; conventional reactors are typically designed for a total solid content of 20% or less. In the literature, MFW total solids generally range from 10 to 30%. At the upper limit, MFW is too dry for efficient anaerobic degradation since the bacterial colony requires a wet environment. As discussed earlier, co-digestion with one or more "wet" substrates, such as dairy manure or WWTP biosolids, may be beneficial. At a minimum, dilution water will be required to increase moisture content. Any water added to the front end process needs to be removed at the back end, though depending upon the nutrient recovery technology, much of the water could be recycled as make-up water. From a financial and energy balance standpoints it may be logical to minimize this addition and removal.

Dry digestion, according to the German Federal Environment Ministry is anaerobic digestion of a substrate with 30% or higher total solids content. Common parlance applies the term to anything higher than about 20% total solids, the upper threshold for conventional pumping. The name "dry digestion" is somewhat of a misnomer, as there still is 50-80% moisture. The process was designed for digestion of MSW, to prevent the sedimentation and scum formation that was common with that particular feedstock in wet digestion systems. The majority of MSW digestion facilities (over 66 full scale plants) in the EU today use dry digestion technologies. Dry digestion is also beginning to be applied to energy crops in on-farm situations. There are only a handful of digester designers that offer dry digestion options. Dry digestion is reported to have the following benefits over wet, slurry-based systems:

1. Higher energy density, allowing for smaller vessels and lower construction costs
2. High dry matter reduces transport and handling costs
3. Digestion residues are suitable for composting without dewatering
4. Pumps, mixers, injectors are minimal
5. Process energy demand is reduced due to less overall mass
6. Improved stability and reliability (no sedimentation, scum layer)
7. Reduced odor emissions and nutrient loss during storage

The three common, commercially available approaches are briefly described below.

Batch process with percolation: biomass is essentially stacked with a front-loader in a temperature-controlled garage type building; multiple compartments with individual access doors can be used (Figure 14). Fresh material is blended with digested material in a given ratio. Leachate is percolated back over the piles and biogas collected with a gas recovery system. The substrate batches are retained in these reactor cells for 20-60 days, depending on degradability of the feedstock and biogas production rates. Rooms are ventilated before emptying.

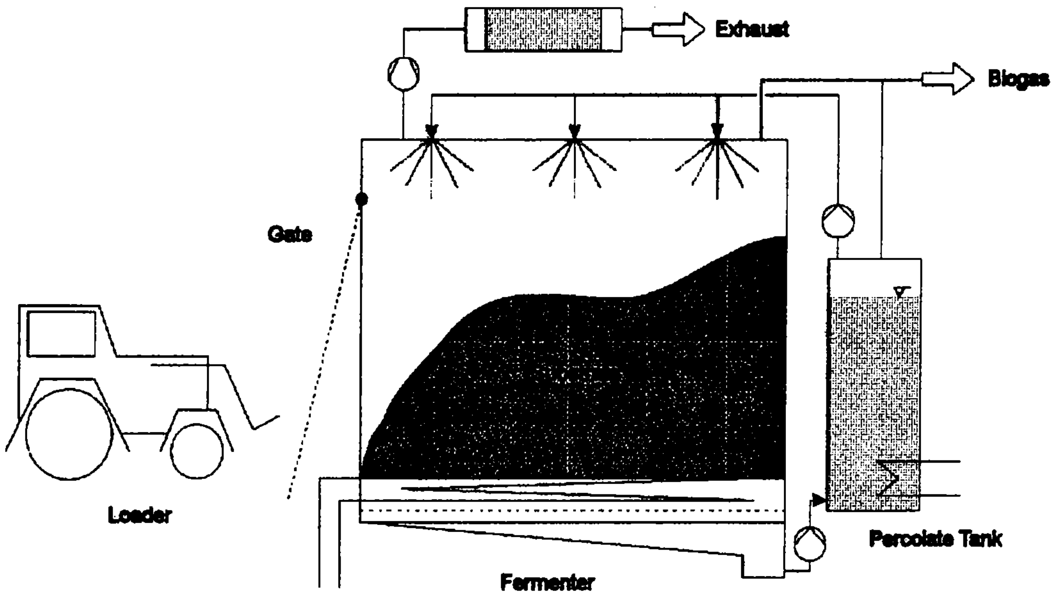


Figure 14. Dry digestion – batch process with percolation (IEA Bioenergy, 2007)

Continuous process – plug flow: Unlike the batch process, material is continually fed into one end of the reactor, a horizontal tube-shaped vessel made of concrete or steel, and digestate is continually pushed out the other end (Figure 15). Liquid from the digestate is used to inoculate the incoming substrates and facilitate mixing. Substrate is not mixed internally, but a mechanism (typically paddles) is used to move the plug through the reactor.

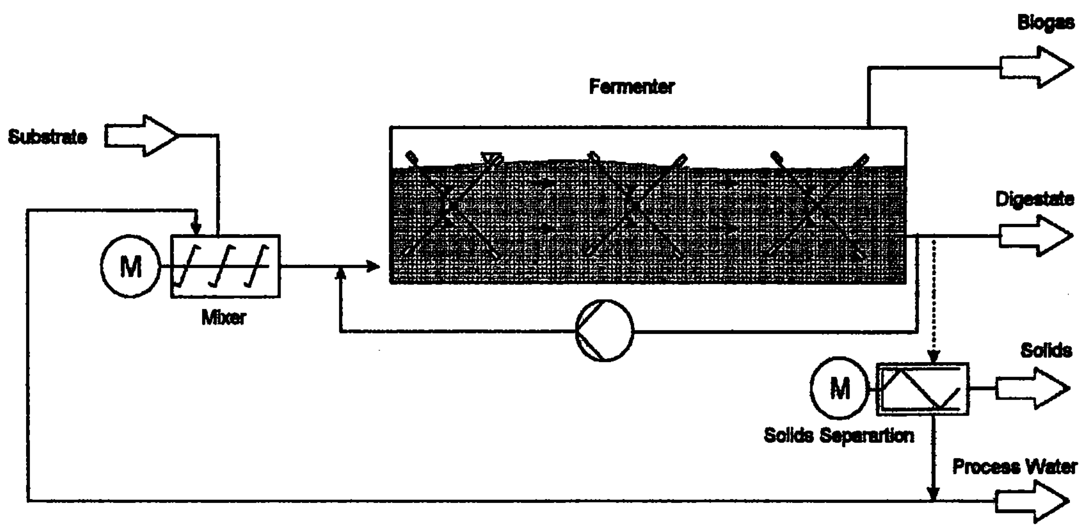


Figure 15. Dry digestion – continuous process, plug flow (IEA Bioenergy, 2007)

Continuous process – silo reactor: Unlike upright wet digestion tanks, the dry silo reactor has no internal mixing (Figure 16). It is essentially a vertical plug-flow digester that progresses top-to-bottom via gravity. Intensive fermentation occurs in the cylindrical portion; post-fermentation occurs in the conical portion. Inactive digestate falls into the cone for removal. Feedstock is mixed with active digestate and pumped externally to the top of the silo.

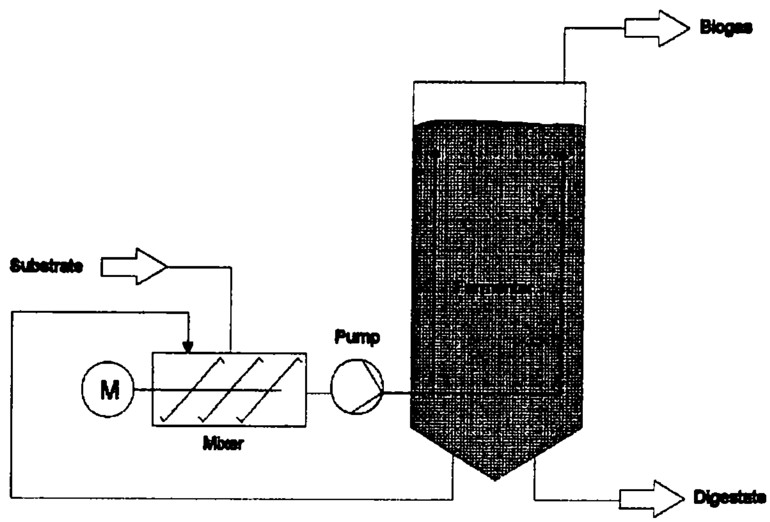


Figure 16. Dry digestion – continuous process, silo reactor (IEA Bioenergy, 2007)

Pretreatment

MFW is readily biodegradable and requires no pretreatment per se to improve the degradation. However, impurities (i.e., plastic, metal, glass) must be removed from the MFW stream to avoid mechanical failure of certain facility components and to produce useable and valuable fertilizer co-products. Less importantly, large volumes of non-degradable contaminants would occupy digester space reducing the capacity available for biogas production.

The amount and type of pretreatment required will depend on the quality of the MFW, which in turn is dependent on the source and collection method. For example, a shredder and magnet may suffice if paper bags are used for collection (or no bags at all). However, if significant quantities of plastic are present in the stream, additional steps would be required. A trommel (or drum) screen is a common method for separating small/soluble organic particles from larger inorganic matter. However, no separation method is 100% efficient! One study showed that the majority of "reject" material was organic matter, regardless of separation technology. The percentage of reject material can vary between 2%, 34% and 41% of incoming mass for shredder/magnet, disc screen and screw press technology, respectively. This experience demonstrates the importance of training and quality control in the collection step. If contaminants are kept to a minimum, the most efficient separation technology may be utilized and transportation/ disposal costs would be reduced.

Methods for dealing with contaminants have been most thoroughly explored in AD systems in which the organic fraction of municipal solid waste (OFMSW) is the feedstock, whether "source separated" or co-mingled. The BTA system (Dufferin, Canada) utilizes a "hydropulper", where a rake skims plastic and other floating debris from the waste stream followed by a "hydrocyclone" that removes grit and other heavy contaminants. The ArrowBio Process – operating on MSW streams in Israel and Australia – also uses differential buoyancy in water vats for primary separation, in conjunction with trommels, manual sorting lines and magnets, before sending a much diluted mixture to UASB digesters.

Additionally, MFW as defined in this study will include some amount of animal by-product (ABP), raising issues related to public, animal and environmental health. There are currently no rules or regulations in place in Oregon specifically dealing with anaerobic digestion of ABP; this will likely change in the future. The ABP found in MFW would be classified as Category 3, or "low-risk", according to a current European Commission Regulation (No 1774/2002). Category 3 material includes "catering waste" (food waste – including used cooking oils – originating in kitchens or restaurants), waste food from supermarkets, parts of animals fit for human consumption but not intended for human consumption for commercial reasons and fish parts. The EU standard requires a hygenisation unit capable of holding Category 3 material at 70 °C (158 °F) for 60 minutes. ECOregon strongly recommends following EU guidelines concerning the anaerobic digestion of ABP.

Conclusions & Recommendations

Anaerobic digestion is proven technology, immediately available for commercial applications from an ample number of qualified vendors with flexible designs. Anaerobic digestion has additional benefits with its positive net energy balance, reduction in greenhouse gas emissions and ability to close the loop on nutrients. The flexibility in acceptable feedstocks provides biogas plants a measure of operational security over other conversion technologies.

MFW shows excellent digestibility. If MFW is to be digested as the sole feedstock, a multi-phased digester technology is recommended. A Lane County-owned pilot-scale demonstration facility (similar to the Biogas Energy Project in Davis, California), while technically feasible, would require financial due diligence during the business plan phase. If MFW is co-mingled with other MSW, a "dry digestion" technology could be considered.

However, for the reasons stated in this study, MFW should be co-digested with other substrate(s). Considering the extreme digestibility of MFW and the benefits of co-digestion, other "bulking" substrates could be blended to improve biological stability, increase methane production and solve waste management challenges. For example, a privately funded dairy farm digester would benefit greatly from delivery of MFW. Indeed, returns on dairy digesters are often marginal without co-digesting energy dense materials.

Complete mix or continuously stirred reactor tank (CSTR) digesters represent a proven and effective technology for feedstock with a wide range of total solids. Complete mix systems run at steady state with continuous flow of reactants and products; the feed assumes a uniform composition throughout the reactor and the exit stream has the same composition as in the tank. This homogenization ensures maximum contact between substrate and microbe, enhancing the digestion process and biogas quality. For this reason, complete mix (aka, "vertical") systems are widely preferred over plug flow (aka, "horizontal") systems in the EU (Figure 17).

