APPENDIX C: OVERVIEW OF COMPOSTING AND ANAEROBIC DIGESTION TECHNOLOGIES

Throughout Europe and North America there are hundreds of composting facilities that process food residuals from industrial, commercial, and institutional (ICI) generators, as well as from residential drop-off and curbside collection programs. A wide range of technologies are used to recycle these organic materials into marketable compost and soil products. The following descriptions of composting facilities and technologies is intended to provide the reader with a ***basic understanding*** of the range of options that are available, estimated capital costs, and for a few technologies, operating costs.

It should be noted that in Canada only Nova Scotia has an organics ban, but there are a number of large scale composting facilities in operation, as well as a wide range of programs in Europe, driven primarily by European Union mandates prohibiting landfilling of untreated MSW. The Project Team did not evaluate these programs because most of the Canadian and European organics recycling programs utilize large, centralized in-vessel composting or anaerobic digestion facilities that process hundreds of tons per day of food and yard waste residuals. Costs and scale for these projects are above that likely to be realistically implemented in Vermont, and so the focus is on technologies that may be feasible at a smaller scale.

GREEN MOUNTAIN COMPOST- CHITTENDEN SOLID WASTE MANAGEMENT DISTRICT

The largest existing food composting facility in Vermont is owned and operated by the Chittenden Solid Waste Management District, which opened Green Mountain Compost facility in Williston in the fall of 2011 at a capital cost of $2.3 million. The facility utilizes aerated static pile technology, and processes food residuals, yard waste, and animal manure. The design capacity of the facility is 5,200 tons per year for food waste, plus additional organic materials.

The aerated static pile system is constructed on a concrete pad with aeration trenches, with a roof over the compost bays. The proper recipe of food waste, wood chips, and other bulking agents are mixed in a vertical mixer to get a homogenous blend that is then loaded into a bay. An aeration blower on a timer controls temperatures in each bay, and provides the required pathogen reduction temperatures of 131 degrees F in 3 days, although material is usually kept in this phase for 14 days.

The material is then removed from the bay, remoistened if necessary, and formed into another aerated static pile that is not under roof for additional weeks of curing.

Following this second aeration phase the compost, is processed through a trommel screen and put in stockpiles to cure and produce the final compost product. The wood chip overs from the screen are recycled back into the process.

Unfortunately, in the spring of 2012, customers who had purchased the first batches of compost product for use in vegetable gardens realized that the compost was harming some vegetable plants. Eventually, after an extensive, year-long investigation, it was determined that a herbicide, Aminopyralid, that was used on hay fields, made its way into the composting process through local sources of horse manure, and adversely affected the compost at very small concentrations of this “persistent” herbicide. Significant measures have been implemented to prevent this from occurring again.

HIGHFIELDS CENTER FOR COMPOSTING

Vermont is fortunate to host the Highfields Center for Composting (HCC) in Hardwick, a not-for-profit organization that has advanced the use of composting in Vermont and the northeast.

In addition to assisting farmers, municipalities, and commercial ventures in developing composting facilities, HCC has developed its own facility in Wolcott, as described below.

HCC is also the Vermont DEC's contractor for providing compost operator training that is required for any operator of a permitted facility by the state's Solid Waste Management Rules (Rule Number 11P-03, March 15, 2012).

HCC made a significant contribution to this report through its Close the Loop Strategic Plan, a statewide organic materials management initiative that brings together food scrap generators, composters, and farmers.

The Close the Loop Strategic Plan outlines a basic strategy for creating the physical infrastructure to collect and recycle all of Vermont's food-scraps by the end of 2017.

An unidentified farm compost system is described below, as well as HCC's facility in Wolcott.

COMMERCIAL SCALE FARM- DESIGN CAPACITY 10 TONS PER WEEK OF FOOD SCRAPS

Capital cost approximately $50,000 to construct receiving/blending area, compost pad, and dry storage area for bulking agents. Other costs would include:

Permitting	$12,000.
Equipment:	Loader/Excavator
	Water and Washing Station (recommended)
	Temperature Probes
	Dump truck

Total costs for a similar new facility and equipment would be at least $150,000.

