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Feasibility Study for Siting Anaerobic Digestion Facility at UMass Amherst Campus

CDM Smith

Massachusetts Department of Environmental Protection

DRAFT
REPORT FOR
PUBLIC
COMMENT

Feasibility Study for Siting Anaerobic Digestion Facility at University of Massachusetts – Amherst Campus

Massachusetts Department of Environmental Protection

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CDM Smith

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Section 1

Introduction

1.1 Introduction

The Massachusetts Department of Environmental Protection (MassDEP) has announced plans to impose a ban on commercially-generated source-separated organic (SSO) materials, with the goal of diverting an additional 350,000 tons per year of SSO materials by 2020. The draft regulations for this waste ban have been out to public comment with the proposed ban scheduled to be promulgated on July 1, 2014. The draft version of the regulations requires generators of over one ton per week of SSO materials week to donate or re-purpose the useable food materials. Any remaining food waste would be required to be shipped to an Anaerobic Digestion (AD) facility, a composting operation or an animal-feed operation. Residential food waste is not currently included in the proposed ban.

The diversion of SSO materials requires an infrastructure of facilities capable of accepting them separate from the current solid waste disposal infrastructure that primarily relies on waste-to-energy and landfills in Massachusetts. MassDEP has identified certain "conversion" technologies including "… aerobic and anaerobic or enzymatic, thermal or chemical degradation of organic materials" in the Site Assignment Regulations for Solid Waste Facilities (310 CMR 16.00) that are appropriate to accept the banned SSO materials and generate electricity as well as a potentially reusable organic product that can be added to a composting operation. Revisions to the Site Assignment regulations and the associated Solid Waste Management Regulations (310 CMR 19.000) promulgated in November 2012 established a specific regulatory approval process for these conversion facilities. In addition to the regulatory changes, the Commonwealth has made several financial incentives in the form of grants and low-interest loans to private and public entities to assist in the development of the required facilities. Potential developers of AD facilities should review information on these incentives from both the MassDEP and Massachusetts Clear Energy Center (MassCEC).

As a result of the proposed ban and the revisions to the MassDEP permitting regulations, there has been substantial interest from both public entities and private companies in the development of conversion facilities throughout the Commonwealth. Several feasibility studies are currently being completed to determine (1) the ability of existing wastewater treatment facilities to incorporate co-digestion and co-generation into their treatment process and (2) the feasibility of development of new facilities specifically designed for the digestion of organic wastes. As part of this initiative, the Commonwealth has preliminarily identified three potential locations on state-owned property where anaerobic digestion (AD) facilities could be sited and operated to accept locally-generated SSO materials.

This report is an evaluation of the feasibility of siting an AD facility at a site on the University of Massachusetts (UMass) Amherst campus adjacent to the Town of Amherst's Water Pollution Control Facility (WPCF). The AD facility would accept SSO materials from the University as well as other local generators and biosolids from the Amherst WPCF and other similar local WPCF's.

This work is being completed under MassDEP's Site Assessment Remediation Support Services (SARSS) V Contract as Project Number 010623. The Task Order approved by MassDEP for this work includes all of the information provided as part of this report.

1.2 Feasibility Study Organization

The issues to be addressed and organization of feasibility study are as follows:

- Section 1: Introduction
- Section 2: Assessment of Proposed Site
- Section 3: Potential Organic Materials Quantities and Characteristics
- Section 4: Conceptual Organics Processing Facilities
- Section 5: Project Pro Forma Financial Analysis
- Section 6: Conclusions

The purpose of this study is to assist MassDEP and the Massachusetts Division of Capital Asset Management and Maintenance (DCAMM) in determining if the proposed UMass site can support a commercial-scale AD facility. It will also provide a specific outline of the permitting and other information that is required to be included in a Request for Proposals (RFP) to lease the site to a private developer for development of an AD facility.

Section 2

Assessment of Proposed Site

The following section summarizes CDM Smith's investigations into the proposed location for an anaerobic digestion (AD) facility on the western portion of the UMass Amherst campus. Based on initial discussions with MassDEP and UMass, a site location was identified to the west of Mullins Way and north of North Hadley Road. The general site vicinity, shown on Figure 2-1, is located in the Town of Hadley (note that Figure 2-1 includes the Amherst WPCF that is not part of the proposed operation). The proposed site is owned by the Commonwealth of Massachusetts.

As part of these initial investigations, CDM Smith reviewed existing information available from public sources and provided by other parties including UMass and the Town of Amherst to develop a summary of environmental or other site conditions that may limit the use of the proposed site or require potentially challenging permitting obligations. The results of this investigation are summarized below.

2.1 Site Summary

CDM Smith visited the proposed site to evaluate its feasibility as well as collected existing condition information from UMass on site topography, approximate property lines, location of utilities, site structures, and roadways/parking areas. A site plan showing general information on the site is provided as Figure 2-2.

The proposed site is currently largely unused with only a small UMass-related geotechnical laboratory on-site. Based on information provided by UMass, this laboratory will be discontinued in the near future. There is an existing site driveway entrance off Mullins Way that would be an appropriate access point for the AD facility. There is a fence to the north that encircles the Amherst WPCF. Much of the site is vegetated with grass, with some trees and shrubs located along the site's western and southern extents. As discussed below, these areas are associated with a wetland resource area.

Surrounding site uses include UMass recreational fields to the east, Route 116 and agricultural properties to the west, the Amherst WPCF and other town facilities as well as the UMass Combined Heat and Power (CHP) facility to the north, and parking areas and other recreational fields to the south.

