Develop Anaerobic Digestion/ Combined Heat & Power

With a commercial food waste ban going into effect in Massachusetts in October 2014, businesses and institutions are considering alternatives to disposing of organic waste in the trash. Anaerobic digestion is one such alternative. Similar to composting, but in an environment devoid of oxygen, anaerobic digestion produces byproducts such as methane (which can fuel the generation of heat or electricity) and liquid or solid digestate (which can be used as fertilizer, soil amendment, and more). Thus, disposal of food waste and other organic materials can become a source of revenue rather than just an expense. Anaerobic digestion/combined heat and power (AD/CHP) may sometimes be referred to as waste-to-energy, bioenergy, biofuel, or biomass, although these broader terms can include the burning of trash, wood, or other agricultural materials. This strategy outlines considerations for municipalities interested in developing anaerobic digestion/combined heat and power.

Food Waste Ban

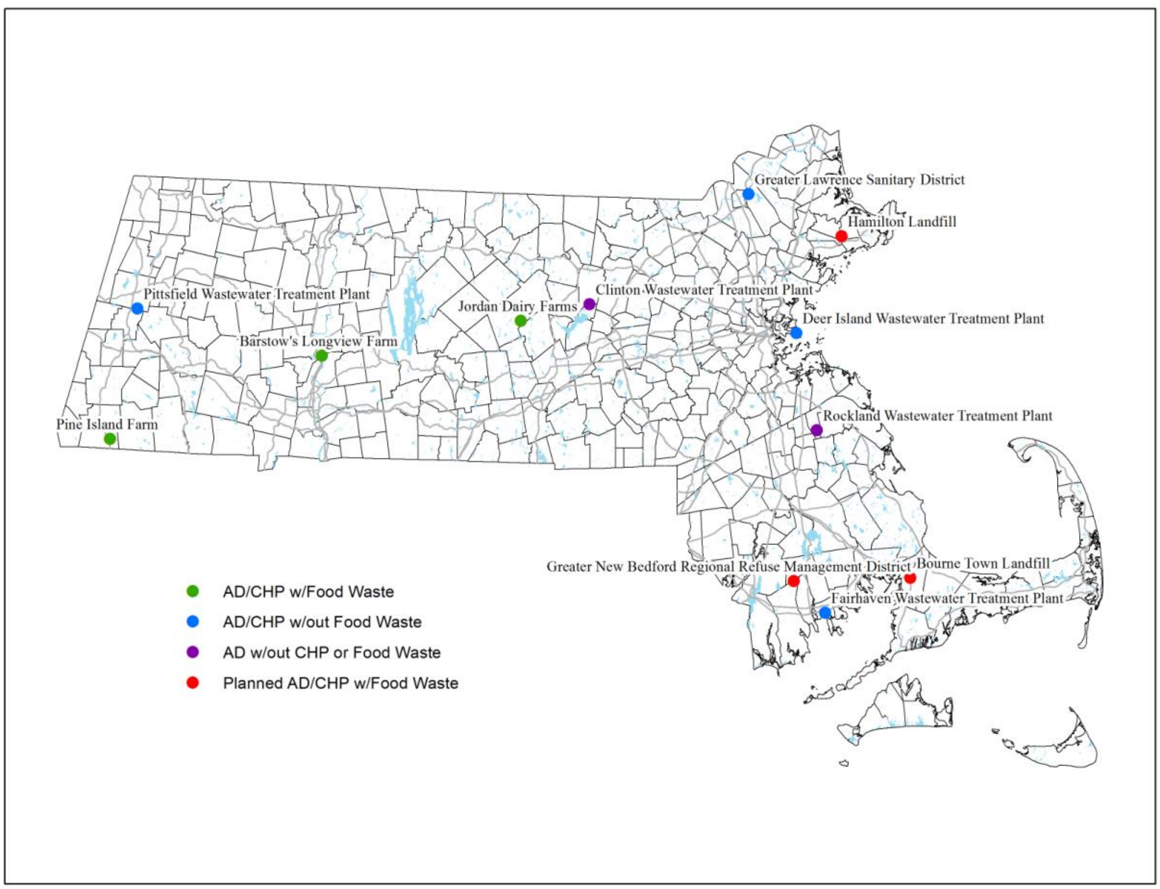
In order to meet its goal of decreasing solid waste disposal of organic materials by an additional 350,000 tons per year by 2020, the Commonwealth of Massachusetts is putting in place a comprehensive strategy, including a commercial food waste ban with an effective date of October 1, 2014. The ban will require businesses and institutions that discard at least one ton of organic material per week to divert that material from solid waste disposal. Assistance in complying with the food waste ban is available through Recycling Works. They have issued a food waste estimation guide that includes rough thresholds for which businesses will be affected and ways to estimate more specifically the amount of food waste produced.

