Technical Assistance Project Summary

Project Contact

Project:	Feasibility of an In-Vessel Composting System for Yard Waste
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Carbon County was interested in investigating the feasibility of an in-vessel system to compost yard waste as a way of reducing annual operating costs of a composting operation and prolonging the composting season.

R.W. Beck performed a technical evaluation and comparison of an in-vessel rotating drum system sized to handle the amount of yard waste generated in Carbon County and a typical windrow system. The benefits and drawbacks of each system were identified. Permitting issues were discussed, and a cost comparison of both methods was made.

The evaluation and comparison of the two systems revealed that the windrow system had the advantages of lower capital costs, increased flexibility, and a large body of operational knowledge. The in-vessel system had the advantages of requiring less land and extending the compost season. The reduction in operating costs of an in-vessel over a windrow system was less significant than initially expected, however.

Based on an analysis of all relevant factors, R.W. Beck recommended that the County pursue developing a traditional open-air windrow system to compost its yard wastes. The County should pursue DEP grant funding to pay for a heavy-duty front-end loader to manage the windrows. If the County is successful with windrow composting, in the future the compost operation site could be used for an in-vessel system should the County choose that option at a later date. Details regarding the advantages and disadvantages of each system are provided in the full report, available at www.depweb.state.pa.us.

January 17, 2006

Mr. Duane Dellecker
Director of Solid Waste Services
Carbon County
P.O. Box 219
490 Ore Street, Suite 2
Bowmanstown, PA 19030

Subject: **SWANA Technical Assistance Project**

Dear Duane:

This letter report summarizes R. W. Beck's evaluation of the feasibility of a yard waste compost system for Carbon County. The objective of the evaluation was to investigate the feasibility of implementing a simple in-vessel composting program for yard waste. This approach is appealing to the County because they envision that such a program would have relatively low annual operating costs, and because the technology may yield a longer composting season. This would potentially help the County to use the compost for a value-added purpose, with the added potential to generate revenues. Potential end uses include growing sod or reclaiming industrialized sites.

This evaluation was performed as part of the Recycling Technical Assistance program sponsored by the Pennsylvania Department of Environmental Protection (DEP) and the Solid Waste Association of North America (SWANA).

The report is divided into the following sections:

- Background on Carbon County's current organics management infrastructure;
- Identification and discussion of permitting implications for compost facilities in PA;
- Technical Evaluation of in-vessel and windrow composting systems;
- Cost comparison of in-vessel and windrow composting systems; and
- Recommendations.

Current Organics Collection and Management Infrastructure in Carbon County

General Information

Carbon County, population 56,846, is located in northeastern Pennsylvania, approximately 90 miles west of New York City and 90 miles northeast of Philadelphia. The northern and eastern portions of the County are part of the Pocono Mountains region of the Commonwealth. At the current time the County is experiencing growth in population and industry primarily related to the westward expansion of the eastern metropolitan area and the opening of the last portion of Interstate 78 into Pennsylvania, which has made access into the New York metropolitan area from eastern and central Pennsylvania faster and more direct.

Carbon County is composed of 23 municipalities, each with its own municipal government. The county has five school districts and a countywide technical school. Carbon County, covering over 500 square miles, is known for its scenic mountains and rivers. Over two-thirds of the County is State Game Land & State Park Land.

Carbon County Recycling System

The Carbon County Solid Waste Department operates a countywide rural recycling program consisting of 16 semi-permanent "blue bin" recycling drop-off sites located at various municipal and commercial properties in the county; however, the County currently has no collection or processing facilities for yard waste or other organics.

The equipment used by the County for recycling collection is a specialized system manufactured by Haul-All. The trucks owned by the County are Haul-All Model RP-235's, a 2001 model and a 2005 model. These trucks are equipped with two 15-cubic yard side-loading compartments for direct loading of recyclable materials; and a 2002 Haul-All "Aug-Pack" system, consisting of a 20-cubic yard bin on the back enclosing an eight-foot auger. The County collects both plastic bottles and cardboard from the drop-off centers cost-effectively using the unique compaction technology provided by these trucks.

The County has also recently finalized plans to purchase a new Haul-All Model 15 leaf vacuum truck in early 2006. This truck, with a 20 cubic yard capacity, will be used for leaf collection.

The specialized nature of the County's recycling system and rolling stock provides unique cost-saving advantages over traditional recyclables handling technologies, which are mostly based on roll-off truck technology and 20-, 30-, or 40-cubic yard containers. However, not having roll-off trucks and containers is somewhat limiting in that the County cannot easily use modified containers of this type as composting vessels or containment systems. Operational labor for the solid waste department is limited to two full-time drivers and one part-time driver.

Potential Compostable Materials

Carbon County solid waste officials plan to start a leaf vacuum program in 2006. They anticipate collecting 5,000 cubic yards per year of leaves. Using a generally accepted density figure of 350 pounds per cubic yard for vacuumed leaves, this translates to 875 tons per year, or 2.4 tons per day (14 cubic yards). Until a composting system is designed and operational, the County plans on land-applying the leaves under permit. The County does not plan on collecting brush or limbs from residents, but may develop a site where residents could deliver their brush.

To plan for growth of the system, Carbon County could project the amount of leaves to be collected in future years. Typically leaf waste generation rates range from around 100 to 250 lbs per capita per year. Carbon County's estimate accounts for about 31 pounds of leaf waste per capita per year. Since Carbon County is primarily rural, fewer residents probably will set out their leaves for collection than in suburban communities; however, keeping in mind these ranges and allowing for the population served and the collection methods, Carbon County's estimates will help them plan accordingly, and can be refined as the program is implemented.

Depending on the compost system chosen, a nitrogen source may be needed to supplement the carbon-rich leaves. The five County school districts, with 7,740 students, plus the County nursing home and prison, with an approximate combined population of 375 people, could be a source of food waste amendment. County employees also mow the grass lawns at the County facilities. These clippings are also a potential source of compost amendment. The school district acreage is approximately 175, and the prison has 15 acres of grass.