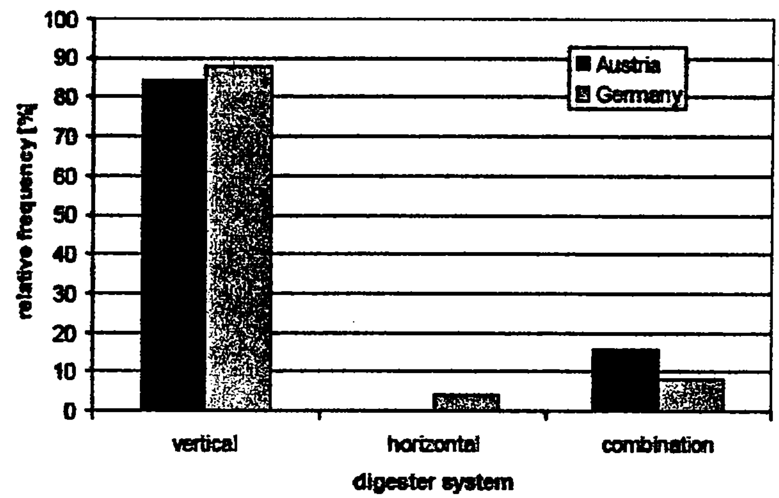


Figure 17. Frequency distribution of digester technologies for AD facilities built in Austria and Germany between 2003 and 2005.

The preferred operating temperature range of new AD facilities in the EU is mesophilic (Figure 18). The greater stability and lower parasitic heat load of mesophilic systems outweighs the decreased retention time and smaller footprint of thermophilic systems.

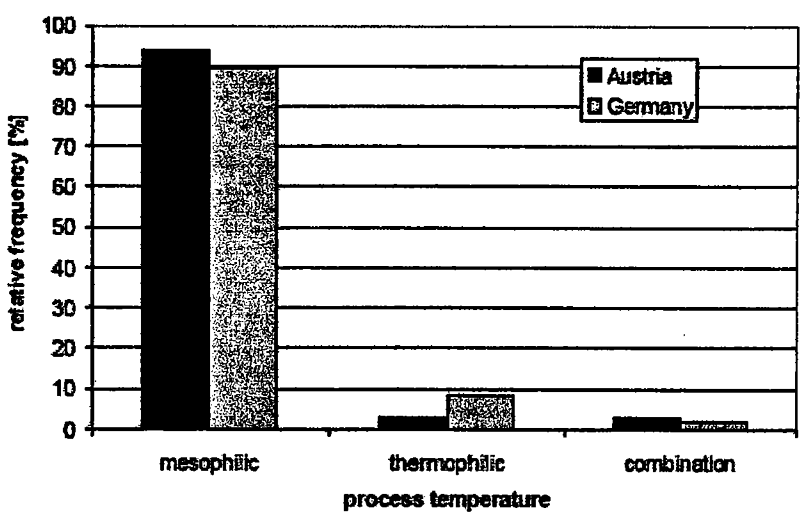


Figure 18. Frequency distribution of operating temperatures for AD facilities built in Austria and Germany between 2003 and 2005

Section 4: AD Energy Output & Co-Product Outputs

Biogas & Biomethane

Biogas produced by the digestion process will contain 30-50% CO_2 and 50-70% CH_4, along with traces of other gases (H_2S, O_2, N_2, H_2). It is considered a low energy fuel; at 65% methane content, biogas would have about 650 Btu per cubic foot. Hydrogen sulfide and water vapor will need to be reduced to acceptable levels for use in a CHP unit. If injection to the natural gas pipeline is desired, methane content will also need to be increased to ~97% by removal of CO_2.

MFW delivery to a biogas plant at a rate of 5,000 tons/year with a methane yield of 435 *m^3 CH_4 / tonne VS* would result in approximately 50,000 scf of methane per day (18,250 Mcf/year). This estimate is based on the assumption that MFW is the sole feedstock. If one or more additional co-substrates are incorporated that contain an equivalent amount of volatile solids with a similar methane yield, methane production would double.

Electrical Energy Potential

Biomethane produced at a rate of 50 Mcf/day could produce approximately 240 kW net in a CHP operating at ~40% efficiency. Since biogas and hence electricity can be produced 24 hours/day, 355 days/year (unlike solar or wind installations), this equates to 1960 MWh/year (considering 10 days of maintenance). In addition, since the electricity is produced from a renewable source, the biogas plant is eligible for Renewable Energy Credits (aka "greentags") as well.

Thermal Energy Potential

Ideally, the site surrounding the biogas plant has use for some or all of the heat generated by the CHP engine. Electricity production with an internal combustion engine and generator is at best 40% efficient; recovery of thermal energy from a CHP unit can raise the overall efficiency to roughly 80%, greatly improving the energy balance of the project. Engine jacket heat can be routed through a heat exchanger to produce hot water; exhaust heat can be routed through a heat exchanger to produce steam. A 240 kW CHP unit could produce up to 0.4 MMBtu/hour of jacket heat and 0.5 MMBtu/hour of exhaust heat.

A certain use of the hot water will be to pre-heat incoming feedstock and maintain mesophilic (or thermophilic) temperatures in the digester vessels. An adsorption or absorption chilling system, building/space heating or greenhouses are other possible applications for the thermal energy carried by water. Steam can be used to offset boiler use, to provide heat for a hygenisation unit or drive a vacuum evaporation system for nutrient recovery.

The best use for thermal energy depends on the nature and needs of co-located operations and neighboring facilities, if any. If no use for thermal energy can be developed on the project site, options other than CHP should be investigated (e.g., biogas upgrade for injection to natural gas pipeline). A complete cost/benefit analysis of the potential uses to optimize the financial benefits of thermal energy recovery is outside the scope of this research element but should be included in any business planning activities.

Fiber

Digester effluent (digestate) will be of lower volume and solids content than the influent feedstock (Table 11). Digestate can be treated as conventional industrial wastewater or directly land applied as irrigation water to adjacent fields. However, better utilization of the nutrient fractions can be achieved by separating the solids and concentrating the liquid.

The digestate can be dewatered into a solid fiber fraction and a liquid fraction (centrate or filtrate) using a centrifuge, screw press or belt press. The dry fiber can be used as a compost material, soil amendment, nursery planting media or animal bedding. The dilute liquid can then be concentrated using vacuum evaporation or membrane technology to produce a concentrated liquid fertilizer (syrup) and clean condensate or permeate suitable for irrigation. Dewatering is an industry standard, proven process; however a complete cost/benefit analysis will tailor a solution specific to project goals. Concentration of effluent centrate or filtrate is less common and will require more in depth investigation.

All macro- and micro-nutrients present in a feedstock will pass through the digester and be present in the digestate (aside from a small amount of sulphur, which exits in the biogas as hydrogen sulfide – H_2S). Nitrogen (N) in the digestate will be primarily in the form of soluble ammonia and thus present in the liquid after dewatering, whereas phosphorus (P), typically insoluble in compound form, will largely end up in the fiber fraction. The distribution ratios of N and P in the fiber and liquid fractions will depend on the solids capture rate of the dewatering equipment used. For example, using a centrifuge with 80% capture rate will result in 80% of the total solids (and, roughly, phosphorus) in the fiber, and 20% of the solids/phosphorus in the liquid.

Table 11. Summary of digestate products from example MFW (sole feedstock) digester system

		Amount (tpd)	TS (%)	Nitrogen (%)	Phosphorus (% as P_2O_5)	Potassium (% as K_2O)	Comments
Input	Feedstock	14	88	3.2	1.2	1.1	municipal food waste
Output	Digestate	10.8	12.1	4	1.5	1.4	send to dewatering
Dewatering Products	Fiber	3	35	2.8	4.3	3.9	assumes 80% solids capture rate
	Centrate	7.8	0.3	4.5	0.4	0.4	send to concentration (if necessary & available)
Concentration Products	Syrup	1.3	20	25.8	2.4	2.2	can be concentrated +/- 20%TS if desired
	Condensate	6.5	~0	~0	~0	~0	"clean" recycle process water, 1.1 gpm

Liquid Fertilizer

Dewatering of digestate with a centrifuge (or screw/belt press) into a solid, fiber fraction and a liquid, centrate (or filtrate) fraction is straightforward and industry standard. The relatively small quantity of centrate – 7.8 tons / day in the scenario from the mass balance flowchart (Figure 19) – may allow for transportation from the site. Depending on the biogas plant location and nutrient management plan, it may be possible to land apply the centrate directly to adjacent agricultural fields. Concentration is an option that will allow for storage, transport to remote growing areas and/or sale as liquid fertilizer. A market assessment would be required to determine whether and how much concentration would be beneficial.

Multiple approaches to concentrating the centrate are commercially available. However, the volatility and molecular size of ammonia may present technical challenges to evaporation and membrane technology, respectively. The majority of the nitrogen present in the centrate will be ammonia, so capturing it is critical to preserving the value of the concentrate. At least two vendors in the EU are having success with multi-effect vacuum evaporators; lab trials and modeling suggest that existing forward osmosis membrane technologies can be effective with centrate as well.

Conventional nutrient recovery approaches, such as chemical precipitation, struvite production, and ammonia stripping may also warrant investigation. In addition, the final use as fertilizer and the potential "organic" status must be considered. As with dewatering, a complete cost/benefit analysis of performance, energy use, capital and O&M can determine ultimate feasibility of the available technology and vendor options.

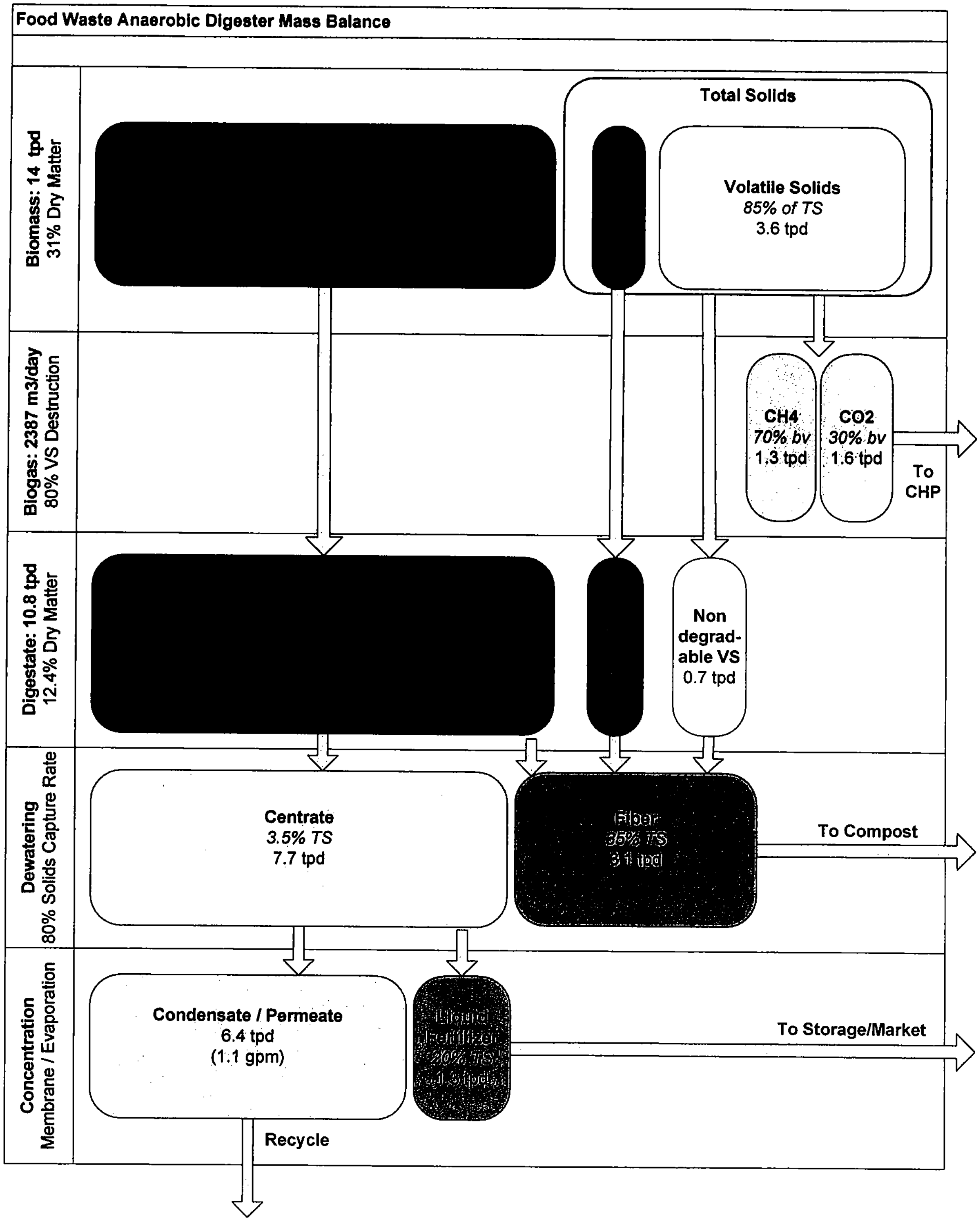


Figure 59. Mass balance diagram of theoretical MFW (sole feedstock) anaerobic digestion process

Environmental Credits

Renewable Energy Certificates

Renewable Energy Certificates (RECs) are also commonly known as Green Tags, Renewable Energy Credits, or Tradable Renewable Certificates (TRCs). One REC represents the environmental and social benefits from one megawatt-hour (MWh) of electricity generated from an eligible source fed to the grid. While this is the generally accepted definition, variations do occur depending on the certifying agency.