HIGHFIELDS COMMERCIAL COMPOSTING FACILITY, WOLCOTT, VT - DESIGN CAPACITY 20 TONS PER WEEK OF FOOD SCRAPS

Capital costs were approximately $160,000, plus $100,000 for 2 loaders, for a total of $260,000. Additional costs for permitting and engineering design were approximately $30,000, a total investment of about $300,000.

A combination of turned windrow and aerated static pile technology is used by HCC, and they produce 2,500-3000 CY/year of finished compost.

BW ORGANICS

BW Organics has been manufacturing rotary drum compost systems for more than 10 years, and has over 100 drums in operation, mostly on farms to process manure and animal mortalities.

They have 12 rotary drums of varying capacity in operation processing food waste.

The ideal recipe for optimal composting of food waste includes some combination of wood chips, horse manure, leaves, and soiled paper/cardboard.

A significant technological advantage of rotary drums is their tolerance of inorganic contamination, particularly film plastic, metal/ceramic objects, and textiles. Since the organic materials are not shredded prior to loading in the drum, the inorganic contaminants are still large enough after discharge from the drum that a trommel screen can be used to remove the majority of contaminants prior to incorporating into windrows. For this reason, many rotary drums were initially used in Europe, and later in North America, to co-compost mixed municipal solid waste and sewage sludge, and some facilities were able to produce a marketable compost product with sufficient screening equipment following the drum.

There are several rotary drum composting facilities operating in the northeast; in Nantucket and Marlboro, MA, and Delaware County, NY. These large facilities process mixed municipal solid waste and sewage sludge in much larger, and more expensive, rotary drums than are practical for Vermont.

The BW Organics drums are typically operated 24 hours per day, turning slowly, which has the advantage of constantly exposing the microorganisms to new food, keeping the material in the drum aerated, achieving temperatures over 131 degrees F, and physically pulping the food waste so that after three days the food waste is no longer recognizable. It can then be discharged and incorporated into outdoor windrows for further composting and curing, typically several more months.

Since the food waste has been significantly degraded during the three days, it has significantly less vector attraction and odor potential.

A blower pushes fresh air into the rotary drum while it is turning, further aerating the material. The exhaust gasses from the drum can also be collected and treated in a biofilter.

The rotary drums are coasted with insulation to assist with heat retention during winter months.

BW Organics will also supply conveyors to load and unload the drums.

Capital costs for the rotary drums vary depending on the size of the vessels, but range from $30,000 to $300,000.

INTEGRITY AG SYSTEMS

Integrity Ag Systems (IAS) markets two types of composting technologies: rotary drums, and breathable environmental barrier fabrics. Most all of their installations are on dairy and hog farms. However, since the technology is designed to be cost-effective for farms, it has significant potential to be applied to food scrap composting in Vermont.

As discussed above, rotary drum composters are an excellent way to process food waste in a proper recipe with yardwaste, wood chips, or horse manure.

IAS has many rotary drums on dairy farms where they compost dairy manure and convert it to animal bedding and marketable compost. There are also 18 drums in use composting mortalities.

Like BW Organics, IAS markets a range of rotary drum sizes and capacities, the largest being 10' diameter by 40' long with roughly 90 CY capacity. That size unit will handle 30 cubic yards per day with a three day retention time, or approximately 15 tons per day of food residuals and bulking agent. The cost for that size drum is $350,000, which includes the control package and a 10 hp hydraulic motor. In addition to electricity costs, IAS estimates $5,000 per year in operation and maintenance costs.

To processes 10 tons per week would require a drum that is 5' diameter by 24' long, which lists for $110,000, including controls and a 5 hp hydraulic motor to drive the unit.

Another IAS product is the Vortron fabric. For composting facilities that use an environmental barrier fabric cover there can be significant advantages for the composting process. Such fabrics keep precipitation from getting into the pile, and retain moisture content of the piles as they are curing. They also control odor since the off-gasses from the pile condense on the underside of the pile keeping odor compounds inside. IAS's Vortron fabric costs $4/square foot. Assuming a 300 cubic yard windrow were to be covered with a 100' X 20' piece of Vortron, or 2,000 sf, that is $8,000 per sheet of fabric per windrow.

GREEN MOUNTAIN TECHNOLOGIES

Originally founded in Whitingham, Vermont in 1992, Green Mountain Technologies has designed and patented a number of composting technologies that are applicable to food scraps.