There are currently no private-sector yard waste or organics processing centers in Carbon County. The only municipality that processes any yard waste is Palmerton Borough, with a population of about 5,000. Residents of Palmerton Borough deposit their brush and yard waste in a pile at a municipal site, and it is chipped by municipal staff using a small chipper. The chipper could potentially be loaned to the County to process brush, but County solid waste officials believe the chipper is old and close to the end of its useful life.

Table 1 summarizes the estimated potential raw materials available for composting in Carbon County.

Table 1
Estimated Carbon County Compostable Materials

Material	Source	Density/ Generation Rate	CY/Year	Tons/Year	CY/Day	Tons/Day
Vacuumed Leaves	County collection	350 lbs/cy1	5,000	875	14	2.4
Other Chipped Brush (Potential)	County drop-off	500 lbs/cy1	4,000	1,000	11	2.7
Grass Clippings (Potential)	County mowing of schools, other facilities, total of 190 acres	400 lbs/cy2	1,200	240	3.3	0.7
Food Waste (Potential)	Prison and nursing home, total population 375	1,526 lbs/cy3	90	68	0.2	0.2
TOTAL			10,290	2,183	28.5	6.0

[1] Nebraska Department of Environmental Quality "Guidance Document for Measuring and Tracking Recyclables and Organics"

[2]Based on 2,400 pounds per acre, as estimated in CT DEP "Quantifying Source Reduction"

[3]Based on estimate of 1.0 lb/person per day of food waste. R.W. Beck previous studies in N.C. and Alleghany County, PA that showed an average of 2.2 lbs per day per employee for case studies of grocery stores, University food service, and restaurants. Few estimates of food waste generation exist, so a conservative figure of half the "per-employee" case study data was used for this study.

Both grass clippings and food waste volumes were estimated for future planning purposes, although at this point in time Carbon County does not plan on incorporating either material into its leaf composting operation. They were included because the County has control, or could have control, over these waste streams. These feedstocks, therefore, could be brought into the process if and when needed.

Incorporating grass clippings, while providing a good nitrogen source, can be problematic because grass clippings are generated in large volumes during the summer months, while leaves are generated in the late fall and winter. Storing grass clippings for later mixing with leaves is difficult due to the tendency of the nitrogen-rich grass to decompose quickly, leading to issues with odors. Alternatively, leaves may be stockpiled during the fall and winter months, and then fresh grass clippings incorporated during the summer into these leaf piles. This practice is fairly common in windrow composting systems. For in-vessel composting systems, where an important goal is to use as little acreage as possible, stockpiling leaves would not be practical due to the space they occupy.

Food waste can also be a good nitrogen source for compost production, and is used in virtually all compost operations using in-vessel technology. With a desired carbon/nitrogen (C:N) ratio for composting in the 20:1 to 30:1 range, by weight, relatively very little food waste is needed as a nitrogen source when mixed with leaves. However, pathogens may be generated in food waste, which can complicate the composting process. The pathogen issues are discussed below in the section that describes in-vessel technologies.

To summarize the yard waste compost operation capacity needs for Carbon County:

Approximately five tons per day of carbon-rich leaves and chipped brush are potentially available to the County for composting. In volume terms, this is approximately 25 cubic yards per day.

If a nitrogen-rich source were added, for the 20:1 or 30:1 C:N ratio to be met, approximately 0.17 to 0.25 tons per day of nitrogen-rich materials would be needed. The assumed one pound per day of food waste generated by County facilities would provide all the food waste amendment needed. However, if grass clippings were used, the amount generated exceeds the amount needed per day by a small amount. The amount of grass clippings generated is controlled by the County, and less of the mowed grass could be delivered to the compost facility to provide just the amount needed.

Permitting Issues

Four types of permits that apply to municipal or county organics composting facilities are provided by the Pennsylvania Department of Environmental Protection (DEP). The type of permit depends primarily on the size of the compost operation site. The four types of permits are summarized below.

- Agricultural land application of leaf waste on areas less then five acres in size:
  - May operate under “Permit by Rule,” as authorized by PA Municipal Solid Waste Regulations (Title 25, Chapters 271, 281 and 285).
  - PA DEP Publication # 254-5403-100, “Guidelines for Yard Waste Composting Facilities,” addresses specific siting and operational criteria that must be met.
- Yard waste compost operations less than five acres in size:
  - May operate under “Permit by Rule,” as authorized by PA Municipal Solid Waste Regulations (Title 25, Chapters 271, 281 and 285).
  - PA DEP Publication # 254-5403-100, “Guidelines for Yard Waste Composting Facilities,” addresses specific siting and operational criteria that must be met.
  - Would apply to Carbon County if a windrow system were chosen, or if an in-vessel system with no nitrogenous amendments (grass or food wastes) were chosen.
- Compost operations more than five, but less than 15 acres:
  - May operate under existing PA “General Permit” WMGM-017 for beneficial use of a waste material, as long as the operations comply with the provisions of this permit.
  - Allows addition of food wastes and other nitrogenous feedstocks.
  - DEP issues a “Determination of Applicability” once the applicant demonstrates compliance with the permit terms.
  - Would apply to Carbon County if an in-vessel system with nitrogenous amendments were chosen.
- Compost operations over 15 acres:
  - Must apply for an individual permit.
  - The permitting process is rigorous and involves bonding, insurance requirements, and public hearings. It can be costly to the municipality. The timeframe for an individual permit is nine months.

All of the in-vessel compost systems currently operational in the Commonwealth incorporate food wastes or manures. They operate under a “Permit-by-Rule: Captive” permit since the feedstocks are generated on-site. For Carbon County, using an in-vessel system for composting only the estimated quantity of leaf and yard waste described above, without any nitrogenous amendments, the “Permit by Rule” would apply. For a windrow system, the “Permit by Rule” would also apply. However, a new General Permit would be required if food wastes generated off-site become feedstock for an in-vessel system.