UMass also provided CDM Smith with a copy of the University's development Master Plan[1] which was reviewed to determine any future plans that may conflict with the proposed AD facility development. There are no development plans shown in the Master Plan for the proposed site. The only potential impact is a long-term plan to extend Mullins Way to the north to connect to other UMass roadways and provide direct access to the Mullins Center. Based on conversations with UMass, there is currently no schedule for this project.

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[1] "UMass Amherst Campus Master Plan," prepared by UMass Amherst Campus Planning Department, dated April 2012.

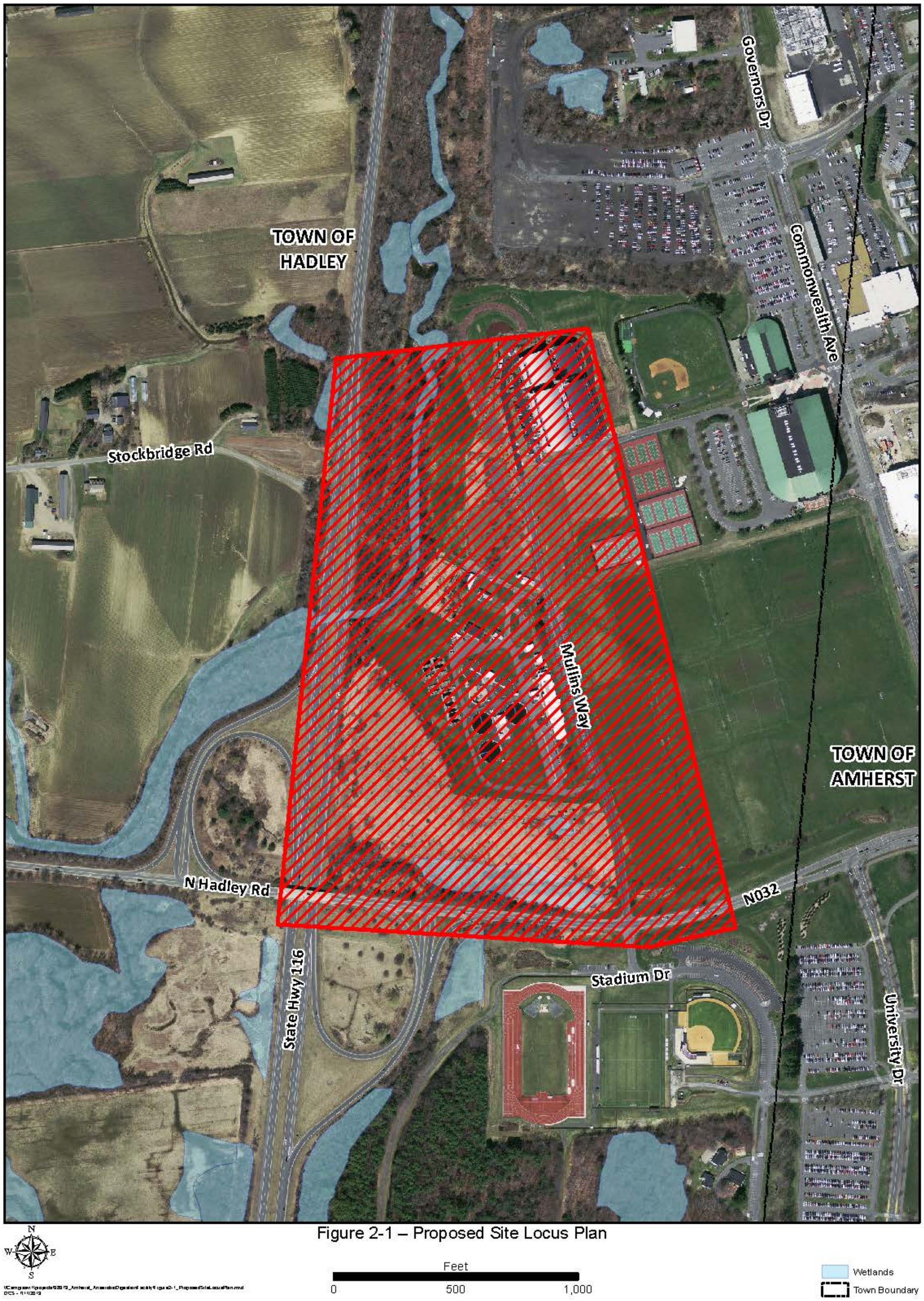
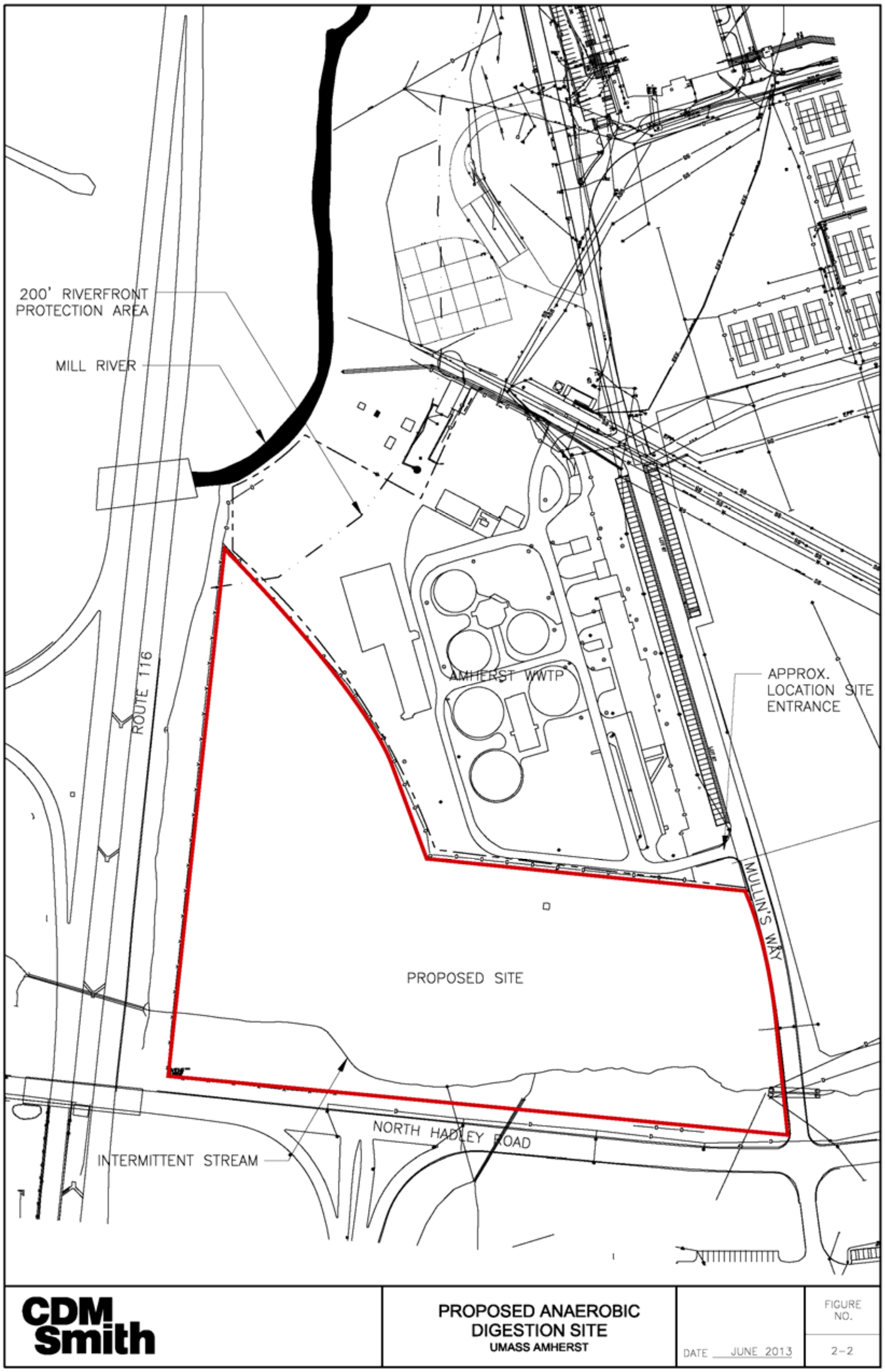