They have sold many EarthTubs™, a 3.3 cubic yard vessel designed for on-site composting of food scraps at institutions. A more recent on-site compost unit from GMT is the Earth Flow™, which is sized for larger institutions and businesses. Both can be viewed at the GMT website and are not further discussed in this report.

EARTH FLOW™ AGITATED COMPOSTING

The Earth Flow™ is a mid- scale in-vessel composting system for recycling organic waste materials at the site where they are generated. It is also available with a biofilter for odor control and has been developed to meet the composting needs of universities/schools, restaurants/cafeterias, commercial food processors, hospitals, multi-unit residential dwellings, camps and other institutional organic waste generators who generate from 700-3,000 pounds per day of food waste per vessel.

The system provides a modular and expandable design with the addition of more units as volumes of organic material increase. A powered auger Is installed in the unit for mixing and shredding most food and bulking agents. An insulated design allows for operation under winter conditions.

The smallest Earth Flow is capable of processing as little as 300 lbs. (136 kg) per day, and the largest as much as 3,000 lbs. (1,363 kg) per day of food scraps and bulking agents. The system is designed to process kitchen prep and plate scrapings,, along with manure, yard trimmings, and wood chips. Meat, cheese, and other fatty foods should be kept below 15% of total waste input., and minimize large pieces of meat, or fat. If soiled and waxed cardboard are to be included as bulking agent, then they need to be processed through a mixer or shredder prior to loading in the system. If it is only food scraps and pre ground wood chips or yard trimmings, then a shredder is not required.

The Earth Flow has been installed in some very cold locations. But it may need supplemental heat if the temperature remains below 10F for more than 7 days. The aeration system should be shut down during cold weather.

The largest Earth Flow costs approximately $120,000. A list of reference facilities is available from Green Mountain Technologies.

CONTAINERIZED COMPOSTING SYSTEM

Another in-vessel composting technology from GMT for food scrap composting is the Containerized Composting System™. A 40 cubic yard compactor box is retrofitted with an aeration system and leachate collection to provide a fully enclosed composting system. Once the container is full, it is connected to a blower which is operated by computer software that monitors the compost temperature in the container, and activates a blower to optimize composting temperatures in the 131 to 140 degree F temperature range.

After a three week retention time is completed, the container is disconnected from the blower pipes, and hoisted onto a roll-off truck and driven to the curing pad, either on-site, or at another location, where it is dumped out of the roll-off container.

The food residual that was in the container has lost its attractiveness to vectors, as well as most of its odor and leachate potential, and can be further cured on an outside pad.

Capital cost for a GMT four container system that can process 10 tons per week of food waste is approximately $80,000, plus the cost of the containers, installation of the plastic liners and aeration system. The system includes:

- 34 foot long, mobile loading conveyor and discharge flail to distribute the mix of food waste and bulking material evenly into the container
- Aeration equipment; stainless steel blower with variable speed motor to regulate air flow in response to temperature
- Two compost temperature-averaging probes per container (total of 8)
- Computer controlled dampers to regulate air flow
- 6 inch Flex ducting and connectors for each container to PVC pipe headers (provided by others)
- 4 HMW polyethylene liners
- 4 HMW high pressure perforated pipe cut in half and extrusion welded to the HMW liner to serve as the plenum
- Software, computer controls, and data logger

Some solid waste districts have old, 40 CY compactor containers that could be retrofitted with a plastic liner manufactured by GMT, thus saving on purchase of new containers. Used 40 CY compactor boxes can be purchased for approximately $6,000; so four containers would add $24,000 to the capital cost.

Additional equipment not provided by GMT, but recommended include:

- Front-end-loader or tractor with bucket
- Mixer to blend the food waste and bulking agent
- Tractor with PTO to power mixer
- Biofilter for odor control
- Screen for final compost product

Costs for this equipment vary significantly depending on used or new, but would be expected to add $50,000 to $100,000.

GMT also manufacturers stainless steel containers, and the cost for such a system escalates to $225,000, but would have a much longer operating life.

AERATED STATIC PILE

Another technology appropriate for Vermont food scraps is aerated static pile (ASP).

GMT designs and installs ASP stems to process yard debris and food residuals. The facility is based on a positively aerated on-floor piping system within four concrete bays controlled automatically for over 16 days to meet regulatory temperature requirements, followed by a turned windrow curing system where the materials can be re-watered and managed for porosity and homogeneity to accelerate the composting process.