Technical Evaluation of In-Vessel and Windrow Composting Systems

The goal of any composting system is to consistently produce quality compost in a reasonable amount of time with infrequent or no odor problems, while minimizing issues with liquid leachate, vectors, and other environmentally undesirable factors. No system removes the operator from the picture – he/she is still needed to determine compost recipes, adjust them for feedstock fluctuations, conduct testing and monitoring required by the permit, stockpile and then load raw materials, then unload and stockpile finished product.

In-Vessel Composting Systems

The choice of an in-vessel system will depend upon the raw material feedstocks, the volume of material to be composted, the capital available, and the site characteristics. The general types of in-vessel systems are:

- Passively aerated bins;
- Mechanically aerated containers;
- Agitated-aerated containers;
- Rotating drums; and
- Agitated beds.

These containerized systems all require the following:

- A container that is supplied with air flow and leachate drainage;
- A mixing and loading machine to thoroughly mix the raw materials and load them into the container;
- A biofilter, which can be filled with finished compost or wood chips, to control odors;
- Process monitoring;
- An unloading system; and
- A site for curing the compost.

The general benefits of in-vessel systems include:

- A controlled process that contains odors and gases;
- Reduced land requirements, particularly improved surface;
- Reduced operational requirements (time involved to load and turn drum vs. time to build and periodically turn windrows);
- A more consistent final product; and
- Aesthetically pleasing facilities.

Usually, in-vessel composting is employed when the primary ingredient to be composted is food waste or another high-nitrogen type of waste where pathogens may be an issue, such as manure or animal processing wastes. In-vessel systems are primarily designed to achieve the EPA requirement of three days at 131 degrees F or higher, to meet “Process to Further Reduce Pathogens” regulations (40 CRF Part 503). In-vessel composting is not widely used for yard wastes alone, mostly because of its high capital costs relative to windrow composting. Since yard waste contains only plant-derived pathogens and weed seeds, in-vessel systems that kill more hazardous pathogens are not necessary. Other materials such as leaves, sawdust and wood chips are added to the primary feedstock material as amendments to provide a carbon source to aid the composting of the nitrogen-rich wastes. Wood chips have the added benefit of providing bulk to the compost.

In general, the material composts inside the container for between 10 and 24 days, then is set outside to cure for an additional 30 to 60 days. Curing finishes the process of pathogen destruction, and allows the compost to cool down and biologically stabilize. Since pathogens are not present in yard waste compost, it is possible that the soil amendment obtained from in-vessel yard waste composting could be land-applied immediately and not need a curing period.

Rotating drums, which Carbon County is interested in investigating, promote decomposition by tumbling material in an enclosed container. The rotation exposes more of the surface area to air and oxygen, and releases heat and gaseous byproducts of decomposition. Rotating drums speeds up the composting process; some manufacturers claim that finished compost is produced in five to 10 days (as compared to open-air windrow-method composting which can take one to several months). The enclosed, controlled environment allows decomposition to proceed at a steady rate even during periods of cold winter weather.

Although in-vessel systems are not usually used for yard wastes alone, the increased control over temperature and air flow, plus the tumbling/agitating functions of rotating in-vessel composters, could contribute to faster decomposition of yard waste. However, because leaves alone have a C:N ratio of about 80:1, as opposed to the optimal 20:1 to 30:1 ratio, it is improbable that compost could be produced from leaves in a vessel in 10 days. Predictions of how long it would actually take are difficult to make, since little data exists. The leaves would almost certainly have to be shredded in order to generate biological activity.

Table 2 lists the major manufacturers of rotating drum composters and their basic specifications. Figures 1 and 2 show a photograph and a schematic of two types of rotating drum units.

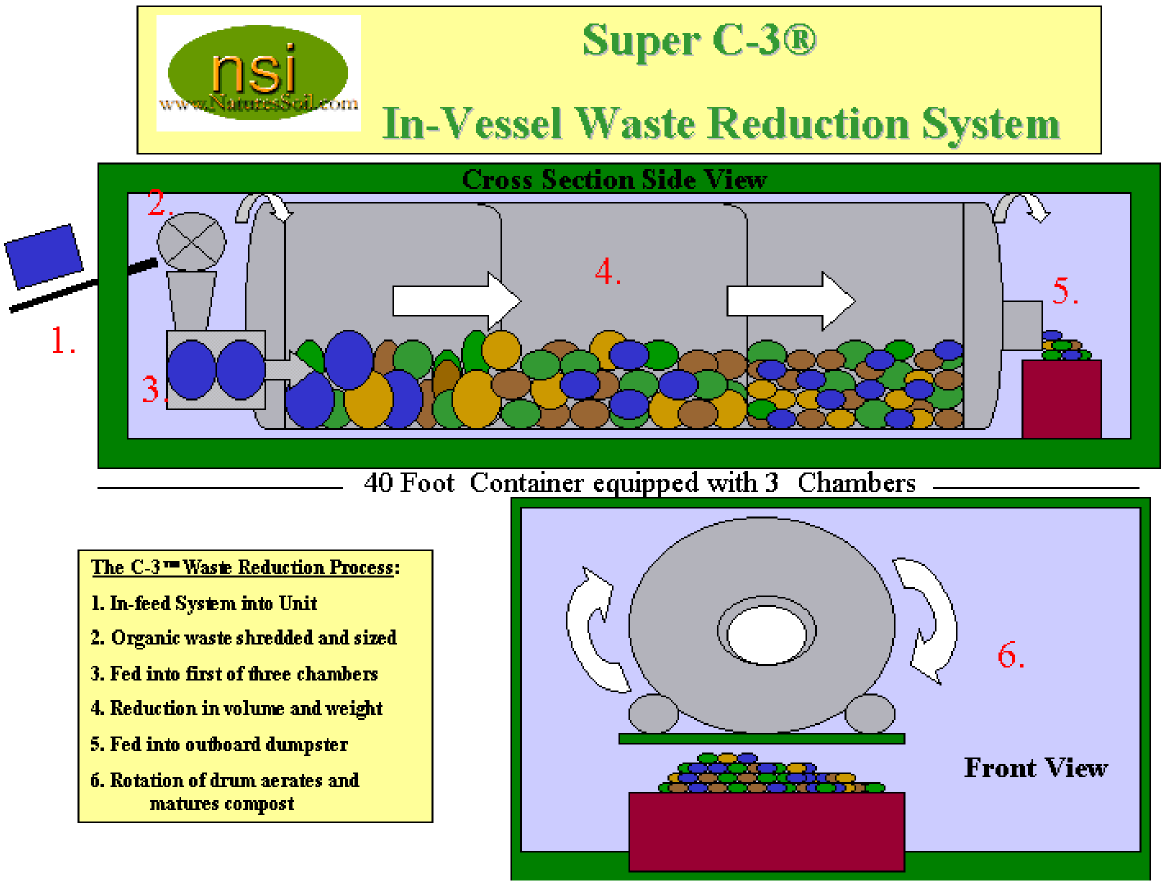
Table 2
Manufacturers of In-Vessel Composting Systems