The process of certifying the source generating technology to qualify for issuing RECs is relatively simple and straight forward. While it varies slightly by certifying agency, typically eligible technologies include wind, solar, biomass, low-impact hydro, geothermal and landfill gas. No other requirements exist to demonstrate additionality, barriers to market, or financial need as may be the case with carbon offsets.

The REC market is divided into two segments. The Compliance Market is driven by state Renewable Portfolio Standards (RPS) that requires utilities to include in their portfolio of power sold to retail customers a percentage of electricity generated from qualifying renewable energy sources. The Voluntary Market is driven by retail consumers (households and corporations) desiring to support renewable energy or to "green" up their image.

RECs can be sold "bundled" with the qualifying electricity or "unbundled" and separate from the electricity. The Tag purchaser can retire the tags in proportion to their conventional energy consumption and then claim to have purchased and used renewable electricity. RECs are issued a unique identification number by a certifying agency to prevent double counting. RECs can be sold in blocks as they are generated or sold on a forward basis. The forward selling of RECs can help bring the funding necessary to develop projects; however the RECs are sold at a discounted rate.

An MFW-based renewable electric generation facility would likely qualify for REC certification. However, further study will be necessary do to project specific variables which include, but are not limited to: site location, interconnection utility, power purchase agreement terms, feedstocks utilized, electric generation technology, and facility commissioning date. Reliable reference price indexes for RECs in the Compliance and Voluntary Market are not available. However, ECOregon recently negotiated two Voluntary Market REC contracts for a biomass based project in the Willamette Valley where opening offers ranged from $4.00 to $8.00 a tag.

Carbon Offsets

The Kyoto Protocol was developed by the United Nations Framework Convention on Climate Change (UNFCCC) and adopted in 1997 by more than 170 countries. Industrial countries which are legally bound by this agreement have agreed to limit or reduce their emissions of greenhouse gases (GHG) by at least 5% below the 1990 levels by 2012. Carbon credits are measured in tonnes of carbon dioxide equivalent (tCO_2e). One carbon credit represents one ton of CO_2e non-emitted or reduced. While emission reductions have different technical names dependant on which certifying mechanism they arise from, they are collectively referred to as 'carbon credits'.

In voluntary carbon markets activities that reduce GHGs produce verified emission reductions (VERs) that can be sold to companies or individuals wishing to voluntarily reduce their carbon footprints. Several voluntary markets are in development around the world. However, there is no single regulating body currently enforcing quality standards in relation to the development and trading of VERs. Greenhouse gas or carbon credits developed in the United States, cannot be traded, purchased, or sold abroad in the international market which operates under the Kyoto Protocol's specific requirements, such as, monitoring, verification, validation and certification.

Although there is no national mandated carbon offset program in the United States, various state and regional programs are being developed for the voluntary reduction of greenhouse gases. There are several initiatives such as the Regional Greenhouse Gas Initiative being developed by nine north eastern states, or the recent California Global Warming Bill. The Western Climate Initiative, a collaboration of western states and Canadian provinces of which Oregon is part, has released a draft design for a regional cap-and-trade system.

Carbon credits and voluntary carbon offsets require certification and verification under strictly defined protocols to test for "additionality". In the US voluntary market these protocols are based on one of the Kyoto approved protocols or other recognized protocols such as the Gold Standard or the Voluntary Carbon Standard. These certifications and verifications can be approved via various organizations such as the Chicago Climate Exchange, Green-e Climate, the Regional Greenhouse Gas Initiative or others. There is no single national standard. Each of these organizations have adopted, modified or even created their own protocols as they see fit.

The purpose of these additionality tests are to ensure that the carbon credits/offsets issued are above and beyond what is mandated or what a project owner would do regardless of good economic business sense or usual business practice. These voluntary projects must pass the stringent additionality tests to demonstrate that they would not have happened otherwise. In other words, if there are no financial, technological, or other barriers to reducing emissions, then those reductions are not truly additional and therefore not to be counted. It is clearly stated that one of the goals of these protocols is to prevent "cherry picking" of projects that should/would have happened regardless of the additional revenues available by the sale of carbon credits.

The potential exists for an MFW project to earn carbon credits from offsetting landfill emissions and other carbon-equivalent sources. The determination process is complex and time consuming and depends on project specific variables such as, but not limited to: project site, project boundary definition, current regulatory environment, technological and/or financial barriers, additionality and other protocol specific requirements.

Sole Feedstock System Configuration:
There are no full-scale commercial biogas plants utilizing Municipal Food Waste as the sole feedstock. The most applicable existing facility is the Biogas Energy Project pilot plant designed at UC Davis and licensed by Onsite Power Systems, Inc. The system uses a thermophilic, acid-phased design, which separates the hydrolysis/acidification step from acetogenesis/methanogenesis. The process, illustrated schematically in Figure 20, claims the following advantages over "conventional" AD systems:

- Non-mechanical mixing system provides reliability
- Modular design that is scalable to any size
- Ability to process high solid content waste (up to 30%)
- Commercially available equipment and components

It is unclear if the operational stability of this demonstration system over extended periods of time has been sufficiently proven at commercial performance standards. Cost estimates for an Onsite Power System AD facility capable of processing 14 tons/day could not be secured for this research element. If it is determined that a demonstration plant utilizing Eugene-Springfield MFW as the sole feedstock is the desired approach, financial and technical performance must be further investigated in the business planning stage.

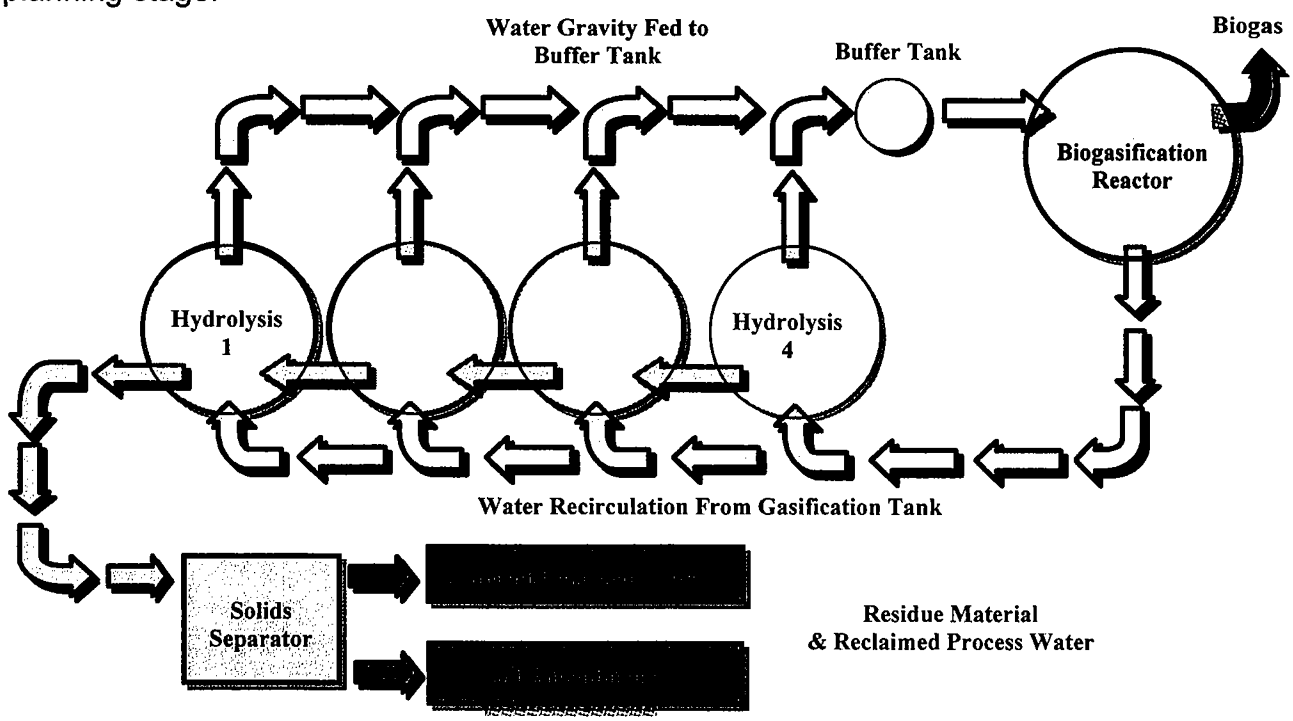


Figure 6. Acid-Phased digestion system, circulation process flow
(*Source: Onsite Power Systems, Inc*)

Co-digestion System Configuration:

As alluded to above, there are advantages to co-digesting MFW with other substrates. A co-digestion biogas plant would likely consist of the following components:

- One reception hall with feedstock storage, fiber storage, CHP unit(s), control/lab room, dewatering and nutrient recovery equipment
- One feed reception pit for dry matter
- One feed storage tank for liquid feed (if necessary)
- One hydrolysis mix tank
- Two anaerobic digester tanks
- One post digester with integrated biogas storage
- One permeate storage tank with the size dependent upon nutrient recovery technology utilized and storage retention time required
- Access road and long-term feedstock storage would require additional land
- Close proximity to the electrical grid or natural gas grid would be required if the biogas plant intends to sell electrical power or upgraded methane

Nutrient Recovery Equipment
All macro- and micro-nutrients present in a feedstock will pass through the digester and be present in the digestate, a product well suited for agronomic, horticultural, and silvicultural uses. Although no formal opinion has yet been requested, Oregon Tilth believes that digestate can be used in certified Organic crop production. Nitrogen (N) in the digestate will be primarily in the form of soluble ammonia and thus present in the liquid after dewatering, whereas phosphorus (P), typically insoluble in compound form, will largely end up in the fiber fraction. The distribution ratios of N and P in the fiber and liquid fractions will depend on the solids capture rate of the dewatering equipment used.

Dewatering will occur with a decanter centrifuge, belt press or screw press. The dry, fiber fraction of dewatered digestate can be used as compost component, soil amendment, nursery planting media or animal bedding. Value can be added to the liquid fraction, which contains all soluble nutrients, by concentration. The dilute liquid can then be concentrated into a liquid fertilizer 'syrup' and a 'clean' stream (condensate or permeate) suitable for irrigation or recycled as process water. It remains to be seen if economy of scale allows for concentration infrastructure considering the relatively small volume of liquid effluent (7.8 tons/day or 1800 gallons/day in the MSW 'sole feedstock' scenario). A comprehensive cost-benefit analysis would be required in the business planning phase.