An ASP system designed for processing an average of 50 tons, or 110 cubic yards, per week of commingled food residuals and yard waste would be regulated as a medium sized composting facility in Vermont, with an annual processing capacity of 2,600 tons, or 5,720 cubic yards

A composting pad constructed of gravel or asphalt, is divided into four zones using concrete blocks stacked 3 high to contain the piles. One aerated zone is used for receiving and accumulating delivered yard waste and food residuals, and three zones are used for managing the composting aeration requirements to maintain temperatures for 16 days or longer to meet regulatory requirements. Each bay has an area 40 feet long by 14 feet wide and a depth of 6 feet at average design flow and a depth of 8 feet during seasonal peak flows up to 60 tons per week. The area behind the 4 zones system contains the blowers, distribution manifold and leachate water collection and treatment systems. It is recommended that there be an asphalt or gravel apron in front of the bays to receive delivered feedstocks.

GMT recommends that a mixer be used to aggressively mix the food scraps and bulking agents before placement into the receiving bay. The mixed material must be kept porous by the addition of horse bedding or other woody materials to keep the mixed material below 900 pounds per cubic yard wet weight at a moisture content of about 60%.

GMTs aeration system is configured to use temperature feedback to regulate the four zone dampers to automatically control compost temperatures in the pile to a set point on the controller and as read by the temperature probe. Each zone's temperature is continuously displayed on the LCD on the control panel mounted on an electrical service pole adjacent to the blower.

The 10 horsepower stainless steel blower is controlled by a variable frequency drive (VFD) to provide air flow to the aeration distribution system.

Air that is blown up through the piles is treated in a one foot deep bio-cover of compost overs from the final screen, or wood chips, that are placed on top of each pile as it is formed. This layer treats and reduces odors by about 80%.

Each aeration zone has a dedicated 12" butterfly damper which regulates the air flow delivered or withdrawn from the manifold below each pile as monitored by temperature feedback from one probe placed in each zone. Panel switches allow each zone to be put into an "off" or "auto" position to assist in moving materials and maintain airflow and pressure in the rest of the operating zones.

The stainless steel blowers are delivered skid mounted and ready to connect to the PVC aeration distribution manifold. The VFD and control system are installed in a NEMA 4 enclosure ready to mount on a post with electric service.

Each zone has two 6" lateral heavy wall HDPE lateral pipes on 4'-8" centers on the asphalt pad. The laterals go through two gaps cut in the block wall at the rear of each bay. The laterals are connected to a 12" PVC header mounted on the concrete block wall or on a uni-strut support system by GMT. Once the 16 day compost period is over, the aeration pipes must be pulled out in 20 foot long sections from under the compost piles. Then the compost can be removed by loader. Operators must be very careful in pulling the air pipes out or they will bend and deform. The air pipe needs to have the holes poked clean as needed. Before a new bay is filled the pipes are reconnected to the manifold by operators and covered in a narrow (2 feet wide) row of clean wood chip to assist in distribution of air throughout the pile. The mixed feedstocks can then be placed over the pipes and the bio-cover layer added to the top.

All water runoff, leachate and condensate from the front apron and the compost bays drains to the lower corner of the apron and into a manhole where a pump moves the water into a 3,000 gallon storage tank that is aerated to reduce foul odors. The water can be used to irrigate the Aerated Static Piles, the bio-covers, or be removed by tanker truck to a wastewater treatment plant. The active compost piles can consume and evaporate up to 630 gallons of water per day, allowing up to a 2 inch rain event to be consumed within a week of processing time. Large rainfall events over an extended period of time will require offsite transportation and treatment. The storage tank is transparent so fill levels can easily be monitored by operating staff.

After controlled aeration in the ASP system for over 16 days to meet the required time and temperature for sanitation, the semi-stable compost is removed and placed in low windrows, no wider than 12 feet and no higher than 6 feet. They must be watered and turned at least once per week to maintain porosity and biological activity for at least 3 weeks.