Manufacturer	Bin and System Size Options	Throughput	Costs	Operational Issues
Nature's Soil, Inc. "Super C-3" Nashua, NH http://www.angelfire.com/co3/NaturesSoil/ (No longer in business, made and installed two machines that are currently in storage)	40' long x 8' wide x 9.5' tall for each digester. 6-foot diameter rotating drum is inside structure.	Load 1 ton per day, 5 to 7 day retention time More than one can be installed, or drum diameter increased.	$125,000 installed for complete system, but it only handles one ton per day. Carbon County would need five times the capacity.	No leachate, evaporation used instead. Baffles move material through interior of drum. No operational experience with yard waste only. Used on-site for food wastes at a hotel and a grocery store.
Augspurger Komm Engineering "Mobile Mulchers" Scottsdale, AZ http://www.akeinc.com/composting.html	Mobile 1: 9' long, 5' wide, 8' tall Mobile 2: 21-50' long, 6-8'wide, 8' high.	3 cy, batch process 10-100 yd3, continuous process	Several Mobile 2 units would be needed, to handle the volume, for a cost of approximately $700,000.	AKE is a consulting engineering firm that provides designs and material specs. Drums are made from spiral culvert pipe. Cycle time is 20-30 days for finished compost, 7 day retention time if cured afterward.
BW Organics "Green Drum" Sulpher Springs, TX http://www.neto.com/bworgani/top.htm	6 sizes, 2 mobile and 4 stationary models. Range from 3 – 6 yd^3 for mobile and 12 – 96 yd^3 for stationary	Operate at 1/3 or ¼ of volume ratings on a continuous daily production basis. Takes 3-4 days to stabilize and kill pathogens, then cures for 2-3 weeks.	Model 1050 stationary, 96 yd3 capacity (handles 25 yd3/day) costs $169,000 plus $8,500 for auger screw loading conveyor and electrical panel. Delivery and installation approx. $7,000 – 9,000 (two trucks, one as permitted load).	Stationary models must be installed on flat concrete pads. Model 1050 would require a 20' wide by 80' long pad. Use single-phase electric. Typical use is on-farm.
Environmental Products and Technologies Corporation (EPTC), "Aerobic Bioreactor" Thousand Oaks, CA http://www.eptcorp.com/index.html	Three models: 4' dia, 15' long; 6' dia 18' long, 8' dia., 24' long.	At 72 hour retention time: 4.5 yd3 per day, 9.5 cyd per day, 25 yd3 per day	Model 824, largest model, 25 yd3 per day: $300,000 including input and output conveyors, O2 generator.	Uses oxygen generator to supply 90% oxygenated air to material mass, resulting in very short composting time of 3 – 5 days. Material loaded and unloaded automatically. Marketed to dairy and food processing industries, no yard waste experience.

Figure 1
BW Organics Stationary Rotating Drum

Source: Reprinted with permission from BW Organics

Figure 2
Nature's Soil C-3 Rotating Drum Schematic



Source: Reprinted with Permission from Nature's Soil

Rotating drum compost vessels operate by very slowly (about 1 RPM) turning a drum loaded with a specific volume of organic material, usually food waste combined with a carbon amendment, mixed thoroughly according to a specific recipe. The tumbling action that results agitates the material and accelerates the compost process. The drum does not turn constantly – it is usually turned once or twice a day for a 15-minute period, which coincides with loading and unloading. Usually the drum is placed at a very slight angle, so that the compost travels down the tube as it decomposes. The angle and the rotation speed are adjusted so that when the compost reaches the end of the chamber, it is sufficiently processed and may be removed and set outside in piles or windrows for curing. Some rotating vessels use a series of interior chambers, and the material passes through these chambers as it is reduced in volume. Some manufacturers adjust the amount of air forced into the chambers based on the degree of decomposition desired; for example, injecting extra air into the first chamber so that decomposition proceeds fastest on the newest material. Some operations use specific techniques that they claim improve their process and end-product. For example, EPTC injects pure oxygen into a manifold in the interior of the chamber.

The land required for an in-vessel composting system is minimal, especially if a yard waste-only product is made that can be land-applied without a curing period. The hard surfaced area required would be significantly less than with a windrow system. The largest rotating drum unit requires a flat concrete pad measuring 20 feet wide by 80 feet long. A hard surfaced area – either concrete or paved – would also be required for areas where material was stockpiled and loaded into the machine, as well as areas where material would be unloaded, possibly cured, and stockpiled for end-use or distribution. The hard surface is required to prevent gravel from mixing with the material when moved. This additional surface is estimated to be one acre. The remainder of the operation – for equipment storage, office, space, or similar functions, could be a gravel or similar surface. A total of three acres of land may be adequate, but would be dependent upon the type and quantity of material throughput. The total area needed for the operation would be calculated for the General Permit application, if the County chose an in-vessel system.