Figure 2-1 – Proposed Site Locus Plan


200' RIVERFRONT PROTECTION AREA
MILL RIVER
ROUTE 116
AMHERST WWTP
APPROX. LOCATION SITE ENTRANCE
MULLIN'S WAY
PROPOSED SITE
NORTH HADLEY ROAD
INTERMITTENT STREAM
CDM Smith
PROPOSED ANAEROBIC DIGESTION SITE
UMASS AMHERST
DATE JUNE 2013
FIGURE NO.
2-2

2.2 Existing Site Conditions

CDM Smith utilized available information from both the Massachusetts Geographic Information Service (MassGIS) and other sources. The intent of this collection is to determine if there are any significant environmental restrictions on the development of the site as well as develop a preliminary outline of site conditions and potential permitting requirements.

2.2.1 Proximity of Site to Human and Environmental Receptors

Figure 2-3 is a figure showing an approximate half-mile radius around the proposed site location. As shown on this plan, there is an on-site wetlands system noticeable as shrubs and trees adjacent to North Hadley Road located along the southern edge of the site and the Mill River crosses the site to the northwest of the Amherst WPCF. There are a series of recreational fields located to the east and south of the site with the closest residence located being the new Honors Dormitories being constructed to the east approximately 1,200 feet. A site locus plan showing approximately 1.5-mile radius around the proposed site is shown on Figure 2-4. This plan indicates that there is a delineated Zone II for a public water supply whose edge is approximately 2,500 feet southwest of the site; and a single vernal pool mapped approximately 1,700 feet to the northwest.

Based on a review of the available mapping, there are no sensitive human or environmental receptors currently located on the proposed site and there are adequate buffers to all identified surrounding site uses and environmental receptors. As detailed below, there is a large wetland system located on the southern portion of the site that requires further evaluation.