Type of Institution	Estimated Threshold
College or University	
Residential	734 students
Non-residential	2,751 students
Secondary School	4,000 students
Hospital	84 beds
Nursing Home	159 beds
Restaurant	70 full-time employees
Event/Venue	476 seats
Supermarket	35 full-time employees
Hotel	301 guest rooms
Correctional Facility	286 inmates

These large institutions will be searching for alternative ways to dispose of food waste, and codigesting it with other feedstocks in anaerobic digesters is a promising method for disposal. The resulting biogas can be a source of electricity as well as heat.

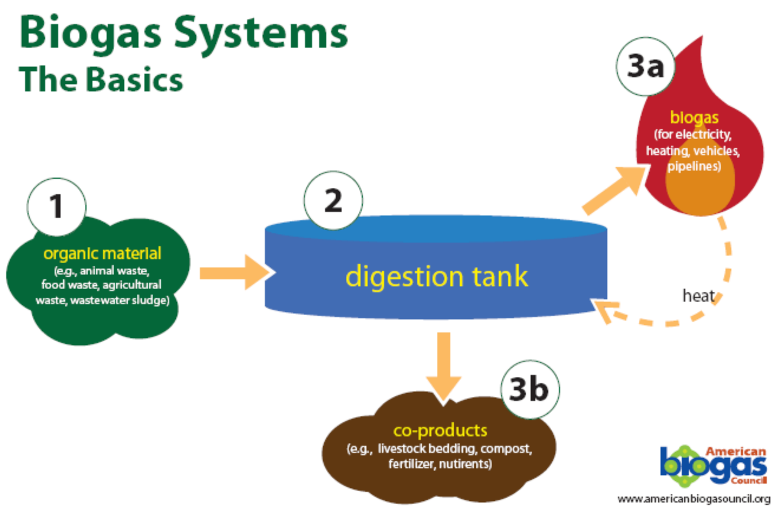
Current Context

Nationwide, anaerobic digestion can be found at more than 1,200 wastewater treatment plants (WWTPs) and 202 farms. Since many municipalities operate their own wastewater treatment plants, such plants represent a significant opportunity for municipalities to begin development of AD/CHP facilities. However, of the 133 wastewater treatment plants in Massachusetts, only six have anaerobic digesters, and only four of those use the biogas produced for more than heating the digestion tanks. Three farms in Massachusetts codigest food waste and use the biogas produced to generate heat and electricity: Jordan Dairy Farm (Rutland), Barstow's Longview Farm (Hadley), and Pine Island Farm (Sheffield). Active or inactive landfills are also potential locations for AD/CHP facilities. A digester is under construction at the Greater New Bedford Regional Refuse District's landfill, the biogas from which will feed into the existing landfill gas-to-energy facility. In Bourne, land adjacent to the active landfill is being leased to a private entity for AD development, and the Hamilton landfill is seeking a private entity to develop a digester on its closed landfill. The Commonwealth of Massachusetts is encouraging development of AD/CHP facilities by offering financial and technical assistance for both public and private entities.



Anaerobic Digestion

Anaerobic digestion is the process of breaking down organic waste through the use of naturally occurring bacteria in an environment without oxygen. It is similar to composting; however, with anaerobic digestion the material is contained within an air-tight vessel and the time required is lessened to about a month. The products of anaerobic digestion are biogas, digestate, and water. The biogas mostly consists of methane and carbon dioxide, with some hydrogen, hydrogen sulfide, and nitrogen. Digestate is a solid or liquid that can be used as fertilizer, soil conditioner, cattle bedding, or even fuel.



Anaerobic digestion is a four-stage process, sometimes all occurring within one container, sometimes in separate containers, with different bacteria instrumental to each stage.

Hydrolysis Output	Acidogenesis Output	Acetogenesis Output	Methanogenesis Output
• Sugars • Amino acids	• Organic acids • Carbon dioxide • Hydrogen • Ammonia	• Acetic acid • Carbon dioxide • Hydrogen • Ammonia	• Methane • Carbon dioxide

Combined Heat and Power

The biogas produced by anaerobic digestion can be used as fuel to heat anaerobic digestion tanks, dewater sludge, or heat the entire facility. With the use of an engine or turbine, biogas can also be used to generate electricity. When both head and power are generated by the same system, it's referred to as combined heat and power or cogeneration. Biogas can also be further purified into natural gas, compressed natural gas (CNG), or liquefied natural gas (LNG). Many AD facilities currently flare (burn) their methane rather than generate electricity.