Labor needs associated with in-vessel compost systems consist of loading, turning, and unloading. Compost vessel manufacturers recommend that the maintenance be done every day, to ensure that the biological process of decomposition is kept balanced. The time required for these tasks depends on the amount of material to be handled, but also on the loading process itself. If the feedstock is uniform and sized to accommodate the capacity of the loading system, then in a best-case scenario the daily maintenance might take an hour or two. However, if the feedstock must be ground or shredded in order to be loaded, increased labor time may be required. If Carbon County expects to collect leaves daily, the 20 cubic yard volume collected would need to be added to the vessel that day, and the vessel would be turned, and finished product unloaded from the other end. This process could take up to one-half day of labor. If the County invested in a leaf shredder to reduce the volume of leaves by 50 percent, it may be possible to load the unit every two days. However, the vessel would still need to be turned daily to ensure air circulation, release of gases, and continual decomposition.

Windrow Composting Systems

Windrow composting is a method used for yard waste that involves a much lower level of technology. In windrow composting, leaves are laid down in elongated piles, kept moist by watering, if necessary, and agitated and aerated by turning with either a loader or a specialized piece of equipment (windrow turner). The leaf windrows are exposed to the weather, unlike an in-vessel system where they are contained. The compost process takes longer, and requires more land than an in-vessel system. However, the system can be expanded relatively easily to accommodate increasing material volumes, unlike a rotating drum which has a finite capacity. The capital costs are generally lower, and, while operational costs can be higher, the functions of material handling and monitoring are necessary with both types of systems.

General guidelines for windrow composting state that between 4,000 and 6,000 cubic yards per year of leaves can be processed per acre of land. PA DEP Guidelines for Yard Waste Composting limit the amount of leaves or yard waste to 3,000 cubic yards per acre. For Carbon County's estimated 5,000 cubic yards per year of leaves, then, two acres would be needed for the processing and storage areas. One additional acre would probably be needed for equipment movement and storage, personnel facilities and shelter, bringing the total land requirement to approximately three acres.

The length of windrows will vary with material quantity, but the width and height should be constructed to specific dimensions to optimize the composting process. Pile widths of 12 to 14 feet are recommended, with heights of 6 to 8 feet. An 8-foot height allows air to penetrate into the pile and results in less compaction than taller piles, but is still usually high enough to retain heat in the winter. A general rule of thumb is that an 8- foot pile contains about 1-1/4 cubic yards per foot of length. If a windrow turner is used, the height and width of the turner generally dictates the height and width of the piles.

The PA DEP guidelines stipulate that windrow piles are not to exceed eight feet in height or sixteen feet in width.

Generally new windrows are constructed to spec with a front-end loader using a 1 cubic-yard scoop. As each width is laid down, the layers are watered with about 15 to 25 gallons per scoop. Watering each layer allows the moisture to be absorbed, as opposed to waiting until the pile is constructed before watering it, which results in run-off. Newly completed windrows are left for seven days, then turned. The piles should be turned so that the material at the outer edges of the old pile is placed in the center of the new pile. Another 10 to 14 days after the first turning, windrows are ready to be turned again. At this point, decomposition has shrunk the original windrows by about 1/3 of their original volume, so that two piles may be combined into one. Again, turning and mixing scoop-by-scoop is important to allow uniform moisture distribution and to aerate and agitate the material. Water should be added if the pile has dried out. After the first two turnings, the piles should be monitored and turned on a schedule that promotes active composting. The PA DEP Guidelines direct that windrow piles must be turned at least once every three months.

There is no set schedule for determining when compost is "finished." The process of composting leaves alone takes a relatively long time because leaves have a natural C:N ratio of about 60:1 to

80:1. Experienced windrow composters report that compost can take eight months to be finished. Of course, the process is slower in the winter time when the weather is cold, and given the time of year when leaves are plentiful, winter is a factor. Adding nitrogen-rich materials, such as food waste or grass clippings, can greatly increase the rate of composting by reducing the C:N ratios. However, the use of grass clippings is best approached with caution, as their high nitrogen content and moisture cause them to become odorous and slimy very quickly. Experts advise that windrow system operators gain two or three years of experience with leaves only before attempting to incorporate grass.

As specified in the PA DEP's "Guidelines for Yard Waste Composting Facilities" (Document #254-5403-100), the Department may prohibit the use of grass clippings at yard waste composting facilities, according to the following provision:

> *The Department may prohibit the use of grass clippings at a yard waste composting facility if the grass clippings cause or contribute to nuisances, or if the site is adversely affecting, or has the potential to adversely affect, the citizens or environment of the Commonwealth. Grass clippings shall not be brought to or received at a yard waste composting facility unless:*
>
> (a) *Grass clippings delivered to the yard waste composting facility in bulk, bags, or other collection containers are emptied of all grass clippings within 24 hours of delivery to the facility.*
>
> (b) *Grass clippings are incorporated into the windrows of partially composted leaves or other yard waste within twenty-four (24) hours of delivery to the facility.*
>
> *Grass clippings are incorporated into the partially composted windrows of partially composted leaves or other yard waste at a ratio not to exceed one part grass clippings to three parts yard waste, by volume.*

Windrows need frequent monitoring for moisture content and temperature. Generally, if piles are too dry, bacterial decomposition will not occur and the piles will not reduce in size. If they are too wet, they will produce run-off and become odorous. Moisture can be gauged by a simple "squeeze test," in which a handful of material is obtained from inside the pile and, when squeezed in a fist, holds together but does not form a lump or ooze water. Temperature is measured using three to four foot stem type thermometers, a necessary piece of equipment for any windrow-composting operation. Temperature should be measured several times per week.