Capital costs from GMT for this ASP system are $83, 200, and include:

- 4 zone Modular Aeration Controller (MAC's) System sized for a 66'x 70' asphalt pad with 4 concrete block bays 14' by 40' using on-floor aeration ducting:
- 1 pc Skid-mounted M-09 -10 hp 220V Stainless Steel blower 2,400 cfm @ 15" w.c. w/ SS transition pieces to 12" duct
- 1 pc MAC's temperature feedback aeration controller panel with panel shrouds
- 4 pc 48" SS Temperature probes and cabling (1 per aeration zone)
- 1 pc 10 hp ABB 220V VFD's with wiring harness to MAC's Controller
- 4 pc 12" Butterfly dampers for zone flow control, PVC housing, SS moving parts
- 5 pc Above-ground distribution manifold with 12" PVC fittings and pipe
- 4 pc Belimo damper actuators for flow control and directional dampers
- 320 ft. 6" HDPE SDR 17 Perforated aeration pipe with caps

- 9 pc Leachate storage, treatment, and irrigation system for 3,000 gallons
- System design and five days of installation, on-site training and startup.

Not included with the capital cost are:

- Electrical work,
- Asphalt pad
- Concrete blocks
- Underground plastic pipe installation

GORE COVER SYSTEMS

W.L. Gore & Associate's "GORE® Cover" system is centered on membrane laminate technology similar to that of its world famous GORE-TEX® fabrics used for outerwear and footwear. The integrated system includes the GORE® Cover, in-floor or on-floor aeration, aeration blowers, oxygen and temperature sensors, controllers, computers, software, cover handling systems, training, engineering guidance, installation support and the experience gained through the hundreds of installations worldwide. In North America there 20 Gore facilities processing a combined 1 millions tons of green waste, biosolids, food wastes and unique applications such as fish and poultry waste.

The largest food waste composting facility on the east coast is the Wilmington Organic Recycling Center in Wilmington, DE where 500 tons per day is processed using the Gore technology. The closest reference facilities with similar Vermont climate conditions are located in Ontario, Canada.

A typical Gore system using a standard 8 week processing time designed to process 10,000 tons per year of a combination of food waste and clean wood waste, and operate in the winter conditions of Vermont, will have a capital cost for the GORE® Cover system of $750,000. Does not include electrical work, asphalt pad, concrete walls, tip area, mixing, grinding, front end loader and construction.

Entry level designs using a reduced 2-4 week processing time are available with lower start up costs from $80,000 - $350,000. Single demonstration units are available for rental capable to process as little as 100 to 250 tons per batch.

The GORE® Cover system uses positively aerated static piles covered with a breathable, but waterproof fabric, which allows gases to move across the fabric barrier, i.e. oxygen and carbon dioxide. A number of states and provinces have classified the Gore technology as "in-vessel" since it encapsulates the composting material inside the covered system during the active composting phase.

Experience with the Gore fabric has shown it significantly controls odors since most odors are dissolved into the water vapor driven off during the composting process, and the water condenses on the underside of the fabric, keeping odor within the pile.

The Gore fabric also maintains moisture in the pile, which is important for the composting process, and therefore does not require the addition of moisture as with open air piles.

Key components to the GORE® Cover technology:

Entry Level Design: SG Mobile™ System

- Minimum 1 Phase processing time of 2-8 weeks
- Standard GORE® cover heap design
- On- floor aeration system
- Mobile portable control unit
- Includes design support, installation services and operator training
- Manual handing of the GORE® covers

Winter Design: SG Mini™ and SG Mid Range™

- Standard 3 phase processing time of 4- 8 weeks
- Bunker GORE® cover heap design
- In- Floor aeration system
- Master control unit
- Includes design support, installation services and operator training
- Mechanical handing of the GORE® covers

Additional Facility Requirements – supplied by other:

- Paved surface for the compost pad, reception, screening and storage area
- Water management control for complete separation of leachate and storm water
- Covered bunker or enclosed reception/tipping area
- Pre-treatment equipment for grinding and/or mixing
- Post-treatment equipment for screening
- Front end loader(s)
- Water and electricity
- Office and scale

ANAEROBIC DIGESTION

FARM BASED ANAEROBIC DIGESTION FACILITIES

There are currently 17 farm-based anaerobic digesters operating in Vermont. Table C.1. (on the next page) provides information on each facility.

In addition one more system is in the latter stages of construction and several more are in the planning stage. Several existing facilities are expanding processing capacity. Fifteen of the existing digesters are combined heat and power systems (i.e. they combust the biogas in reciprocating engines to produce both electricity and heat). In these cases electricity is exported to the grid while heat is utilized to support the digestion process and as a supplement or displacement of fossil fuel use (heat related) on the farm. Two of the installations convert all of the biogas directly to heat using a modified natural gas boiler.