Table 2-1
Summary of Site Permitting Considerations

Siting Consideration	Specific Criteria	Exist On-Site?	Exist Nearby?	Distance
Proximity to Sensitive Human Receptors	Homes/Residences	No	Yes	1,200 feet
	Schools	No	Yes (UMass)	1,200 feet
	Assisted-living and daycare facilities, senior or youth centers	None identified	None identified except UMass	N/A
	Abutting private land uses including zoning of nearby properties	Site is zoned Industrial by Hadley	Land uses to east are all related to UMass	N/A
	Agricultural property	No	Yes	700 feet to west
	Airports	No	No	N/A
Proximity to Environmental Resources	Wetland resource areas	Yes	Yes	On-site
	Vernal pools,	No	Yes	N/A
	NHESP[2] habitat	No	No	N/A
	Floodplains	No	Yes	Mill River
	Designated Wildlife Management Areas	No	No	N/A
	Protected drinking water supply areas	No	Yes	Edge of Zone II located 2,500 feet to southwest
	Areas of Critical Environmental Concern (ACEC)	No	No	N/A
	Designated open space	No	No	N/A

[2]NHESP: Natural Heritage and Endangered Species Program

Figure 2-3 – Proposed AD Facility Site
Half-Mile Radius Sensitive Resource Plan

Feet
0 500 1,000

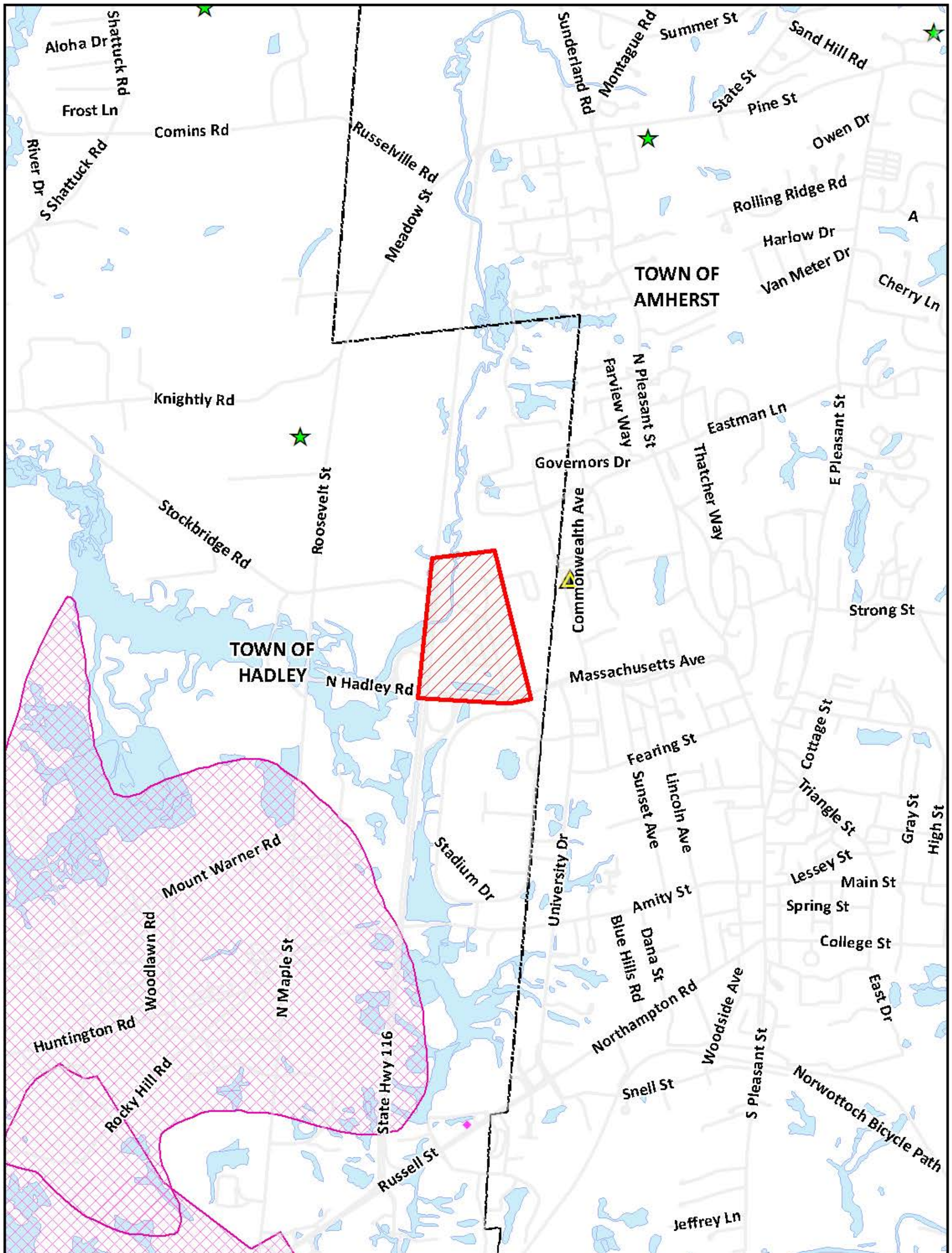


Figure 2-4 – Proposed AD Facility Site
1.5-Mile Radius Sensitive Resource Plan

2.2.2 Other Siting Considerations

In addition to the proximity of the site to various receptors, there are several other considerations that will impact the development of an AD facility at the site. The findings to date for each of these general categories are summarized below.

2.2.2.1 Traffic and Access

During several conversations with UMass facilities staff, a potential concern with additional truck trips and site access routes were presented and discussed. Based on these discussions, it is clear that the proposed facility will have to insure that the materials are delivered in appropriate sealed containers, that an established route for shipping and receiving off-site materials be established and enforced during operations and that the number of additional trucks associated with the facility is minimized.