Tasks associated with windrow composting systems include building the windrows, turning the windrows, and keeping track of the age of windrows and the progress of the composting process. Carbon County's daily collection of 20 cubic yards of leaves would build a windrow approximately 8 feet tall, 14 feet wide, and 16 feet long. These windrows could be constructed daily, or the leaves could be stockpiled over the course of a week for later windrow building. Turning of the previously constructed windrows would be done after seven days, again after 14 days, and then periodically until the compost was ready for curing in a pile. It is possible that the work of building new windrows, and turning older ones, could take place once per week, for a full day of labor. The actual labor spent would depend on how the volume actually built up, and the time of year.

When the volume of yard waste to be managed reaches approximately 25,000 cubic yards per year, a specialized compost turning machine is advisable, as the capacity of a front-end loader to turn piles efficiently will be exceeded. These machines are designed specifically for agitating and aerating windrow piles, and accomplish the work quickly. The less expensive models are towed behind a tractor or other piece of equipment, and use the PTO (power take-off) for power. Others are self-propelled. They can work from the side, or straddle the piles. Some have built in water tanks for watering the pile as it is turned. These machines vary considerably in price, ranging from $20,000 to $150,000 and more, depending upon the capacity and features. Generally the less expensive models are attached to tractors or loaders for the power, and do not include watering systems. The more expensive models are self-propelled, include watering systems, and can handle larger windrows.

Cost Comparison of In-Vessel and Windrow Composting Systems

A cost-analysis of rotating drum (in-vessel), and windrow-composting systems is provided. These results are presented in Table 3.

Table 3
Cost Comparison: In-Vessel vs. Windrow Composting System for Yard Waste

Equipment	Purpose	Cost Estimate In-Vessel System	Cost Estimate Windrow System
Front-end loader	Move materials, turn windrows in windrow system [1]	$90,000 to $100,000	$90,000 to $100,000
Brush chipper or shredder (optional)	Pre-process brushy materials[2]	$15,000 to $100,000	$15,000 to $100,000
Trommel screen (optional)	Screen finished compost for horticultural use[3]	$60,000 to $150,000	$60,000 to $150,000
Leaf shredder	Volume-reduce leaves to use smallest composting vessel, load material more easily, and encourage decomposition	$50,000	Not needed
Compost vessel, including loading and unloading conveyors, leachate management system, and electronic monitoring and controls	Enclose the composting process	$177,500 to $300,000	Not needed

Equipment	Purpose	Cost Estimate In-Vessel System	Cost Estimate Windrow System
Concrete pad for vessel (80'x20')	Hard surface for vessel installation[4]	$10,160 to $14,080	Not needed
Watering equipment	Keep piles optimally moist	Not needed	$1,000
Thermometer	Monitor temperature in piles	Not needed	$50 to $150 analog $300 – 750 digital
Windrow turner (optional)	Facilitate pile turning	Not needed	$20,000 to $100,000
Approximately two acres of paved surface	Placement of windrows and equipment movement, receiving, curing, stockpiling[5]	Not needed	$229,988 to $261,360
Aggregate and grading – approximately 1 acre for windrow system, and 2 acres for in-vessel system	Ancillary equipment and access space[6]	$130,680	$65,340
Total Capital Cost Range Without Options		$458,340 to $594,760	$386,428 to $428,225
Total Capital Cost Range With Options		$533,340 to $844,760	$481,428 to $778,225

[1] Cost estimate assumes a 3 to 4 cy bucket
[2] Cost estimate assumes 200 cy per hour processing capacity
[3] Cost estimate for equipment processing capacity of 10 to 50 cy per hour
[4] Sources: 2005 National Construction Cost Estimator, Craftsman Books, Carlsbad, CA at $6.35 per sf for 6" reinforced concreter over 4" gravel bed, and estimates from R.W. Beck engineers for $8.80 per sf, for the same specifications.
[5] Sources: Interview with compost operator in Lynchburg, VA, at about $1 per sf for 3" asphalt over gravel site; and 2005 National Construction Cost Estimator, Craftsman Books, Carlsbad, CA, at $3.52 per sf for grading, 4" gravel, and 4" asphalt over previously unimproved site.
[6] Cost estimate based on $1.00 per sf for grading and gravel, per conversations with professional compost consultant.

The cost figures show that the only required piece of equipment for a windrow system is a front-end loader, a versatile unit that can handle virtually all of the material handling tasks associated with a composting operation. For an operation of the scale of Carbon County's, turning windrows with a loader vs. a specialized windrow turner should be satisfactory for several years.

The most significant cost for a windrow composting system is the hard surface. A gravel or dirt surface is not appropriate, as eventually the gravel will be mixed up with the compost during the windrow turning process. Generally, either a 6-inch reinforced concrete pad over a 4-inch gravel bed, or a 4-inch asphalt pavement over a 4-inch aggregate base, would be sufficient. The asphalt is less expensive at approximately 36 percent to 45 percent the cost of an equivalent concrete surface.

The actual windrows for a system sized for Carbon County's leaf generation would require 1.5 acres of hard surface. An additional one-half acre would be needed for receiving, curing, and stockpiling finished compost. Blacktop asphalt pavement would be significantly less expensive than concrete, with costs ranging from about $230,000 to about $260,000. The remainder of the site could most likely be surfaced in an aggregate mixture.

Temperature monitoring and watering are done with readily available, relatively inexpensive tools.