TABLE C.1. EXISTING VERMONT DAIRY FARM DIGESTORS

Vermont Dairy Farm Anaerobic Digesters as of April 1, 2013

Farm/Project Name	Town	County	Digester Type	Status	Start Year	Cows Feeding Digester	Non-manure feedstock?	Biogas End Use(s)	Capacity (kW)	System Designer	Receiving Utility
Blue Spruce Farm	Bridport	Addison	Mixed Plug Flow	Operational	2005	2,500	yes	Cogeneration	490	DVO, Inc.	Green Mountain Power
Chaput Family Farms	North Troy	Orleans	Complete Mix	Operational	2010	2,100	yes	Cogeneration	300	RCM International	Vermont Electric Coop
Dubois Farm	Vergennes	Addison	Mixed Plug Flow	Operational	2010	1,200	no	Cogeneration	450	DVO, Inc.	Green Mountain Power
Four Hills Farm	Bristol	Addison	Mixed Plug Flow	Operational	2012	1,200	yes	Cogeneration	400	DVO, Inc.	Green Mountain Power
Gebbie's Maplehurst Farm	Greensboro	Caledonia	Complete Mix	Operational	2012	450	no	Cogeneration	150	RCM International	Hardwick Electric
Gervais Family Farm	Bakersfield	Franklin	Mixed Plug Flow	Operational	2009	950	yes	Cogeneration	400	DVO, Inc.	Enosburg Electric
Green Mountain Dairy	Sheldon	Frankin	Mixed Plug Flow	Operational	2007	1,600	yes	Cogeneration	300	DVO, Inc.	Green Mountain Power
Jonesian Farm	Hyde Park	Lamoille	Complete Mix	Operational	2012	220	no	Cogeneration	60	UEM Inc.	Vermont Electric Coop
Kane's Scenic River Farms	Enosburg Falls	Franklin	Mixed Plug Flow	Operational	2011	850	no	Cogeneration	225	DVO, Inc.	Green Mountain Power
Keewaydin Farm	Stowe	Lamoille	Mixed Plug Flow	Operational	2011	95	no	Cogeneration	20	Avatar Energy	Stowe Electric
Maxwell's Neighborhood Farm	Coventry	Orleans	Mixed Plug Flow	Operational	2008	750	yes	Cogeneration	225	DVO, Inc.	Vermont Electric Coop
Montagne Farm	Swanton	Franklin	Mixed Plug Flow	Operational	2007	1,200	yes	Cogeneration	300	DVO, Inc.	Green Mountain Power
Monument Farms	Weybridge	Addison	Mixed Plug Flow	Operational	2011	500	yes	Cogeneration	150	DVO, Inc.	Green Mountain Power
Pleasant Valley Farms	Berkshire	Franklin	Mixed Plug Flow	Operational	2006	1,950	yes	Cogeneration	600	DVO, Inc.	Vermont Electric Coop
Westminster Farms	Putney	Windham	Mixed Plug Flow	Operational	2009	1,200	yes	Cogeneration	225	DVO, Inc.	Green Mountain Power
Benjamin	Franklin	Franklin	Complete Mix	Under Construction		450	yes	Cogeneration		Biomethatech	
Jasper Hill	Greensboro	Caledonia	Post separation complete mix	Under Construction	2013		yes	Water Heating	n/a	several	n/a
Neighborly Farms	Randolph	Orange	Complete Mix	Under Construction	2013	60	yes	undetermined		Andigen	
Foster Brothers Farms	Middlebury	Addison	Horizontal Plug Flow	Not In Service	1982	380	n/a	Cogeneration	85	Hadley/Bennett	
Nordic Farm	Charlotte	Chittenden	Vertical Plug Flow	Not In Service	2005	250	n/a	Cogeneration	65	Weeks/Scruton	

There are approximately 170 dairy farm anaerobic digesters in the US.

All of the digesters utilize dairy manure as the primary feedstock. In addition, because of the added gas potential of non-manure organic materials, a majority of the farms add non-farm feedstock to their digester tanks. To date, the off-farm feedstock has consisted of liquid food processing waste with solids content roughly in the range of 2 to 15 percent. Wastes types currently employed include dairy processing wastes such as ice cream and whey, DAF material from a variety of food processors, and brewery waste.