A number of options exist for recovering nutrients from the digestate:

- An "ammonia stripping plant" is designed to capture nitrogen only. Wastewater is heated and pH adjusted, falls through a packed column counterflow to rising air which removes ammonia vapor which is condensed as ammonia sulphate using sulfuric acid. Lack of phosphorus removal makes this option undesirable as the sole application.

- A "pellet reactor" is designed primarily to capture phosphorus as struvite (magnesium ammonia phosphate). Wastewater is pumped through nozzles into a reactor chamber, reacts with MgOH and a seed material to form struvite (magnesium ammonium phosphate) pellets. Limited nitrogen removal makes this option undesirable as the sole application.
- Ultrafiltration/Reverse Osmosis has excellent nitrogen and phosphorus removal. This method is proven at multiple biogas plants worldwide. Typical process is to run pre-screened effluent through multi-stage UF membranes; the filtrate is cooled, acidified, anti-scalant added & sent through multiple RO units utilizing pressure gradients. Drawbacks include high capital and operating cost.
- Forward Osmosis is the removal of water from an influent stream into a high salinity "draw solution" using an osmotic gradient. The draw solution is then reconstituted by water removal with Reverse Osmosis. While theoretically a viable solution, minimal applications at commercial scale create a significant risk factor.
- Evaporation, using multi-effect, fluidized bed, vacuum evaporators, is a method often mentioned as synergistic in the literature, utilizing waste heat from the CHP. While this technique has been used at a number of European biogas plants, performance assessments have been elusive and contradictory.
- Flocculation, a common method in wastewater treatment, is not appropriate as a stand alone solution. It is available as a dewatering pre-treatment for any of the other technologies. Caution is required with regard to flocculant choice to ensure organic status compliance is maintained.

Electricity Production Equipment

If electricity is the desired end use of the biomethane, the most common application is in a combined heat and power (CHP) unit, also called co-generation. The unit is typically a stationary internal combustion engine and integrated generator specifically engineered to operate on biogas (or natural gas). Dozens of vendors worldwide, with a range of experience, provide biogas compatible CHP units with varying performance specifications. The electricity generated could be used at the facility, in a net-metering situation or sold to the utility. Multiple, smaller CHP units would provide redundancy and could be located at different locations within the facility to more efficiently utilize waste heat, if necessary.

Electricity production from biogas via fuel cells is another method. Fuel cells have been used at a limited number of commercial scale digesters, including two in the United States with varying success. Although potentially promising, fuel cells should be considered unproven for this application at this time.

Biogas Upgrading Equipment

Biogas conversion in a CHP unit is most viable when there is an on-site use for the electricity and heat. In the event of biogas production in excess of the heat and/or electricity required, options include compression and/or increasing the methane content to pipeline-grade (~97% CH_4). Over 25 biogas plants in the EU, and at least four in the USA, are currently delivering methane to the natural gas grid. However, this is a relatively new development that will require assessment in and of itself.

A preliminary assessment indicates a number of technologies are available to "scrub" biogas:

- Membrane
- Pressure swing absorption
- Amine absorption
- Water scrubbing (DWW)

Technical and financial considerations of performance, reliability, capital and operating cost, safety, energy usage, waste products, etc. must be assessed for each technology and available vendors. Likewise, compression technology must be addressed. Issues of "interconnection" with the natural gas utility will also need to be detailed such as quality requirements, contract mechanisms, costs and timelines.

Capital/O&M Expenses Findings
The budgetary cost estimate for the development of the co-digestion biogas plant are described in Section 6: Revenue and Expense Review and ROI Estimates

Feedstock is typically the primary operational expense for a biogas plant; however tipping fees may apply to the MFW scenario.

Anaerobic digester O&M has been quoted at 1.5% of the $3.5M digester capital cost (approx. $50k/yr). This does not include the cost of feedstock. CHP O&M has been quoted at 1.2¢/kWh, assuming a 930kW generator operating 355 days/year (approx. $95k/yr). In addition, both the AD and CHP have electrical demands, slightly reducing the net amount of available electricity. These parasitic loads are relatively small compared to some other conversion technologies.

A full-scale biogas plant would likely require 2 full-time employees. Much of the daily operation of a modern biogas plant is automated. A well-designed process control system will collect data, monitor performance, sound alarms (remotely) and provide process control via feedback loops.

Section 5: Potential Sites

The study explored five sites where food waste to renewable energy related operations and infrastructures could potentially occur:

1. Metropolitan Wastewater Management Commission site on River Road
2. Metropolitan Wastewater Management Commission site on Aubrey Lane
3. Lane County site at the Glenwood Transfer Station
4. Lane County site at the Short Mountain Landfill
5. Junction City owned site at Municipal Wastewater Treatment Ponds

The site factors examined included:

- Permits needed
- Current Site Use
- Waste on Site
- Water and energy
- Advantages and disadvantages of site

Permits Needed

No matter the site of a food waste to energy project, the Oregon Department of Environmental Quality will have to issue a solid waste disposal permit.

According to Oregon Department of Environmental Quality (DEQ), an anaerobic digester project will require a solid waste permit so that organic feedstocks can be brought onto the digester site. This is because organic feedstocks are deemed by DEQ as "solid waste". Solid waste is defined as "*useless and discarded*" material (ORS 340-093-0030.82), regardless of whether it is sold, given away for free or disposed of at a cost.

The process of anaerobic digestion fits within the current definition of composting defined as "*the managed process of controlled biological decomposition of organic or mixed solid waste*" (ORS 340-093-0030.18).

Therefore anaerobic digestion will be permitted under the solid waste facility sub-category "composting facility" whether aerobically composting is performed on-site or not as opposed to the sub-category "energy recovery facility". Imported materials would be classified as "*green feedstock*" (ORS 340-093-0030.37) since they are being used in a composting operation.

From a compost facility permitting perspective, the proposed anaerobic digester would require a DEQ Compost Facility Full Permit regardless of feedstock. The reason being this type of permit can be tailored to site-specific situations, including anaerobic digestion.

For composting facilities, Oregon Administrative Rules (OAR) Chapter 340-096-0060(3) requires all compost facilities, subject to regulation, to undergo a risk screening to determine the potential environmental risk a facility poses to human health and the environment.

The following facility operational and physical information will be used by DEQ to conduct an environmental risk screening.

- A description of the composting operation including feedstock types, volumes and sources, any grinding or other preparation of feedstocks, composting methods, and uses of composted material;
- A description of all existing or planned structures and features for managing leachate and stormwater, including but not limited to information about any detention or infiltration basins, and any infiltration structures such as filter strips and bioswales;
- If the facility is subject to the pathogen reduction requirements of OAR 340-096-0070(5), a description of the methods the facility will use to achieve such pathogen reduction;
- A description of the methods the facility will use to achieve vector control;
- Any seasonal variations in the operation of the facility;
- Contact information including the composting facility operator, composting facility owner, and property owner; and
- The location and site schematic, including areas for management of leachate and stormwater, of the existing or proposed composting facility by latitude and longitude, identified on a map;
- The location of and distance to surface water in the drainage area of the composting facility, and all drainage channels, ditches and any other water conveyances leading from the composting facility to surface water, identified on a map;
- The locations of all commercial and residential structures within a one mile radius of the composting facility, identified on a map or photograph (aerial photograph);

A complete permit application will also include:

- A Land Use Compatibility Statement (LUCS).
- A Recommendation from the local solid waste planning authority.
- Demonstration of the need for a new, modified or expanded facility.
- A Certificate of Business Registry.
- Identifying any other known or anticipated permits.
- Application Fee and Compliance Fees (if required).
- Any other information the Department deems necessary.

Finding

The preparation of the permit application for a food waste to energy project will require specific site and project details that will need to be developed by project proponents.

Short Mountain Landfill

Location: Eight miles south of Eugene on Interstate 5.

Ownership
The Landfill is owned by Lane County and operated by the Lane County Solid Waste Management Division.

Current Site Use
Short Mountain Landfill is Lane County's only municipal solid waste landfill. The landfill receives 800 tons of waste daily from 16 County operated transfer sites and commercial waste haulers. No public accommodations exist at Short Mountain. The landfill has an expected capacity until 2088.

Waste on Site
The majority of the municipal food waste disposed of in the Eugene-Springfield Metro area ends up at the Short Mountain Landfill.

Fit for community and zoning
The site is already zoned to receive municipal solid waste. It has had its current use for more than 40 years and will continue to be used as a landfill for many decades to come.

Transportation
The site is designed for truck traffic, with trucks coming into the site loaded with municipal solid waste and leaving empty.

Environmental site issues
The County is required under its operating permit from the Oregon Department of Environmental Quality to collect and control methane emissions at the Landfill. The methane occurs naturally from the breakdown of the organic materials, like food waste, buried in the landfill.

In 1985, Lane County requested proposals for services for "Recovery of Landfill Gas." Lane County and Emerald Peoples Utilities District entered into an agreement effective September 17, 1986 for the development of Landfill Gas to Energy facility and the Short Mountain Landfill. The initial agreement term was 10 years with automatic 10-year renewals for the life of the landfill gas.

The landfill gas to electricity system became operational in 1992. Under the agreement, EPUD captures the landfill gas and utilizes it to create electricity for sale by EPUD. The methane is extracted from the landfill through a series of vertical and horizontal wells connected by plastic pipes. After the gas goes through a clean-up system to remove impurities, it's injected into a Caterpillar engine specifically designed to run on landfill gas. Electricity is created through the combustion of the gas in the engines turning generators.

The project's total cost to date is approximately $2.6 million. The project generates approximately 2.5 megawatts of electricity annually, enough electricity to power about 1,500 homes.

Permits and planning required
The elements needed for an anaerobic digestion project are already permitted at Short Mountain.

The required planning that is needed includes identification of where on the site a project could occur.

Advantages and disadvantages of site
The Solid Waste Division recently produced a Short Mountain Landfill Renewable Energy Park plan. The concept called for installation of a pilot-scale anaerobic digester for food waste and other organic materials using the waste heat for hydroponic greenhouses and installing a 2MW solar array on the closed face of the landfill.

The Short Mountain Energy Park Plan concept has been presented to the Lane County Board of Commissioners. Board members expressed support for various elements of the plan.

Under the current use and future landfill site designs, there is not enough space to conduct a full-scale food waste diversion program.

There appears to be enough space to conduct a pilot anaerobic digester project as outlined in the Short Mountain Landfill Renewable Energy Park plan.

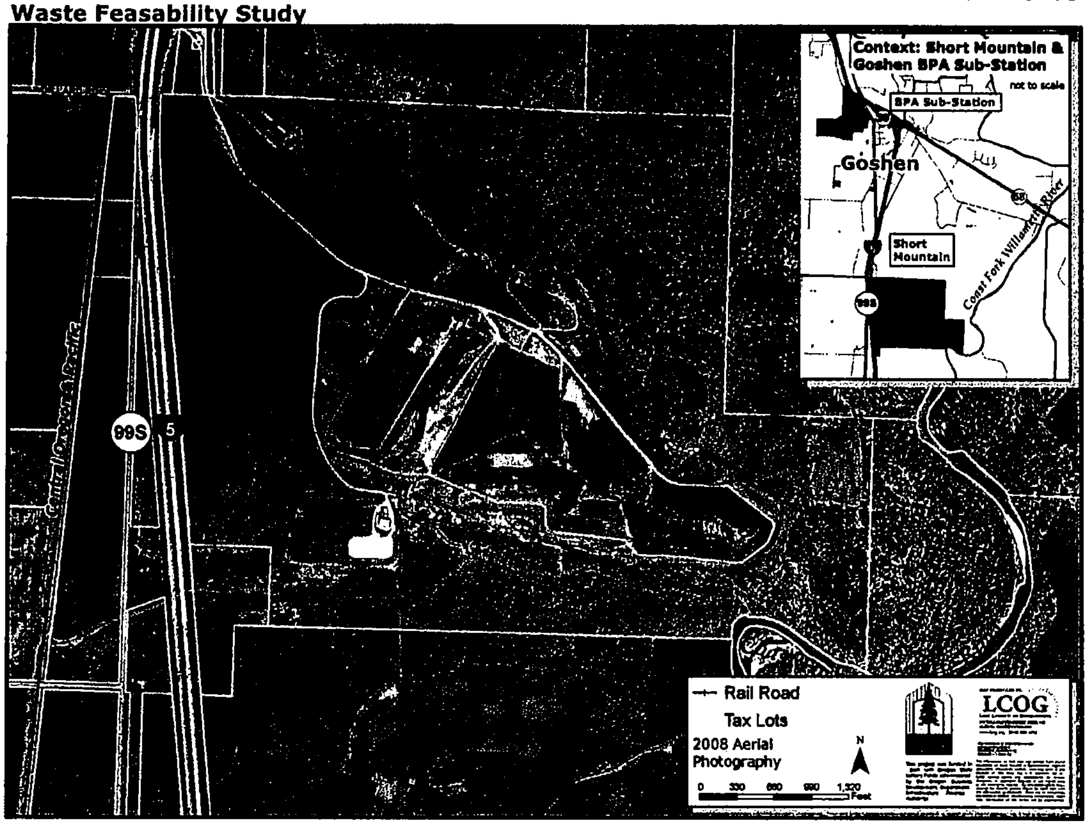
In addition, a strong synergy exists if a pilot anaerobic digester project could use the existing methane to electricity system.