In contrast, in-vessel composting requires the up-front expenditure of a large amount of capital for the enclosed rotating drum. The high cost is based mostly upon the low density of leaves – the large volume is simply difficult to feed into, and process, using enclosed containers. These vessels are mostly designed to compost food wastes, which have a high density, and thus the volume to be loaded and processed is much smaller. For leaves, the largest unit on the market would be required and the associated costs are significant. The least expensive unit would be the largest “Green Drum” by BW Organics. Including a feed auger/conveyor, the unit would cost $177,500. Delivery from Sulphur Springs, Texas and installation would bring the total price to between $184,500 and $186,500.

Manufacturers of rotating drum composters advise that the loading area, at a minimum, be placed under a shelter of some sort, such as a pole shed, to facilitate loading during inclement weather. The auger conveyor can become clogged with snow and freeze in the winter. The total hard surface area needed for an in-vessel system would be about 1,600 square feet for the concrete pad to hold the digester, and an additional half acre of paved surface for receiving, loading, unloading and stockpiling. The costs of the hard surface would total approximately $31,940 to $ 90,745, depending on the amount of grading and other surface preparation required.

The seven-year amortized costs of both composting options, considering DEP grant funding, are presented in Table 4.

Table 4
Ten-Year Amortized Costs of Composting Equipment

Composting System	Equipment	Cost[1]	Annual Cost without DEP Grant	Annual Cost with DEP Grant[2]
In-Vessel	Rotating Drum	$250,000	$44,784	$4,478
	Front End Loader	$105,000	$18,809	$1,881
	Surface Concrete and Asphalt	$61,342	$10,989	$10,989
	Leaf Shredder	$50,000	$8,957	$896
	TOTALS	$466,342	$83,538	$18,243
Windrow	Front End Loader	$105,000	$18,809	$1,881
	Surface Paving	$245,679	$44,010	$44,010
	Watering/Temp Monitoring	$1,500	$269	$27
	TOTALS	$352,179	$63,088	$45,918

[1] Assumes an interest rate of 6 percent

[2] Assumes DEP portion is 90 percent of eligible costs and County's portion is 10 percent of cost.

As shown by Table 4, the initial capital cost of an in-vessel compost system is higher than a windrow system, because of the specialized equipment required. However, when a potential DEP grant for 90 percent of the equipment cost is figured in, the in-vessel system is less expensive. The highest initial cost for the windrow system is surface paving, which is not eligible for DEP grant funding.

Table 5
Annual Labor Cost for In-Vessel and Windrow Composting Systems

System	Tasks	Hours per Week	Hours per Year	Labor Cost per Year (3)
In-Vessel(1)	Stockpile raw material	5	90	$6,908
	Load Vessel	10	180	
	Turn	1.25	22.5	
	Unload	10	180	
	Stockpile finished material	5	90	
Windrow	Stockpile raw material (1)	5	90	$10,622
	Build Windrows (1)	7.5	135	
	Turn Windrows (2)	6	210	
	Monitor	5	260	
	Stockpile finished material (2)	5	170	

1 Fall and early winter months only (18 weeks)

2.Not in winter months of January, February, March and April (17 weeks)

3 Based on County worker's hourly rate of $12.28

Table 5 presents an estimate of the annual labor hours and costs required to maintain both types of composting systems. The in-vessel system costs are over $3,700 less than the costs for the windrow system, mostly because, at least theoretically, the entire composting process could be accomplished using the rotating vessel during the 18 weeks in which leaves are collected. The estimates for the windrow system assume some flexibility in labor costs, in that the windrows do not have to be turned during the winter, but they do require attention during the summer, the most biologically active time period.

These estimates are drawn from previous studies and conversations with the in-vessel equipment manufacturers, and are therefore not field-tested and proven. It is advisable for Carbon County to use these figures as rough estimates only. For the volume of leaves expected by Carbon County, it may be difficult to load the compost vessel within these hourly estimates. Again, however, there is some flexibility in handling leaves in the winter, and the County could stockpile them and meter them into the vessel in smaller batches. Of course this would increase the labor costs.

Conclusions and Recommendations

Rotating Drum: Advantages

- **Conserved space –** The unit itself takes up little space, and therefore the amount of land that must be hard-surfaced is minimized.
- **Enclosed process –** The compost process is enclosed. Any odors that might arise from the decomposition would be contained. Since the system is impervious to weather, dust during dry times or leachate run-off during rainy periods would not be an issue. The organic material would continue to compost during cold winters. The tumbling agitation of the leaf and brush material inside the container would break it down and expose more surface area to the composting process, greatly speeding up the decomposition and making compost faster.
- **Potential to land apply –** The compost produced by an enclosed rotating drum could probably be land-applied without a lengthy curing period, since the pathogens found in leaves and yard waste are limited to weed seeds, acorns, and diseased plant materials.

Rotating Drum: Disadvantages

- **Potential for imbalances –** Even though the process is self-contained, and in the more expensive systems the monitoring, addition of process air, exhaust of gases, and leachate management are controlled and automated, it is still very important to remember that what happens inside the drum is a biological process. Even with all the latest sophisticated machinery, imbalances in the critical parameters of oxygen levels, moisture levels, temperature, and pH can occur.
- **Imbalances more difficult to correct –** If biological imbalances do occur, they are more difficult to correct in an enclosed container. One operator of a rotating drum system who was interviewed for this project said that the computer control never worked correctly, and odors emanating from the vessel was a frequent problem. In the worst case, the material may need to be removed from the container, spread out and re-mixed, the problems addressed, and then the material re-loaded. Aside from the odors and leachate that might result from exposing the material, the labor and time involved in such corrections could be significant.
- **Less rapid processing time than with other waste streams –** The time it would take to actually take to make compost from leaves alone in a vessel is unknown, although a 10-day time frame is unrealistic due to the high C:N ratio of leaves.
- **High capital costs –** The capital cost of a system is high. Because leaves and yard waste are voluminous, the largest rotating drums must be used even for relatively small generation rates such as Carbon County's. The systems identified are equipped with auger conveyors for loading the drums, which may not be appropriate for leaves and chipped brush. A leaf grinder will most likely be needed for up-front volume reduction. A rotating drum large enough to handle Carbon

County's leaf and yard waste volume could cost between $174,500 and $300,000, plus freight and installation.