The potential of increasing the use of high-energy off farm feedstock, including pre and even post-consumer food residuals, in the digestion process is of significant interest to farmers for a variety of reasons. Often discussed, is the added revenue farmers could receive from both tipping fees and through the export of additional electricity. Often overlooked, but of growing interest given advancement in nutrient sequestration technologies, is the added nutrient value off-farm feedstock may bring to the farm.

The potential role anaerobic digestion can play in the implementation of Act 148 will depend on a variety of factors. Even when looked at from a capacity perspective the question is multi variable. For example, most of the operating farm digesters were constructed to allow for dairy herd expansion. More specifically, digester tanks were sized to accommodate the manure from many more cows than were present at the time of construction. In addition, in most cases, engines were sized to accommodate additional biogas. Both of these factors will need to be evaluated, on a farm by farm basis, in order to fully appreciate the potential for existing projects to accept Act

148 type food residuals. Further complicating the analysis is the fact that as digester economics improve relative to dairy economics (e.g. once the initial digester system has been paid off) some farmers may opt to reduce herd size to accommodate additional off-farm feedstock thereby generating more electricity.

Two additional facets of the Act 148 anaerobic digester interface are important to consider.

One is that there is currently a shortage of pre-consumer liquid residuals available to Vermont farm-based digester operators. Vermont simply does not have enough food processors to meet current demand for this material. The question is can "solid" food residuals make up the difference?

From a theoretical perspective, if 10% of the 12 million gallons of installed digester capacity, based on an average of 21 days of retention time in a digester, were to be made available for liquid food residuals, that would be over 50,000 tons per year, more than the Project Team's estimated 45,000 tons per year of food residuals. However, since almost all of the food residuals generated in Vermont are not in liquid, or pumpable form required for adding to the existing farm digesters, that food residual would have to be processed either on the farm (carrying an estimated cost of $50,000 to $100,000 for pulping equipment, reception building, storage tank), or prior to delivery to the farm.

However, since most dairy farms would probably not want to construct and operate a state permitted food residual processing facility on the farm, it is more likely that the food residuals would have to be collected, processed, and transported to the farms from regional processing facilities such as solid waste transfer stations. For the few large quantity food residual generators such as hospitals and universities, there are also commercially available food grinders that can be installed to liquefy food residuals and then store it in tanks for collection and transport to farm-based AD facilities.

It is important for the state to recognize the farm-specific issues that will have to be addressed for this to occur, including increased size of the electrical generator, additional digester vessel capacity, and the farm's nutrient management plan to accommodate additional nitrogen and phosphorous for land application of liquid digestate. A collaborative effort from ANR and AAFM will be required to identify and facilitate such capacity expansion on farms.

Such an evaluation should be justified given that Vermont has made a considerable public investment in the existing dairy farm digester systems. Indeed, if one considers the combination of federal (USDA REAP, ARRA, USDA NRCS), state (CEDF, AAFM), and local (GMP RDF) grants that have supported these projects, public "ownership" far exceeds private ownership. Given this high level of commitment it behooves the State to further analyze the potential of utilizing Act 148 feedstock in these systems. It is recommended that ANR discuss these opportunities with Green Mountain Power Renewable Development Fund.[1]

[1] This section was prepared with assistance from Mike Raker, Agricultural Energy Consultants, LLC. The Renewable Energy Development Fund is comprised of GMP, AAFM, DPS, CLF, Renerable Energy Vermont.

ZERO WASTE ENERGY

Based on a German technology, Zero Waste Energy (ZWE) is a California company marketing a high solids anaerobic digestion technology that may be appropriate for larger regions in Vermont, in the 10,000 ton per year range of organic residuals generation. The term “high solids” refers to processing organics in a mixture similar to that used for composting, at a total solids content of around 60 percent. A similar mixture of food residuals and yard waste, including some paper, is loaded by front end loader into garage like structures in batches, a gas-tight door is closed, and percolate is circulated from an underground storage tank through the organic material for approximately 21 days under anaerobic conditions. This creates methane gas, which is captured and combusted in electric generating engines, or collected and converted into compressed natural gas.