Recommendation

- A pilot scale anaerobic digester should be set up at Short Mountain as part of the proposed "Short Mountain Landfill Renewable Energy Park."
    - Food wastes should be co-digested with other organic substrate(s) to improve biological stability, increase methane production and solve waste other management challenges.
    - Methane should be fed to the current EPUD system for conversion to electricity.
    - The amount of methane and electricity yield should be analyzed to determine if the pilot project produces more methane and electricity per ton than the landfill.
    - A mutually beneficial agreement between the County and EPUD for the AD methane should be explored.

Lane County Food Waste Feasability Study

Short Mountain Site



Glenwood Central Receiving Station/Transfer Station

Location: 1/10 mile west of intersection of 17th and Glenwood Blvd, in the Glenwood area of Springfield, inside the metro area's urban-growth boundary.

Address: 3100 E. 17th Avenue, Springfield

Ownership: The Glenwood Central Receiving Station is owned by Lane County and operated by the Lane County Solid Waste Management Division.

Current Use

The Glenwood Central Receiving Station receives solid waste for consolidation and transfer to the Short Mountain Landfill. This facility also receives source separated recyclable materials for recovery and recycling purposes. Recycling of 27 different materials occurs at site.

Approximately 800 tons of MSW are delivered each day to the Glenwood Central Receiving Station. The waste is brought to the site by licensed waste haulers and self-haulers. The waste is placed in the central receiving pit. From there it is transferred to long haul trucks and sent to Short Mountain.

Waste on Site

The majority of the municipal food waste disposed of in the Eugene-Springfield Metro area passes through the Glenwood Central Receiving Station.

Fit for community and zoning

The site is already zoned to receive municipal solid waste. It has had its current use for almost 20 years. It is adjacent to businesses that also receive wastes.

Transportation

The site is designed for truck traffic, with trucks coming into and leaving the site loaded with municipal solid waste. The site is adjacent to rail, but does not have rail access.

Permits and planning required

The Oregon DEQ permit authorizes the facility to accept for storage and transfer to an appropriate facility or end use, the following wastes: 1) solid waste (SW); 2) household hazardous waste (HHW); 3) universal waste (UW); 4) hazardous wastes from conditionally exempt small quantity generators (CEG); and 5) certain difficult to manage SW that are described in the Department-approved Lane County HHW Collection Facility Operations Plan.

Advantages and disadvantages of site

The site is not designed for sorting of food waste material, which is currently delivered mixed with other wastes to the central receiving pit.

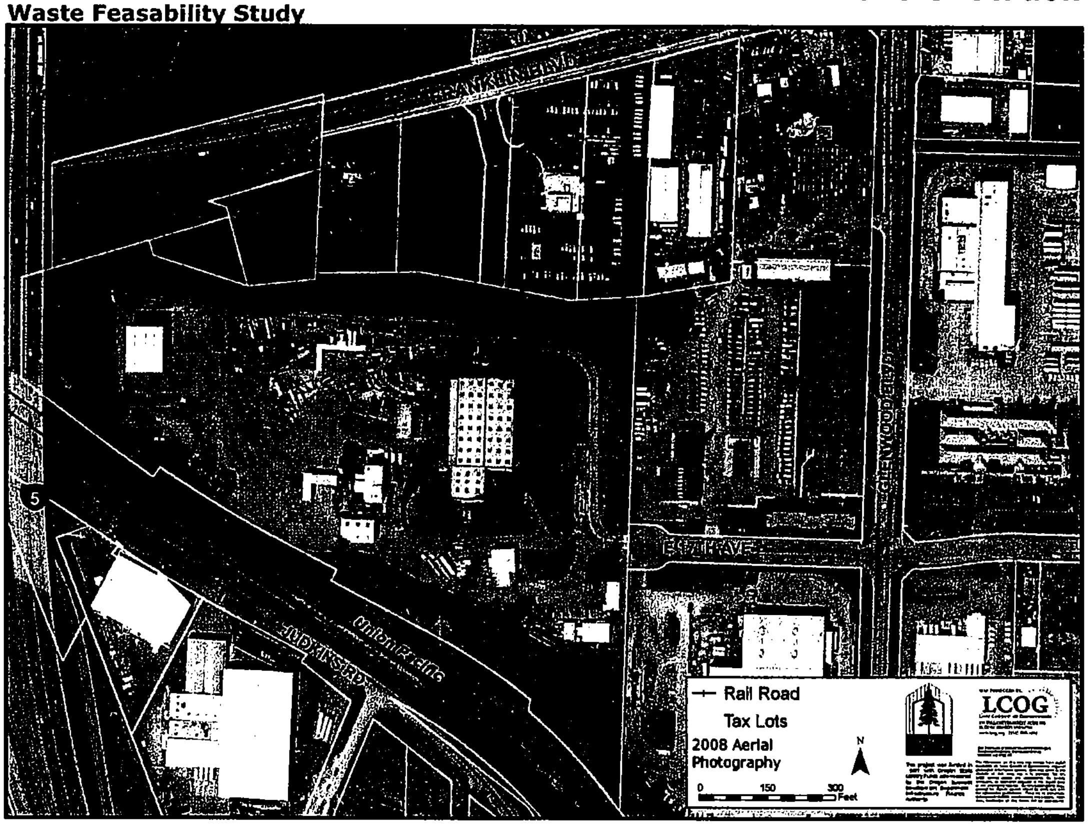
Under current use and future site designs, there is very little space to do a food waste to energy project. Creating an area to sort food waste, would appear to impact other uses on the site.

Using the property for a renewable energy project would require a redesign of the site as there is not enough existing space to site an anaerobic digester. Such a redesign would impact current uses of the site.

Recommendation
Implementing a food waste diversion program to renewable energy project at Glenwood Central Receiving Station would impact current elements of the waste disposal system. Because of that, planning for a food waste diversion program to renewable energy system should encompass an overall look at the current waste system process, because so many factors of the current system would impact a food waste program.

Lane County Food
Waste Feasability Study

Glenwood Transfer Station



Metropolitan Wastewater Management Commission Treatment Plant

Location: 410 River Avenue, Eugene

Ownership: The Metropolitan Wastewater Management Commission owns the Treatment Plant, Water Pollution Control Facility.

The MWMC is a municipal agency created by the municipalities of Eugene, Springfield and Lane County to ensure:

- Regional wastewater facilities are operated in a cost effective manner;
- Sufficient capacity is planned and built to accommodate community growth;
- Existing facilities are well-maintained;
- Environmental quality goals and requirements are met.

Current Site Use

The Metropolitan Wastewater Management Commission (MWMC) Treatment Plant, Water Pollution Control Facility, is the facility that treats sewer system wastes from the Eugene-Springfield Metro area. It has been at its current site for 30 years.

At the treatment plant, wastewater is treated in four separate processes, including anaerobic digestion, before being discharged into the Willamette River. The solids that are removed from the anaerobic digester undergo further treatment for their conversions to biosolids at the Biosolids Management Facility.

The treatment plant is designed for an average dry weather flow of 50 million gallons per day, and a wet weather flow of 200 million gallons per day. Treatment is done around the clock - 24 hours a day. Operators monitor over 2,800 different points in the system by using computer graphics and instrumentation designed by the operators for the monitoring of the treatment process. The WPCF is the second-largest treatment facility in the state.

Waste on Site

Two types of waste are processed on the site: municipal biosolids and grease that is disposed of in the municipal sewer system, mostly through residential sinks.

The waste is treated in one of three anaerobic digesters owned and operated by MWMC.

Fit for community and zoning

The site is zoned as the regional wastewater treatment plant. The zoning already allows some solid waste to be brought to the site: biosolids, fats, oils and greases. Using as an example other wastewater facilities that are now adding food waste to their anaerobic digestion, bringing food waste on to the site, would have little impact in regards to the perception of the site by the surrounding community.

Transportation
The site has capacity for large truck traffic and access on and off Beltline highway and the regional highway system.

Environmental site issues
A comprehensive upgrade to the facility and the collection system is currently occurring in order to meet a growing population and changing regulations. According to MWMC staff, that upgrade needs to be completed prior to considering adding food waste to the anaerobic digestion system.

Permits and planning required
The site is currently permitted as a wastewater treatment facility. If food waste was to be brought on site to be processed, it would require a solid waste permit from DEQ.

Advantages and disadvantages of site
There are numerous advantages to processing food waste at wastewater treatment facilities:

- The anaerobic digester infrastructure already exits.
- The system has established operators in place
- The system is municipal owned
- The food waste increases the methane production

However, co-digestion with WWTP sludge can limit the end-use options for fiber and nutrient coproducts. Oregon DEQ regulates the land application of digested biosolids derived from domestic septage to protect public health and the environment. "Class A" and "Exceptional Quality" biosolids (which meet more stringent EPA criteria for pathogens, metals, etc) can be produced from WWTP sludge via AD and intensive composting; these categories of biosolids have few restrictions for use but may have a public perception problem that limits marketability.

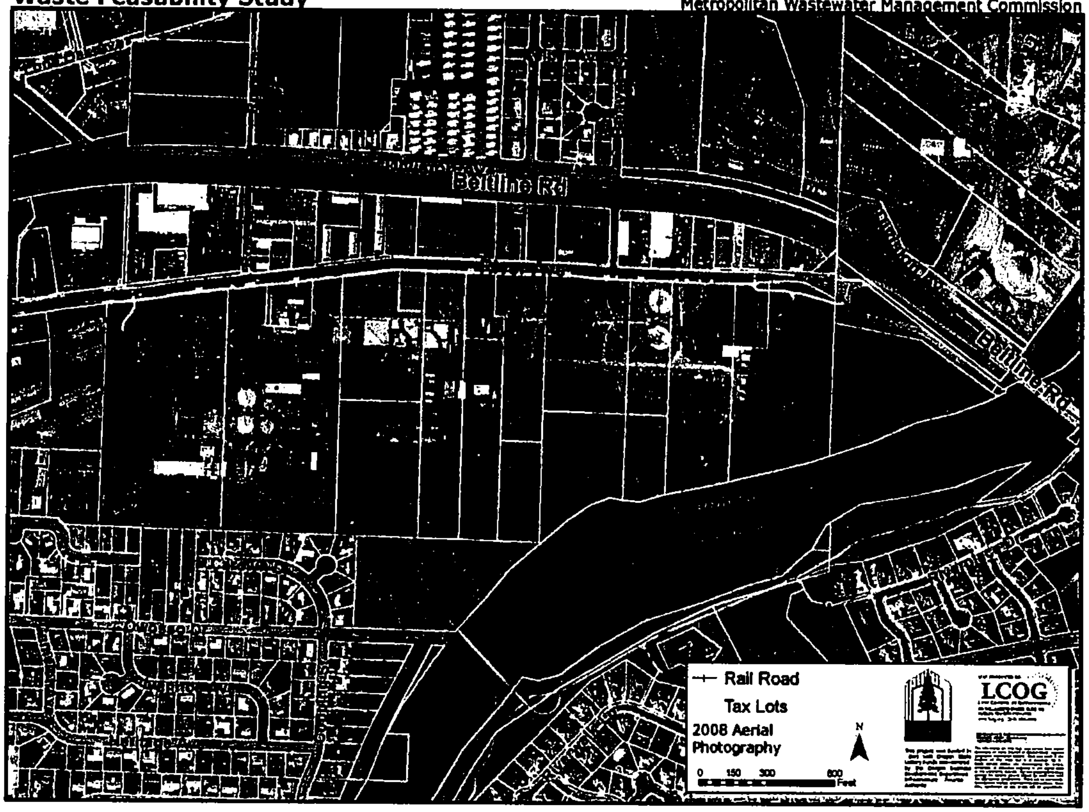
There is interest from MWMC staff to explore food waste as an additive to their anaerobic digestion process. However, because of all of the current MWMC projects, staff feels it would be several years before they could conduct the necessary studies and tests needed to determine the feasibility of, and operational issues, to incorporate food waste into their AD.