- **Significant labor required –** The expected reductions in day-to-day operations and maintenance costs, with respect to windrow systems, are not dramatic. In order to keep the process going, material must be loaded daily, unloaded daily, turned daily, and monitored daily. Corrections in air flow, temperature, and moisture still may have to be made. While theoretically all of the labor could be expended during the leaf generation season, in reality no large-scale in-vessel leaf composting system has been field tested. The amount of labor may actually be higher than projections.
- **High replacement costs –** A vessel has a limited life span. Given the corrosive nature of the composting process, particularly if food waste were to be added, it may be worn out in seven to 10 years.
- **Uncharted territory –** Few communities have used an in-vessel system for yard waste composting, so there is not much operating experience from which to learn.

Windrow System: Advantages

- **Lower capital costs –** The equipment costs for windrow systems are much less than for in-vessel systems. The most significant capital expenditure for a windrow system is a good front-end loader with a large (3 or 4 cubic yard) bucket. A machine of this sort is useful for many other things besides managing a composting operation, so the costs may be allocated among other tasks to reduce the total composting cost. Compost experts do point out that the composting environment is very corrosive to metals, and a front-end loader, or any piece of equipment, used for composting may have a reduced life span compared to equipment used for less demanding uses. This should be taken into account when amortizing the costs over the life of the equipment. This expectation also emphasizes the need to evaluate the quality of construction, corrosion protection, and composting experience with any equipment manufacturer.
- **Flexibility –** A windrow composting program is flexible. It can be continued indefinitely because no specialized equipment would wear out. It could also easily be discontinued if that becomes necessary. A large hard surfaced pad would be the only relic of the program, and it could be used for other things – including in-vessel composting if the County decided to go that way after several years of composting experience.
- **Common –** Many communities have experience with windrow composting systems, so common problems have been solved, and the operational knowledge exists to deal with them.

Windrow System: Disadvantages

- **More space required –** Windrow systems require more land area, and more hard surface area, than in-vessel systems. For Carbon County, assuming 5,000 cubic yards of leaves per year to start, and no brush or nitrogenous additions, approximately 14 windrows would be needed, measuring 12 feet wide, 8 feet high, and 200 feet long. This is calculated using basic area and volume measurements. In a practical sense, because about one-third of the material would either be volume-reduced in a year, or perhaps moved off-site to final use, 10 windrows might be needed at any given time. With a 20-foot aisle around the windrow area, and 14-foot aisles between the windrows, the total area needed just for the windrows would be about 1.5 acres. Because the material needs frequent turning and handling, this area would need to be hard surfaced. To plan for future growth, and to have room for equipment storage, shelter, curing piles, and other on-site needs, a total area of three to four acres would be needed. Paving of the additional surface is optional.

- **Weather Impacts –** Weather affects windrow composting systems. During a cold winter, decomposition may slow or stop. During a rainy spring or summer, piles may become saturated with water, causing leachate run-off and anaerobic conditions, and additional labor costs may be needed to spread the windrow out to dry and then rebuild it.

Recommendations

Based on an analysis of all relevant factors, it is recommended that the County pursue developing a traditional open-air windrow system. While up-front costs of site preparation are higher than an in-vessel system, the overall benefits of windrow composting, and its “knowns”, point to it as the more practical choice. While this analysis attempted to discover as much as possible in terms of the operational and cost factors associated with in-vessel yard waste composting, the “unknowns” still advise caution. While DEP grant funding may cover 90 percent of the cost of the composting vessel, it may still not be cost-effective in terms of recurring operational costs and lifetime of the equipment.

Site preparation and paving costs may be lower than estimated in this report, depending on the type of site the County is considering, whether it is already improved to a degree, and whether County resources can be used in the grading and paving to reduce total costs.

To help make the system as cost-effective as possible, the County should apply for a 902 DEP grant to fund the purchase of a heavy-duty, high-capacity front-end loader, and any other equipment for which grant funds are allowed.

Additional recommendations include:

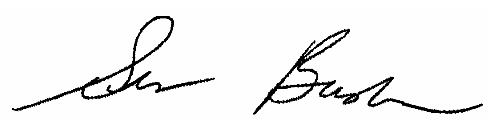
- The County should accept leaf waste, and perhaps ground wood, only, until their processing technique is perfected;
- The County should develop a plan for the disposition of the end product, possibly including sales of compost or leaf mulch to residents to help offset the operational costs of the compost system;
- The County might consider accepting small quantities of County-generated grass clippings at some point in the future, but they should be added to an awaiting, partially decomposed pile of leaves rather than being stockpiled in anticipation of an upcoming batch of leaves;

- The County might consider the possibility of adding food waste to composting at some point in the future starting with a single food waste generator and using kitchen scraps, which are less likely to be contaminated than post-consumer food waste;
- The County might consider purchasing a chipper and making it available for rent to municipalities to help offset some of the costs, as wood chippers are not widely available to municipalities in the County;
- The County might set up the leaf composting operation to allow for the delivery of residential bagged leaf waste, as many residents generate leaf waste beyond that which is typically vacuumed. However, labor issues with removal of bags may make this infeasible. If bags are necessary for leaf collection and/or delivery of compost, Kraft paper bags are preferred and plastic bags should be prohibited.
- A comprehensive educational program for residents should be established, to encourage participation in the program and also to inform residents how the vacuum system will work, and educating them about how to set out leaves; and
- The County might consider opening composting site to tours in order to educate residents about composting as well as about the importance of keeping yard waste free of contaminants.

We hope these findings are useful to you, and we appreciate the opportunity to work with Carbon County on this project. Please contact me at (401) 782-6710 should you have any questions.

Very truly yours,

R.W. BECK, INC.



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