After the 21 days of digestion, the doors are opened and a loader removes the material, commonly known as digestate, that can then be further composted to produce a soil product.

ZWE has one unit operating in California, and several more coming on line in the next year.

Capital and operating costs for a 10,000 ton per year facility are shown below in Table C.2.

TABLE C.2 ESTIMATED CAPITAL AND OPERATING COST FOR ZWE 10,000 TPY FACILITY

· Project Planning/Design Support/Preliminary Drawings	$120,000
· SmartFerm Systems, Foundation and Installation	$2,325,000
· Sub-Grade Excavation and Percolate Tank	$850,000
· Mechanical and Electrical Installation	$150,000
· Piping and Duct Work	$55,000
· Combined Heat and Power System	$420,000
· SmartFermTechnology License	$30,000
· Back up Generator	$10,000
· Start-Up and Commissioning	$30,000
· Contingency	$100,000
Estimated Total Project Costs:	**$4,090,000**
Estimated Annual Operating and Maintenance Costs:	**$175,000**

QUASAR ENERGY GROUP

In contrast to the high solids anaerobic digestion technology discussed above, there are technologies that make a liquid slurry of food scraps that can be pumped into tanks and digested to produce methane and energy. Similar to the on-farm systems discussed above, a number of facilities are being installed at locations other than dairy farms, and are designed to process food scraps, fats, oils, and grease, without dairy manure.

To process ICI food scraps in such a liquid system requires that the food scraps be pre-processed into a pumpable form either at the point of generation, or at the anaerobic digestion facility. There are special grinders on the market that can be installed at an institution to turn the food scraps into liquid, and store it in on-site tanks where the material would be removed by a tanker truck and delivered to the AD facility.

There are also technologies that can process food scraps into a slurry at the AD facility, separating inorganic contaminants prior to pumping into the digester.

quasar energy group, based in Cleveland, Ohio, is a full service waste-to-energy company with a laboratory and engineering facility at The Ohio State University's Ohio Agricultural Research and Development Center (OARDC) campus located in Wooster, Ohio. **quasar** designs, builds, owns and operates anaerobic digestion facilities using U.S. components to produce renewable energy.

The closest facility to Vermont is on the Jordan Farm in Rutland, Massachusetts, and has been operating for two years. Approximately 60 percent of the input to the facility is liquid food waste.

quasar builds facilities that can generate electricity, or compressed natural gas (CNG), depending on the market rates for electricity. They have constructed a series of CNG vehicle fueling stations to power company vehicles.

Besides the liquid, or low solids AD facilities, quasar is also integrating high solids AD facilities, such as at the Zanesville, Ohio plant.

The following is a list of quasar facilities in operation and under construction, as well as CNG fueling stations.

#	Location	kWh	Year Operational	Renewable Resources	Source
Massachusetts Facilities					
1	Rutland, MA	300	2011	electricity.thermal heat	manure & food waste
New York Facilities					
2	Buffalo, NY	1000	under construction	electricity	mixed organics
3	Wheatfield, NY	1000	2013	electricity	mixed organics
Ohio Facilities					
4	Ashley, Ohio	800	2013	electricity, CNG	mixed organics
5	Cleveland, OH	1300	2012	electricity, CNG	food waste/FOG/manure
6	Columbus, OH	1000	2010	electricity, CNG	biosolids/food waste/manure
7	Dayton, OH	1000	under construction	electricity, CNG	mixed organics
8	Haviland, OH	1000	2011	electricity	manure, food waste, FOG
9	North Ridgeville, OH	1000	2012	electricity	biosolids, food waste
10	Norton, OH	1000	under construction	electricity, CNG	biosolids, food waste
11	Wooster, OH	600	2010	electricity/ heat/CNG	manure/food waste
12	Wooster II, OH	1000	under construction	electricity, CNG	biosolids, food waste
13	Zanesville, OH	1000	2010	electricity/CNG	biomass/food waste/manure
14	Zanesville, Ohio iADs	1000	2012	electricity/CNG	high solids material

The potential for such AD facilities in Vermont is uncertain since the facilities have a high capital cost ($5 million to $7 million), and the fact that there is not a large quantity of pumpable food scraps currently available. However, there may be sufficient sources of industrial and food manufacturing liquids, such as whey, off-spec soft drinks, beer, oils, etc. to support a facility or two in Vermont.