Recommendation
Further explore opportunities for a food waste to energy project with the Metropolitan Wastewater Management Commission.

Lane County Food Waste Feasability Study

MWMC River Avenue Site

Metropolitan Wastewater Management Commission



Metropolitan Wastewater Management Commission Biocycle Farm

Location: Corner of Aubrey Lane and Highway 99, north of Eugene

Ownership: The Metropolitan Wastewater Management Commission owns the Treatment Plant, Water Pollution Control Facility.

Current Use
Liquid and dried biosolids, once fully treated to regulation standards, are land applied at the Biocycle Farm. Poplar trees are grown on the site because they grow rapidly, consuming large amounts of nutrients and water in the process. Liquid biosolids supplies both water and nutrients for the trees. The farm includes a total of 595 acres with about 395 acres of trees.

Advantages and disadvantages of site

The site is large enough to encompass a food waste to renewable energy project.

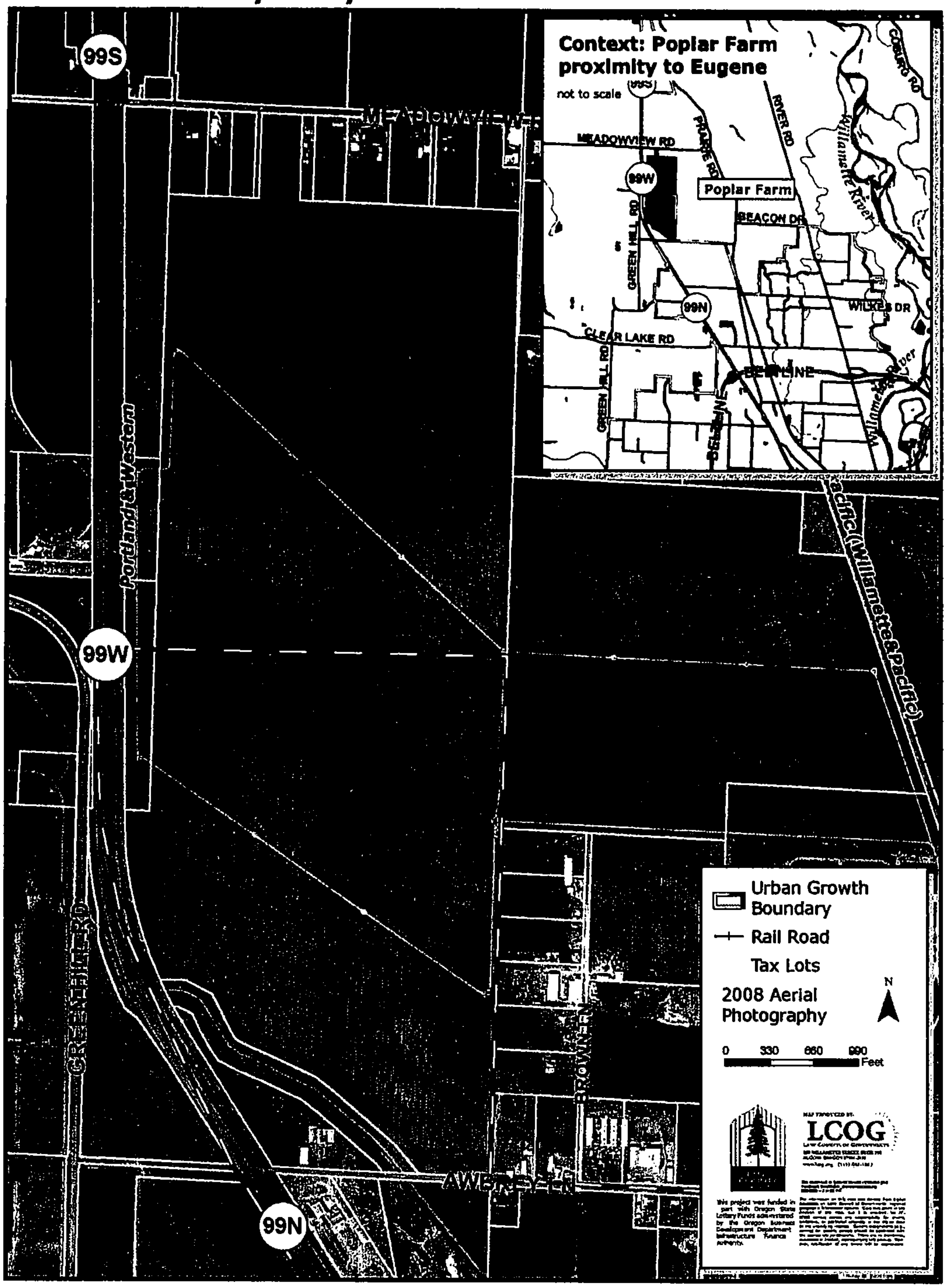
Since the announcement of this study, another renewable energy project has negotiated a lease to locate at that site.

The study team met with parties involved with the project. The project did not appear to be compatible with the envisioned food waste to energy project.

Based on the above, the study team stopped investigation of the site for proposed food waste to energy project

Lane County Food Waste Feasability Study

MWMC Poplar Farm



Junction City Municipal Wastewater Treatment Ponds

Location: The site is located adjacent to the Municipal Wastewater Treatment Ponds on High Pass Road, 2 miles west of Junction City.

Ownership: The site is owned by the City of Junction City.

Current Site Use

This site is adjacent to the parcel containing the City's wastewater treatment ponds. The City's future wastewater facilities expansion is planned for a portion of this same property. Currently the City leases the 20-acre site for the growing of grass seed. The City has determined that there are, at a minimum, five acres available on the south-east corner of the property, adjacent to High Pass Road.

Water and energy

The Bio-Energy facility will need to make some improvements for wastewater access and to bring water to the site.

There currently is electricity to the site. However the utility interconnect will need to be upgraded in order for the facility project to sell electricity to the grid. A utility substation is located seven-tenths of a mile from the property. The substation serves Bonneville Power Administration, Lane Electric Utility District and Emerald Peoples Utility District.

Transportation

Improvements will need to be made to the access road into the site. It will need to be upgraded to accommodate two fully loaded semi-trucks: one entering and one leaving the site.

Waste On-Site

The BioEnergy Production Facility will be a zero waste facility. All wastes will be reused or turned into value added benefit products. In addition all feedstocks being used by the facilities are wastes.

At full production, the facilities will use up to ENTER AMOUNT gallons of water per month. At least 50% of that water will be recycled back into the facilities each month. The water will come out as clean, as a result of the facilities process, and there would be opportunity for sale of that water.

At the Junction City site, there is an opportunity to use treated wastewater as some of the initial water into the facilities. The opportunity to pursue synergies that could be helpful for mitigating wastewater issues and for optimizing the City's new planned wastewater plant is both a benefit to the BPF and the City.

Fit for community and zoning
The property is zoned properly for the facility. In addition, though there will be complete odor control and odor mitigation done at the BPF there is the potential for odor issues occasionally. Being located adjacent to the Junction City wastewater treatment ponds, which have a strong odor, will minimize the opportunity for there to be off-site odor complaints.

The project is also compatible with Junction City current branding effort to become an agri-tourism hub and a renewable energy community.

Environmental site issues
A wetlands mitigation plan has been filed for the site. The mitigation plan requires additional work, which should be completed by June 2010.

Permits and planning required
A biogas plant will require a DEQ solid waste permit prior to bring in outside feedstocks.

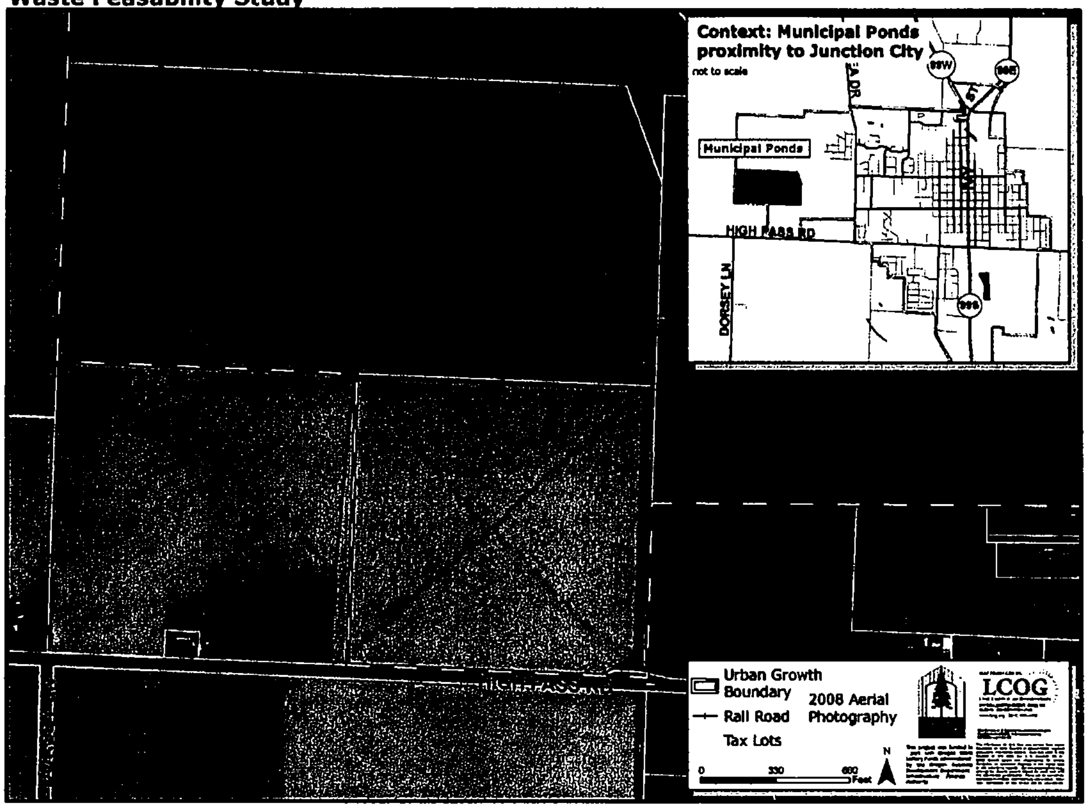
Advantages and disadvantages of site
The Grass Straw Bioenergy Study identified the site as a potential for a BioEnergy Park, where renewable energy facilities are co-located in order to maximize infrastructure and operations synergies. Several studies have determined that integrated bioenergy systems are superior to traditional fossil fuel systems in terms of environmental compatibility and expected benefits. These included efficiencies of integration with improved economics over a stand-alone system, water re-use opportunities and added value from plant waste streams that can become feedstock in an adjacent facility.

The Grass Straw Bioenergy business plan for the Junction City Bioenergy Production Facility does not presently include municipal food waste.

Being outside of the Eugene-Springfield Metro area may limit the use of the site for a food waste project.

Recommendation
The "Bioenergy Production Facility" being considered for Junction City should be considered as a site option for a future food waste to energy project.

Junction City Municipal Ponds



Section 6: Revenue and Expense Review and ROI Estimates

Introduction

Among the questions this section will help answer are the following:

- What will it cost to build a food waste to energy plant?
- What are the revenue expenses of such a facility?

To help answer those questions, we developed a financial model that includes capital expenditure, operations and maintenance, revenue, expenses, avoided costs, environmental credits, state and federal tax credits, funding sources, and costs of capital.