Benefits

AD/CHP can turn a cost into a benefit. Possible advantages for municipalities include the following:

- Generates renewable energy to offset purchase of utility energy
- Provides a recycling alternative for food waste
- Reduces volume of organic matter
- Reduces odors
- Produces fertilizer and/or soil amendment
- Generates revenue from tipping fees

Considerations

Feedstock

Many AD facilities only process one type of waste, but codigestion of multiple feedstocks together can help to balance the carbon/nitrogen ratio and increase the biogas output up to three times. Food waste in particular has a high energy content. However, adding food waste (a "dry" feedstock) to sludge (a "wet" feedstock) requires pretreatment and equipment modification. Possible feedstocks include:

- Wastewater sludge
- Cattle manure
- Food manufacturing residues
- Pre- or post-consumer food waste

Siting

To balance the energy used for transportation, facilities should be within 30 miles of their feedstocks, or less, depending on the type of feedstock (Hohn, 2013; Dagnall, 2000; Dagnall, 1995). Ideally, at least half of the feedstock would be located on site, since a reliable source of feedstock is required in order to secure private funding. Although smaller systems exist, most AD/CHP systems have a footprint of four acres or more. Potential sites include:

- **Municipally owned**
  - Wastewater Treatment Plants
  - Active or Closed Landfills
- **Privately owned**
  - Dairy/Pig Farms
  - Food Manufacturing Facilities
  - Supermarket Distribution Facilities
  - Industrially Zoned Land

Public Opinion

Concerns about AD/CHP facilities primarily are heard from residents who live nearby or along roads used to access the facility. For that reason, siting facilities away from residential areas and minor roads can be important. Public education is also an essential component of AD/CHP development. Technology used decades ago has left images in the public consciousness of a smelly operation. Modern AD/CHP technology has much more in common with a light or medium industrial facility than a solid waste dump.

Concern	How to Address
Odor	• Educate about improvements in technology • Use enclosed buildings and proper air handling for organics receiving • Locate away from residential areas
Traffic	• Identify amount of traffic increase early in the process (number of trucks, frequency, etc.) • Locate away from residential areas • Locate near major roads
Noise	• Proper planning and design to minimize offsite audibility of operations
Hours of Operation	• Locate away from residential areas • Locate near major roads
Safety	• Use tried and tested technology from natural gas transportation

Types of Digesters

Wet/Dry

Anaerobic digestion is considered either wet or dry depending on the amount of solids in the feedstock and whether it is easily pumped. There is some variation in the categorization of the makeup of wet and dry feedstocks, but generally less than 20% solids is considered wet and more than 20% solids is considered dry. Animal manure, wastewater sludge, and food manufacturing waste are wet, while table scraps and yard waste are dry. Different equipment and methods are required for wet and dry anaerobic digestion. Thus, facilities already conducting wet anaerobic digestion generally will require that food waste first be pretreated (screened, ground, and slurried), either onsite or offsite, prior to introduction into the digester. Because dry material containing lignin is more difficult for the bacteria to break down, yard wastes are not generally compatible with wet digestion systems. However, yard wastes and the digestate from a wet digester can be compatible ingredients when making compost.

Batch/Continuous

- **Batch digesters** are the simplest and least expensive option. In these, the feedstock is fed once into the digester and left alone until it is processed. Gas production fluctuates during this time, depending on what stage in the process it is at. Since methane can react explosively with oxygen, with batch digesters the methane must be completely purged from the digester before opening the container. Most facilities with batch digesters do not do cogeneration and flare (burn) the methane to prevent it from escaping into the atmosphere.

- **Continuously fed digesters** require removal of finished digestate and gas and addition of new feedstock regularly, so that the gas production is constant. There are single-stage and multi-stage continuously fed digesters, in which the steps of the process take place either in just one container or in a separate container for each step.

- **Covered lagoons** and tubular (or fixed dome) digesters are not considered appropriate for the colder temperatures in Massachusetts.

Mesophilic/Thermophilic

- **Mesophilic** systems run at a lower temperature (35° C). Because of this, less energy is required to run them and the bacteria levels are generally more stable, although processing time is longer.
- **Thermophilic** systems run at a higher temperature (55° C). There is some suggestion that thermophilic digesters are a better choice for dry feedstock, such as food waste.

Types of Generators

There are three main types of technology used to generate electricity at anaerobic digesters: microturbines, fuel cells, and internal combustion engines. Decisions about what type of electric generator to use are based on size and cost. According to MassDEP, microturbines are appropriate for smaller facilities, such as wastewater treatment plants processing less than 6.8 million gallons per day (MGD). Minimum flow for fuel cells is 10.7 MGD, and for internal combustion engines 41.4 MGD. Estimated cost to purchase generators is $4,484 per KW for microturbines, $7,426 per kW for fuel cells, and $2,039 per kW for internal combustion.

Financial and Technical Assistance

Capital costs for AD/CHP facilities are large, and in the wastewater realm combined sewer overflow replacement is taking precedence. However, grant funding is available for audits, feasibility studies, and facility design (more is available for rural and agricultural use). Public-private partnerships can be a cost-effective alternative to municipal ownership. Opportunities for outside assistance include:

- MAPC Direct Local Technical Assistance
- MassCEC Commonwealth Organics-to-Energy
- DOER Green Communities
- MassDEP Sustainable Materials Recovery Program

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