Access to the proposed site will likely use an existing driveway off Mullins Way. Mullins Way is currently a peripheral road in the UMass system that provides access to the Central Heating Plant, as well as the Mullins Center Lower Level service entrance, parking lot and recreational fields. UMass provided CDM Smith information on the current vehicle trips (trucks and cars) during peak morning and afternoon hours. The data provided did not count trips during the morning peak hour but did have afternoon peak hour traffic counts from March 2012 that showed 560 vehicles heading west by the Mullins Way intersection and 300 vehicles heading east. A total of 26 vehicles were observed leaving Mullins Way during the peak hour with eight vehicles entering the roadway. Based on the initial site visit by CDM Smith, there appear to be adequate site lines and visibility for traffic turning onto Mullins Way from North Hadley Road or vice versa. CDM Smith notes that both the Amherst WPCF and the UMass CHP facility are currently accessed by 18-wheeled truck vehicles that are similar to the largest trucks that potentially would access the AD facility.

2.2.2.2 Aesthetics

The clearest views into the proposed site are from the UMass campus including the associated fields located to the east of the site. There are also some views from North Hadley Road to the south and Route 116 to the west that are currently substantially obscured by vegetation.

CDM Smith notes that the other facilities in proximity of the site, the UMass Combined Heat and Power (CHP) facility and the Amherst WPCF both have significant architectural features incorporated based on their existence with direct views from the UMass campus. It is assumed that proposed AD facility will also incorporate architectural features for similar aesthetics and views from both UMass and the public roadways.

2.2.2.3 Available Area and Topography

On a preliminary basis, CDM Smith assumes that an AD facility of the size to be commercially viable and operate efficiently will require between 4 and 6 acres of flat developable land. Based on the site walk and the existing topographic survey information, an adequate area exists at the site for the AD facility. CDM Smith notes that on-site processing of solid residuals in an operation such as enhanced composting with windrows might require more area than is available considering existing wetland resource areas and their associated buffer zones. A preliminary assessment is that there is approximately eight acres of developable land on the proposed site. As discussed below, the available area will need to be confirmed with a final delineation of on-site wetland resource areas and visual buffers.

The proposed site is generally flat with gentle slopes to the perimeters. Any future development on this site will need to incorporate additional stormwater controls to mitigate peak run-off as well as treat stormwater before it is discharged into the surrounding wetland system.

2.2.3.3 Proximity to Utilities

The proposed site has local access to several of the key utilities necessary for the successful development of a large-scale AD facility. These include users of the generated gas, electricity and any excess heat, generation of biosolids suitable for digestion, availability of water that may be required to be added to the digestion process, and a facility to potentially accept the dewatered digestate.

CDM Smith met with the operator of the UMass CHP facility and the Amherst WPCF to discuss their facilities as well as their ability to be integrated into the operations of a new AD facility. The following is a summary of these discussions.

2.2.3.3.1 Amherst WPCF

The Amherst WPCF located directly to the north of the Site is operated by the Town of Amherst. The WPCF treats wastewater from both the Town of Amherst and the UMass campus.

The Amherst WPCF, located approximately 200 feet from the Site,can potentially provide multiple ways to be integrated into the proposed AD facility. The WPCF can potentially utilize the electricity generated by the AD facility, it generates a biosolids stream that could be utilized as a feedstock, and it can receive appropriately pretreated dewatered sidestream (filtrate or centrate) for disposal. The following is a summary of each of these potential items:

- ***Use of generated electricity -*** CDM Smith was provided a summary table of the WPCF's electrical usage from May 2011 through September 2012. Based on this table, the WPCF use varied from a low of approximately 2,300 kWh per day during the summer months to a peak of approximately 3,800 kWh per day during the fall. It is anticipated that the variation is based on the influent flows that increase from an average of 2.5 MGD to 3.5 MGD when the colleges are in session. Electrical generation from the proposed AD facility will exceed this amount and require connection to another off-site user.

- ***Generation of biosolids -*** *T*he Amherst WPCF currently disposes of their biosolids at the Upper Blackstone Water Pollution Abatement District incinerator facility in Millbury, Massachusetts. As a back up, they dispose of biosolids at an incineration facility in Cromwell, Connecticut. The WPCF generates an estimated 15,400 tons per year at an average of 6.5% solids (approximately 1,000 dry tons per year). The Town pays approximately $500 per dry ton for disposal of biosolids with a price adjustment tied to the cost of diesel fuel.

- ***Acceptance of water from digestate -*** As discussed in Section 1, there will likely be a liquid side stream from the digestion process that will require treatment and disposal. This liquid side stream will have elevated concentrations of ammonia that could be between 1,000 and 2,000 mg/l.

  Most WPCF's including the Amherst facility, have an effluent limit on their discharge for nitrogen-containing compounds, including ammonia. Currently, the concentration of ammonia in the influent to the Amherst WPCF is between 30 and 35 mg/l so the direct discharge of any untreated side stream from the AD facility to the Amherst WPCF would have a significant impact on its operations. Therefore, for the purposes of this feasibility study, CDM Smith has assumed that the AD facility will incorporate an on-site pretreatment facility that which remove ammonia to a lower concentration similar to the current Amherst WPCF influent.

CDM Smith also notes that the Town of Amherst does not currently have an Industrial Pretreatment Program (IPP) that provides regulations and guidelines for the discharge of flows from sources such as the AD facility into the WPCF. Assuming that an agreement could be reached to accept the liquid side stream, The Town would prefer to have a direct agreement with the AD facility operator that outlines the discharge into their WPCF and not have to take on the administrative burden of implementing an IPP. CDM Smith also notes that the headworks for the WPCF are located on the northern portion of the plant away from the AD facility.

The Amherst WPCF currently provides treated effluent that is utilized by UMass in their steam facilities after further treatment. Effluent from the Amherst WPCF could also be utilized as incoming waste dilution water in lieu of utilizing potable water.