We used data collected from the other parts of this study to determine much of the above. Other data was collected from relevant projects and interviews with AD and energy experts.

Conceptual System Recommendations

Based on the study findings, a potential project should be a wet A.D. system co-digesting a mixed feedstock. Such a system could consist of the following components:

- One reception hall with feedstock storage, fiber storage, control/lab room
- Dewatering and nutrient recovery equipment
- One feed reception pit for dry matter
- One feed storage tank for liquid feed (if necessary)
- One hydrolysis mix tank
- Two anaerobic digester tanks
- One post digester with integrated biogas storage
- One permeate storage tank with the size dependent upon nutrient recovery technology utilized and storage retention time required
- CHP unit(s)
- Utility Interconnect

Estimated Construction Budget

Based on equipment vendor preliminary cost estimates of the above system configuration, the estimated construction costs range from \$8 Million to \$9.5 Million. The cost estimates from equipment vendors and service providers were collected in both 2008 and in 2009. Final budget costs will be based on bids and request for proposals. For purpose of the financial calculations, we are using a construction budget of \$9.5 Million as follows:

Table 12: Construction Costs and Capital Expenditures by Category	Estimated Cost
Facilities	
Material Handling Facility	$ 600,000
Reception Pit	$ 250,000
Storage Tank for Liquid Feed	$ 500,000
Hydrolysis Mix Tank	$ 750,000
A.D. Tanks	$ 1,600,000
Post Digester Tank with Biogas Storage	$ 800,000
Combined Heat and Power	$ 2,600,000
Dewatering/Nutrient Recovery	$ 1,000,000
Digestate Storage and Transfer Tank	$ 600,000
Utility Interconnect	$ 800,000
Total Equipment Costs	**$ 9,500,000**

Estimated Revenue

The revenue model for this project is based on the sale of electricity through a Power Purchase Agreement from a utility.

A renewable energy Power Purchase Agreement (PPA) is a contract composed of many items. The revenue and expense section, the focus of this study element, is composed of several key items:

- Purchase of Energy: The price the utility is paying for the electricity.
- Purchase of Environmental Attributes
  - Renewable Energy credits (Green Tags).
  - Green house gas credits
- Cost of Delivery: The cost to wheel the power to the utility that is purchasing the power and who is being paid to do the wheeling. (Usually the utility that serves the area where the energy project is located).

PPA's are usually developed in advance of a project being constructed. A PPA for a food waste to energy project could be signed in 2010 for delivery in 2011 when the project comes on-line.

Renewable energy projects in Oregon that have the opportunity to sign PPA's in 2010 could have a significant revenue increase over PPA's signed in the past few years because of the adoption of feed-in tariffs by the investor owned utilities: Pacific Power and Portland General Electric.

The feed-in tarrifs that will take effect in April 2010 for the first 5% of the green energy purchased by the investor owned utilities are expected to be in the $.25kwh range compared to current pricing in $.0825 kwh. This offers a project three times the current revenue opportunity. It is expected that because of the significant advantage of this incentive, the 5% goal of the utilities will be met very quickly.

To benefit form the feed-in tariff, a project needs to be ready to go. Because of the status of the projects being looked at in this study, we anticipate that a project will be able to sign a PPA in 2010, therefore we are using $.25kwh as the revenue figure for the economic model.

Not included in the revenue line are other potential revenues that a food waste to energy project could capture. These included renewable energy credits and green house gas credits (carbon, methane). Both of these could be significant for a project, but because the market for both is very volatile, we have decided to not include them in the revenue projections.

Net present value and internal rate of return calculations

eDev created a Net Present Value (NPV) and Internal rate of return (IRR) economic model for the project In addition to using the above capital costs, it was estimated the anaerobic digester would consume 75,000 tons of feedstock and generate 2 MW of electricity operating on a continual basis throughout the year.

A range of inputs and outputs was calculated for the following four items:

a) Capital costs
b) Feedstock costs
c) Electric rates
d) Equity/debt ratio

Our previous work for Lane County Economic Development on the Annual Rye Grass Straw project last winter and spring suggested that the first three inputs and outputs tend to have the biggest impact on determining the economic viability of a project. We added the equity/debt as a fourth element.

A baseline estimate for these three elements was calculated:

a) Capital costs - $12.5 million (including land development costs)
b) Feedstock costs - $60 per ton for 50,000 tons of annual rye grass straw and a tipping fee (payment to the facility) of $60 per ton for 25,000 tons of food wastes.
c) Electric rates - $.25 per kilowatt hour based upon an assumed price of $.35 per kilowatt hour less wheeling and connection costs.
d) Equity/debt ratio – 20% equity and 80% debt.

Based upon this particular scenario, the project would generate a net present value of $6.41 million and an internal rate of return of 16.4%. However, there is quite a wide range of internal rates of return ranging from a negative-15.8% to a positive 30.1% depending upon assumptions.

Economic models for potential renewable energy projects

eDev employed economic models that are typically used for analyzing whether a project or investment should be pursued. The three major parts to this economic model include:

1) Inputs and assumptions model
2) Discounted cash flow model to calculate NPV
3) IRR model

Inputs and assumptions model

The inputs and assumptions model includes different elements that can be changed to reflect different assumptions. For example, three primary drivers that affect the NPV and IRR of renewable energy projects are feedstock costs, off takes (product sales), and capitalization costs. We did analyze debt/equity ratios separately. Other drivers, such as enzyme costs, debt/equity ratios, MACRS/straight line depreciation do not have as big of an effect.

For each of the inputs and assumptions models for the four conversion processes, we kept commonalities such as the capitalization costs, debt/equity assumptions, and conversion efficiency in converting biomass into a product, interest rates, BETC tax credit, and MACRS depreciation schedule.

Input and assumptions model

The turbulence in the commodity markets such as oil, corn, and wheat in the previous year suggest that attempting to project future sale prices and costs can be quite difficult and, at time, an exercise in utter futility. This model allows the user to enter in any amount for the feedstock costs or the product sales cost. Based upon current prices, we believe that $60 per ton for 50,000 tons of grass straw feedstock is a reasonable price assumption. As of December 2009, there is quite a substantial amount of grass straw that could be obtained at no cost. The model also assumes that there will be 25,000 tons of food wastes that will be able to be obtained at a tipping fee (payment to the AD processor) for $60 per ton. Based upon that 2:1 ratio of grass straw/food waste, the average feedstock input cost per ton is $20 per ton.

The bio-energy prices for the anaerobic digester were projected from a range of $.11 to $.35 cents per kilowatt hour. The range is much higher than what has been previously estimated for electricity prices. This range is predicated upon a requirement that the investor-owned utilities (IOU) in Oregon will be required to purchase 5% of their future electricity from firm power renewable energy facilities. PGE is expected to issue a Request for Proposal in April 2010 for firm power renewable energy. The likely net kilowatt price after wheeling and connection fees is projected to be $.25 / KW.

The capital costs were based upon a projected $3 million for land development and $9.5 million for anaerobic digester and power generation equipment capable of generating 2 MW of firm power. The facility is expected to produce power 24/7 with one week down for maintenance per year.

Discounted cash flow model

The discounted cash flow model to calculate NPV is very similar to a National Renewable Energy Lab economic model used to analyze pyrolysis projects. Our model has been adapted to reflect the Oregon Business Energy Tax Credit (BETC) and the federal ITC 30% one-time payment. The Oregon BETC allows the owner to take a tax credit over five years totaling 50% of the capitalization costs at a rate of 10% tax credit per year or the company may sell the tax credit upfront at a discounted rate.

The model assumes a 20-year cash flow as well as a 10% discount rate. The purpose of a discount rate is to address the issue that a dollar today is worth more than a dollar five years from now. The National Renewable Energy Lab uses a 10% discount rate for energy project analysis. A 10% discount rate punishes the value of future cash flows. For example, the annual cash income for the anaerobic digester processor in the fifth year is calculated to be $2.1 million, but the discounted annual cash flow is only $1.3 million.

The first two years of discounted cash flow model is shown:

Net present value for Anaerobic Digester processor - 75,000 tons per year. 2 MW output

Year	-1	0	1	2
Fixed Capital Investment	$50,000	$12,500,000		
Electricity production - 2 MW annually			$4,320,000	$4,320,000
Total annual sales			$4,320,000	$4,320,000
Annual Manufacturing and Financing Costs				
Raw materials			$1,500,000	$1,500,000
Interest expense			$625,000	$585,600
AD O&M			$187,500	$187,500
CHP O&M			$105,120	$105,120
Total product cost			$2,417,620	$2,378,220
Annual depreciation				
General plant				
MACRS - 10 year double declining			$2,500,000	$2,000,000
MACRS remaining value			$10,000,000	$8,000,000
Straight line			$1,250,000	$1,250,000
Straight line remaining value			$11,250,000	$10,000,000

Total expenses + MACRS depreciation				$4,917,620	$4,378,220
Net revenue				-$597,620	-$58,220
Losses forward				$0	$0
Net income (before tax credits)				-$597,620	-$58,220
Federal ITC (30% of project - one time lump sum payment)				$3,750,000	
BETC tax credit (50% of project costs)				-$1,250,000	-$1,250,000
Net taxable income				$1,902,380	-$1,308,220
Tax rate @ 35%				$665,833	$0
Annual cash income				$1,902,380	$1,941,780
Discount factor (10%)		1.1	1	0.909	0.826
Annual present value	$18,960,098			1,729,263	1,603,910
Total capital invest + interest		$55,000	$12,500,000		
Net present value	$6,410,098				
Internal rate of return	16.4%				
PV of income	36,758,880			3,926,880	3,568,320
Income tax payable	11,166,629			665,833	0
Discount factor (10%)			1	0.909	0.826
PV of taxes	3,369,634			$605,242	$0

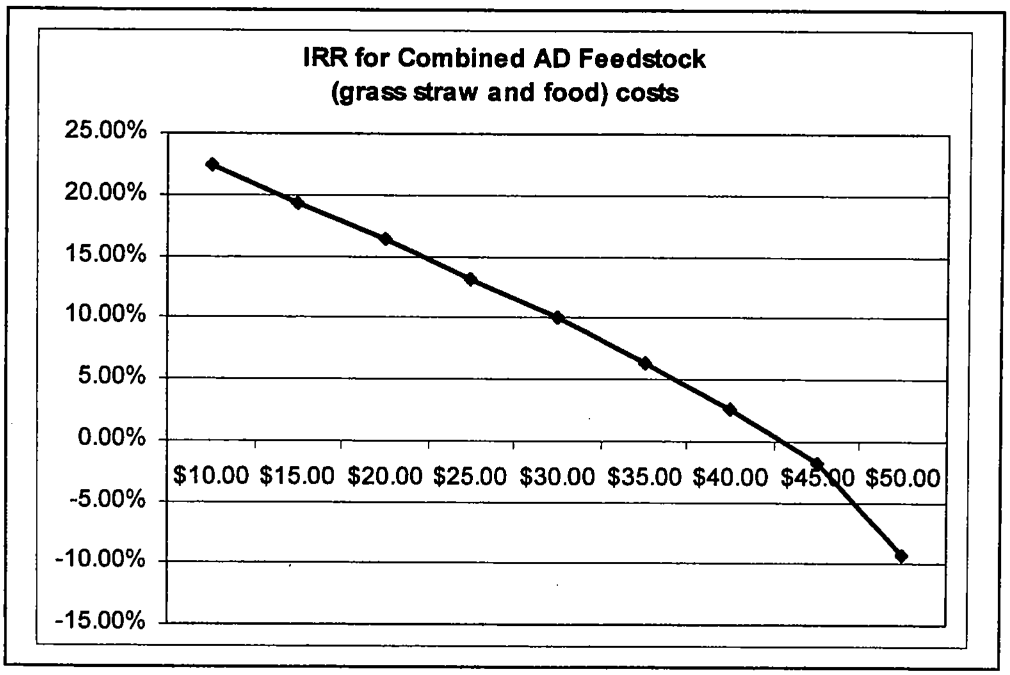
Internal rates of return (IRR)

Programs such as Excel can calculate the IRR by entering the projected cash flows less the investment costs. The following chart shows the baseline estimate described in the Executive Summary:

75,000 tons per year	
Investment 1st year	-$50,000
Investment 2nd year	-$12,500,000
Cash flow 1st yr	$1,902,380
Cash flow 2nd yr	$1,941,780
Cash flow 3rd yr	$1,998,240
Cash flow 4th yr	$2,054,052
Cash flow 5th yr	$2,113,608
Cash flow 6th yr	$2,171,700
Cash flow 7th yr	$2,245,068
Cash flow 8th yr	$2,316,474
Cash flow 9th yr	$2,401,128
Cash flow 10th yr	$2,476,824
Cash flow 11th yr	$2,527,380
Cash flow 12th yr	$2,527,380
Cash flow 13th yr	$2,527,380
Cash flow 14th yr	$2,527,380

Cash flow 15th yr	$2,527,380
Cash flow 16th yr	$2,527,380
Cash flow 17th yr	$2,527,380
Cash flow 18th yr	$2,527,380
Cash flow 19th yr	$2,527,380
Cash flow 20th yr	$2,527,380
	16.4%

We then plot the IRR for a variety of different input values, such as a range of capitalization costs. A chart is then produced. This chart displays the IRR for a range of feedstock costs per ton for an anaerobic digester ranging from $10 up to $50 per ton. We assumed electricity sales at $.25 cents/KW and capitalization costs at $12.5 million.