Finally, the Town of Amherst is undergoing planning for potential upgrades to the WPCF in response to anticipated permit changes from regulatory agencies as well as exploring additional ways to re-use their effluent. This planning process is ongoing and the results of it should be incorporated into the procurement documents for the AD facility.

2.2.3.3.2 UMass CHP Facility

The UMass CHP facility located approximately 1,200 feet to the north of the proposed site became operational in 2007 and currently provides all of the steam needs and approximately 80% of the electrical needs of the campus. The CHP facility utilizes natural gas from both a pipeline and a 25,000 gallon liquefied natural gas (LNG) storage tank fed by three to four trucks per day as fuel. The LNG facility was necessitated by the capacity limitations of the existing pipeline as well as a desire to limit the use of No. 2 fuel oil.

The total peak campus electrical load is currently 26.5 MW with a future peak of 42 MW when new buildings currently being planned or under construction come on-line by 2017. The blended electrical rate counting both on-site generation and purchases from Western Massachusetts Electric Company (WMECO) is $0.07 to $0.08 per kWh. Electricity from WMECO is purchased at an average cost of $0.14 per kWh.

The CHP facility could potentially use either the biogas or electricity generated by the AD facility. Based on discussions with the operator, the biogas would have to be cleaned up with the removal of hydrogen sulfide and siloxanes to a level so as not to damage existing facility boilers. Another issue is that the biogas would have a substantially lower heating value (approximately 600 BTU/ft^3) compared to natural gas (approximately 1,000 BTU/ft3) and may require changes to existing or new dedicated equipment.

The CHP facility and associated electrical distribution system could also incorporate electrical power generated by the AD facility. Preliminary discussions indicate that the AD facility could net generate approximately 1 MW of power which would be approximately 5% of the future peak power needs of the UMass campus.

2.2.3.4 Construction Considerations

As discussed in the presentation on wetlands below, the proposed site has received a substantial amount of fill to the existing grades. CDM Smith was not able to determine the source or geotechnical quality of the fill materials as part of this feasibility study.

However, UMass provided geotechnical cross-sections in the vicinity of the proposed site that showed deep (greater than 50 feet in thickness) natural clay deposits. CDM Smith's design of the Amherst WPCF required over excavation of the existing soils (note that the Amherst WPCF is several feet in elevation below the proposed AD facility site) and backfill with compacted structural fill.

Additional information needs to be developed for potential AD facility developers as to the existing geotechnical conditions including a subsurface boring program suitable for the private companies to determine the foundation needs of any structures and underground utilities.

2.2.3.5 Local Permitting Requirements

According to the Town of Hadley's zoning map, the proposed site is zoned in an Industrial District. Based on discussions with the State, the proposed project is not subject to local bylaws such as the Town of Hadley's zoning regulations. However, based on discussions with MassDEP, the AD facility developer will be asked to comply with the general requirements of the town's bylaw to the extent possible.

In Hadley's zoning bylaw, industrial uses include "Any manufacturing or industrial use, including processing, fabrication and assembly, provided that no such use shall be permitted which would be detrimental or offensive or tend to reduce property values in the same or adjoining districts by reasons of dirt, odor, fumes, gas, sewage, refuse, noise, excessive vibration or danger of explosion or fire." With the appropriate design controls, the proposed AD facility will be able to meet these general requirements.

2.2.3.6 Wetland Resource Areas

Based on the conclusions from regional mapping that there was a significant wetland resource area located along the southern portion of the proposed site, a CDM Smith wetland scientist visited the site on May 20, 2013 to conduct a preliminary site inspection. The purpose of the site visit was to identify the presence or absence of wetland resources on the parcel and determine their approximate boundaries.

Based on this initial visit and the collection of additional information on wetland resource areas around the proposed site, CDM Smith concludes the following:

- Prior to conducting the site inspection, CDM Smith reviewed aerial images of the parcel and the current USGS Quadrangle for the project area. A stream or drainage ditch was noted along the south margin of the parcel north of North Hadley Road. This channel appears to be a drainage channel and no flowing water was observed in the channel at the time of the inspection. This was determined to be a channel that conveys intermittent flow, i.e. not a perennial stream, and thus it is not subject to protect as a river pursuant to the River Protection Act (see photography Figure 2-5).

Figure 2-5
View of Dry Drainage Ditch North of North Hadley Road

- There are on-site wetlands bordering the ditch, regulated as Bordering Vegetated Wetland (BVW), this means there is a 100-foot buffer extending landward from the BVW boundary.
- The site was altered in the past leaving a wide transition zone, i.e. mixed wetland and upland characteristics, landward of the BVW. The drainage ditch is located in a valley approximately six to ten feet lower than the majority of the site. We observed a zone of saturated soils and wetland vegetation adjacent to the ditch, on a narrow plateau adjacent to the ditch and extending up the slope. The extent of saturated soils was observed to be approximately 25 to 50 feet north of the ditch. Beyond this limit no signs of wetland hydrology were observed, even though there was a mix of wetland and upland plant species and soils exhibit hydric characteristics.
- Detailed on-site fieldwork is recommended to determine the wetland-upland boundary.