As displayed, feedstock costs have a very dramatic effect on the IRR of this project. That effect is not surprising given what has happened to the corn ethanol industry in the past two years dealing with higher corn prices that what had likely been expected in their economic models.

Net present values

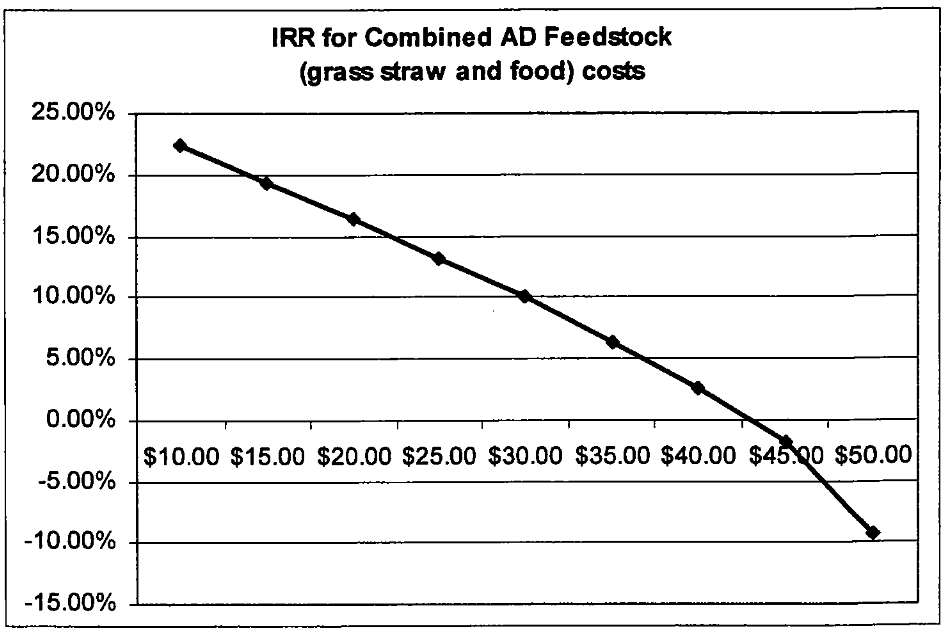
Net present values are used as a complement to internal rates of return. There is an intense discussion about which approach is better. Net present values and internal rates of return are discussed in Appendix 1. Under the "preferred" scenario, the project has

20-year annual present value cash flows of $18.9 million and initial capitalization costs of $12.5 million which yields a net present value of $6.4 million.

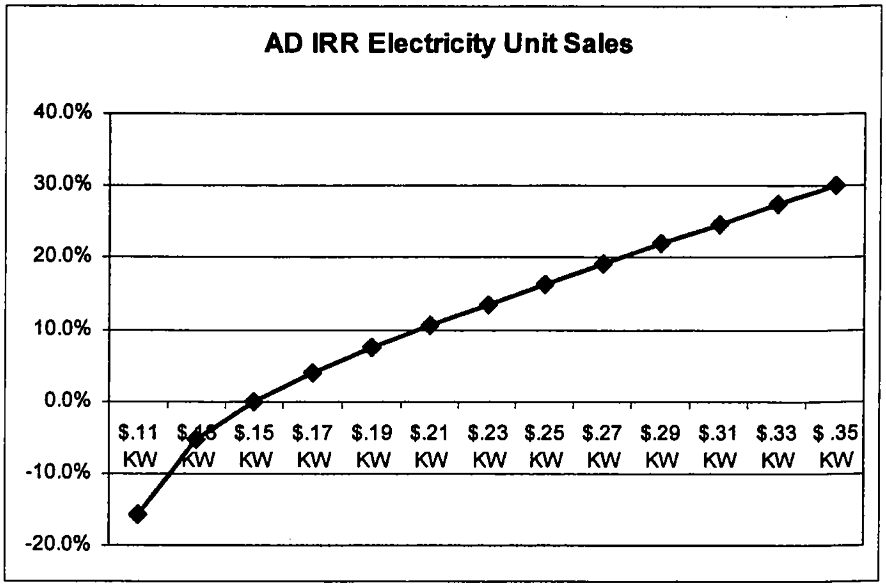
Anaerobic digester energy conversion process

Three primary drivers for the anaerobic digester were varied and plotted: feedstock costs per ton, product sale price, and capitalization costs. An abbreviated fourth analysis addressing equity/debt investment ratios is discussed in the final paragraph.

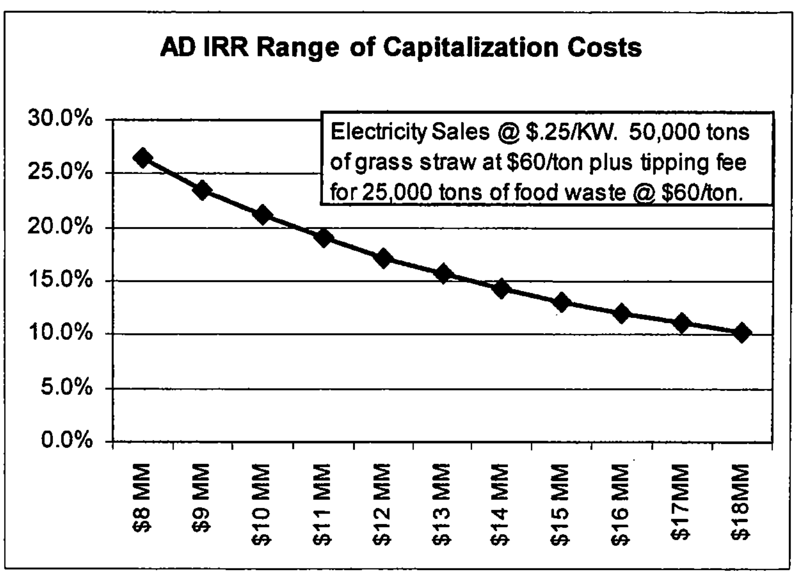
The first chart analyzes the average feedstock costs consisting of 50,000 tons of annual rye grass straw and 25,000 tons of food wastes ranging from $10 to $50 per ton. The net bio-energy price was estimated at $.25 cents per kilowatt hour. The capitalization costs including $3 million for land development were $12.5 million. If one assume that average feedstock will cost approximately $20 per ton, the project has a 16.4% IRR and a NPV of $6.4 million. However, if one assumes that the feedstock costs will average $50 per ton, the project has a negative 9.3% IRR and a NPV of negative $12.7 million.



The second chart displays the percent sale price of bio-energy sold ranging from $.11 KW to $.35 KW. The average feedstock costs were set at $20 per ton and the capitalization costs were set at $12.5 million. If one assume that average bio-energy price is $.25 KW, the project has a 16.4% IRR and a NPV of $6.4 million. If the bio-energy price drops to $.11 KW, the IRR drops to a negative -15.8% and the net present value is a negative $14.1 million. In contrast, if the bio-energy price is $.35 KW, the IRR rises to 30.1% and the net present value similarly rises to $21.1 million.



The third chart displays the capitalization costs ranging from $8 to $18 million. Capitalization costs do not have as big of an impact on the IRR as feedstock costs and bio-energy sale prices. For example, capitalization could be 25% greater than anticipated and still not necessarily impact the economics of the project. Even if the construction costs spiral to $18 million dollars, the IRR is projected at 10.2% although the net present value drops to only $208,000.



As displayed on each of the three charts, there is a wide range in the internal rates of return depending upon assumptions and understandings or misunderstandings.

Each of these above simulations was based upon a 20% equity investment and an 80% debt investment. This ratio may not be available in today's challenging credit market. One additional analysis was completed based upon a 50% equity / 50% debt ratio. The average feedstock costs were set at $20 per ton, the electrical rates at $.25 / KW, and capitalization costs of $12.5 million. The IRR increased to 17.6% from 16.4% and the NPV increased to $7.3 MM from $6.4 MM due to reduced interest expense payments dropping from $3.6 MM to $2.2 MM. No further analysis of equity/debt ratios were conducted due to its minimal impact. However, the project developers may need to raise a substantial amount of equity for the project.

The Net Present Value for Anaerobic Digester Processor spread sheet is contained in the Appendix.

Potential Project Funding Sources

There are a variety of loan and grant programs that can be used for a food waste to energy project:

- Oregon Business Energy Tax Credit (BETC)
- State Energy Loan Program (SELP)
- State Energy Program (SEP)
- US DOE Loan Program
- USDA RD Loan Program
- Federal Production Tax Credit
- American Recovery and Reinvestment Act Bonds

Each of these is described in more detail below, with additional information included in the Appendix.

Oregon Business Energy Tax Credits

The Oregon Business Energy Tax Credit (BETC) can be applied to 50 percent of the eligible project costs up to a maximum of $20 million in eligible costs for Renewable Energy Resource Generation projects.

A project owner can be a public entity that partners with an Oregon business or resident who has an Oregon tax liability. This can be done using the BETC Pass-through Option.

The Pass-through Option allows a project owner to transfer their Business Energy Tax Credit project eligibility to a pass-through partner for a lump-sum cash payment. A project owner may be a public entity or non-profit organization with no tax liability or a business with tax liability that chooses to use the Pass-through Option.

The tax credit can cover all costs directly related to the project, including equipment cost, engineering and design fees, materials, supplies and installation costs. Loan fees and permit costs also may be claimed.

State Energy Loan Program (SELP)
The purpose of the Energy Loan Program is to promote energy conservation and renewable energy resource development. The program offers low-interest loans for projects that:

- Save energy
- Produce energy from renewable resources such as water, wind, geothermal, solar, biomass, waste materials or waste heat
- Use recycled materials to create products
- Use alternative fuels

The Energy Loan Program can loan to individuals, businesses, schools, cities, counties, special districts, state and federal agencies, public corporations, cooperatives, tribes, and non-profits. Projects must be primarily in Oregon.

Oregon State Energy Program (SEP)
Oregon plans to use funding from the Recovery Act to fund energy efficiency improvements, develop renewable energy resources, and ensure environmental protections through the established State Energy Program. The state will focus on public buildings to most effectively use its existing expertise and programs, while also providing an opportunity for government to take a leadership role in demonstrating innovations in energy efficiency and renewable energy technologies.

SEP Performance Measures
- jobs created
- energy saved
- renewable energy installed capacity and generate
- greenhouse gas emissions reduced
- energy cost savings
- funds leveraged

Project Priorities
- Projects previously identified and not funded
- Projects identified by utilities and communities
- Prioritize regions must hard hit by recession (use unemployment data)
- Projects with largest job creations are first priority
- Energy savings and fuel type to maximize energy and emission reductions

Eligible Projects
- Energy efficiency projects
- Renewable energy resource projects

US DOE Energy Loan Program
The U.S. Department of Energy will provide up to $30 billion in loan guarantees for renewable energy projects. The first solicitation is for projects that employ innovative energy efficiency, renewable energy, and advanced transmission and distribution