Following the site inspection, CDM Smith examined the 1945 and current topographic survey supplied by UMass for this site. The comparison found that the site and vicinity has been significantly altered including relocation of Route 116 including a new cloverleaf and North Hadley Road, relocating the Mill River around the cloverleaf interchange, construction of the Amherst WPCF, removing portions of the old North Hadley Road, and significant changes of site topography. As depicted on the current topographic survey, the parcel is elevated above the Amherst WPCF, and the drainage ditch. Therefore, hydric (wetland) soils are not expected to be present on this elevated landform because water should drain off the parcel to the north, south and west. Presence of hyrdic soils on this rise may be observed because either soils were placed there during roadway or WPCF construction, or relocation of the Mill River; or the site was previously a wetland and these are now remnant hydric soils. In either case, CDM Smith recommends that the limit of wetland hydrology be utilized as the primary factor to delineate the limit of wetland along the ditches to the south and west.

Given the extent of on-site wetland resource areas and their associated buffer zones, the procurement documents for the AD facility should include a full wetland delineation.An Abbreviated

Notice of Resource Area Delineation (ANRAD) be submitted to the Town of Hadley Conservation Commission for review and approval to confirm the delineated wetlands.

2.3 Summary of Site Considerations

Based on the information collected by CDM Smith to evaluate the proposed site on the UMass campus, our findings can be summarized as follows:

- The proposed site is adequate in size and has no significant technical constraints that would limit the permitting and construction of an appropriately sized AD facility.
- Additional investigations beyond the scope of this feasibility study need to be completed and incorporated into the procurement documents for the private development of an AD facility at the UMass site. These investigations include:
  - Delineation of wetland resource areas on-site and filing and approval of an ANRAD with the Hadley Conservation Commission;
  - Installation of subsurface borings sufficient to characterize subsurface geotechnical conditions so that potential proposers can determine the required foundation requirements for any structures; and
  - Any information on the source of the fill currently on-site and a determination if the soil needs to be characterized per MassDEP regulations prior to construction.
- Traffic and site access will be significant considerations for the AD facility operator. The RFP needs to incorporate truck routes that limit access to Route 116 to North Hadley Road to Mullins Way. The number of trucks and time of deliveries need to be carefully evaluated and determined.
- Because the proposed site is directly visible from the UMass campus, the AD facility will have to include architectural and landscaping treatments compatible with the Amherst WPCF and the UMass CHP facility as well as the UMass campus. These treatments will add cost to the facility compared to the minimum operational components that have been utilized at similar operations.
- Subsequent evaluation needs to be completed on the liquid sidestream from the AD facility to determine if it can be treated directly at the Amherst WPCF (and at what cost) and/or the requirements for treatment by the AD facility operator prior to being discharged to the WPCF.

Section 3

Potential Organic Materials Quantities and Characteristics

3.1 Introduction

The financial viability and environmental benefits of the proposed AD facility will be partially determined based on the availability and adequate supply of appropriate feedstocks. The quantity and type of feedstocks will also control the type and number of trucks that will potentially enter the AD facility site. Initial discussions with MassDEP focused on two potential types of organic materials to feed the proposed AD facility – (1) biosolids from local wastewater treatment facilities and (2) source separated organic (SSO) materials from local sources including UMass. This section summarizes the process undertaken by CDM Smith and results of the evaluation of the feedstock sources available in the vicinity of the UMass-Amherst site.

3.2 MassDEP Proposed Ban on Organics Disposal

The 2010-2020 Massachusetts Solid Waste Master Plan (Master Plan) prepared by MassDEP proposes a goal of reducing the quantity of waste disposed of in the Commonwealth by an additional 30% by 2020. To accomplish this goal, the Master Plan proposes adoption of a number of strategies for increasing the diversion of organic material from the solid waste stream. Among the alternatives for handling the diverted organics is utilization of AD facilities for the disposal of SSO materials that are currently disposed of either in a landfill or waste-to-energy facility. This initiative is creating a significant amount of interest in the use of existing digesters at wastewater treatment facilities (WWTF) for co-digestion and encouraging the development of new organics digestion facilities at sites such as the UMass-Amherst location.

Based on information provided in the Master Plan, private-sector solid waste transporters and disposal companies (referred to herein as "haulers") currently direct approximately 100,000 tons per year of SSO materials to organics processing facilities in Massachusetts. There are approximately two dozen such facilities currently operating, typically as a small-scale composting facility. MassDEP estimated that approximately 400 businesses and institutions are currently diverting organic wastes to disposal facilities. Typical SSO material generators include supermarkets, larger restaurants, colleges or universities, or food producers.

Over the past two years, MassDEP has led a public process through various task forces and advisory committees to develop a clear pathway for the permitting of AD facilities that can accept SSO materials – either at wastewater treatment plants or standalone. These efforts culminated in the promulgation of revised Solid Waste Management (310 CMR 19.000) and Site Assignment (310 CMR 16.00) regulations in November 2012.

In July 2013, MassDEP published draft revisions to section 310 CMR 19.017 of the Solid Waste Management Regulations that propose to ban from disposal in landfills and waste-to-energy facilities

SSO from non-residential entities that generate greater than one ton or more per week. It is anticipated that approximately 1,700 entities (including the UMass-Amherst campus) will be required to separate their SSO materials prior to their remaining solid waste being taken to a transfer station, landfill or waste-to-energy plant for disposal. Note that MassDEP estimates that 1,000 of the 1,700 potentially impacted businesses currently have some form of SSO diversion program currently in-place. Waste bans are enforced through inspections at the solid waste transfer station or disposal facility of select loads and have been historically in-place for a wide variety of recyclable materials including paper, plastics, glass, tires, metals, and leaf and yard waste. The public comment period for the proposed SSO ban closes in August 2013 and MassDEP expects to have the proposed ban on disposal of these SSO materials go into effect in the summer of 2014.

Note that there are certain SSO materials such as high purity fats-oils-grease (FOG) materials that are also collected from restaurants and other food establishments and recycled through an existing system of rendering companies. These high quality wastes are a tradable commodity since they can be used directly in the manufacturing of biodiesel fuels. Since FOG wastes will significantly improve the energy generation from an AD facility, the potential UMass facility should allow for their acceptance if they are available.

3.3 WPCF Biosolids

There are many examples of AD facilities in both Massachusetts and the United States that utilize WPCF biosolids to generate electricity and reduce the volume-requiring disposal. The proposed UMass facility also has the potential to receive biosolids from several surrounding WPCF's and provide a consistent incoming volume to the AD facility.

One potential source of WPCF biosolids is the Amherst WPCF located immediately to the north of the proposed AD site. Based on a site meeting with the operator, the town currently hauls biosolids at an average solids content of 6 to 7% to two locations – incinerators at the Upper Blackstone WPCF in Millbury, Massachusetts and the Mattabasset Regional Sewage Authority's facility in Cromwell, Connecticut. The current average cost for disposal is approximately $500 per dry ton including transportation and disposal with a fuel adjustment clause. Note that it is typical that biosolids from municipal WPCF's in the vicinity of Amherst are transported larger distances to regional disposal facilities.

MassDEP provided CDM Smith with a summary of local WPCF's and their annual volume of biosolids. This information is summarized in Table 3.1 below.

Table 3-1
Summary of Annual Biosolids Generation by Municipal WPCF's Near UMass -Amherst Site

WPCF	Dry Tons Generated Per Year	Approximate Percent Solids of Transported Biosolids	Wet Tons Per Year at Transported Percent Solids	Driving Miles from Proposed Site
Amherst	1,000	6.5%	15,400	0
Hadley	125	4%	3,125	6
Northampton	1,125	20%	5,625	8
Belchertown	95	4%	2,375	13
Hatfield	50	2.5%	2,000	13

Source: MassDEP

3.4 Potential Sources of SSO Materials

3.4.1 State-Wide Sources

MassDEP published a 2002 survey (updated in 2011) titled "Identification, Characterization, and Mapping of Food Waste and Food Waste Generators in Massachusetts" (completed by Draper/Lennon, Inc). The report separated Massachusetts food waste generators into the following categories:

- Manufactures/Processor
- Distributors/Wholesalers
- Hospitals
- Nursing Homes (and related facilities)
- Colleges and Universities
- Independent Preparatory School
- Correctional Facilities
- Resorts/conference facilities
- Supermarkets
- Restaurants

The study also provided a database which included the location and anticipated organic food waste generation in (tons/year) for each source. Though details as to the method of development of estimated quantities can be found in the study, it generally used the methodology shown in Table 3-2. The exception to this is that the producers within the Manufactures/Processor and Distributors/Wholesalers sectors were estimated on a state-wide basis due to the variability between each specific source location.

Table 3-2
Summary of Methodology Used to Determine Quantities of SSO Materials by MassDEP

Generator Sector	Food Waste Generation Estimates by Generator Category
Hospitals	Food waste (lbs/yr) = N of beds * 5.7 meals/bed/day * 0.6 lbs food waste/meal * 365 days/yr
Nursing Homes and Similar Facilities	Food waste (lbs/yr) = N of beds *3.0 meals/bed/day * 0.6 lbs food waste/meal * 365 days/yr
Colleges, Universities, and Independent	*Residential Institutions* Food waste (lbs/yr) = 0.35 lbs/meal * N of students * 405 meals/student/yr
Preparatory Schools Residential Institutions	*Non-Residential Institutions (e.g., community colleges)* Food waste (lbs/yr) = 0.35 lbs/meal * N of students * 108 meals/student/yr
Correctional Facilities	Food waste (lbs/yr) = 1.0 lb/inmate/day * N of inmates * 365 days/yr
Resorts /Conference Properties	Food waste (lbs/yr) = 1.0 lbs/meal * N of meals/seat/day2 * N of seats * 365 days/yr
Supermarkets	Food waste (lbs/year) = N of employees * 3,000 lbs/employee/yr
Restaurants	Food waste (lbs/year) = N of employees * 3,000 lbs/employee/yr

3.4.2 Local College and University Sources

At the start of this study, MassDEP provided CDM Smith with a summary of estimated SSO material volumes generated by UMass and four other local colleges. This information is summarized on Table 3-3.

Table 3-3
Summary of Estimated SSO Materials Generated by Local Colleges/Universities

College/University	Tons SSO Materials Per Year
UMass Amherst	1,200
Amherst College	120
Hampshire College	100
Mt Holyoke College	150
Smith College	220

Source: MassDEP

CDM Smith met with the operator of the UMass-Amherst campus solid waste collection and recycling program to review their current efforts and evaluate the potential for a significant increase in total SSO materials collected. Currently UMass collects food waste from all of their major cafeterias that is transported in "toters" to the central solid waste facility located on the eastern side of the campus. This SSO material is consolidated onto a roll-off container and transported to a regional composting facility where it is mixed with leaf and yard waste. Currently, the tipping disposal fee at the composting facility is $34 per ton. Based on our meeting, CDM Smith believes that most of the readily available SSO materials from campus-controlled facilities is being collected and does not anticipate a significant increase in the quantity of SSO materials collected by the University.

3.4.3 Other Regional and Local Sources

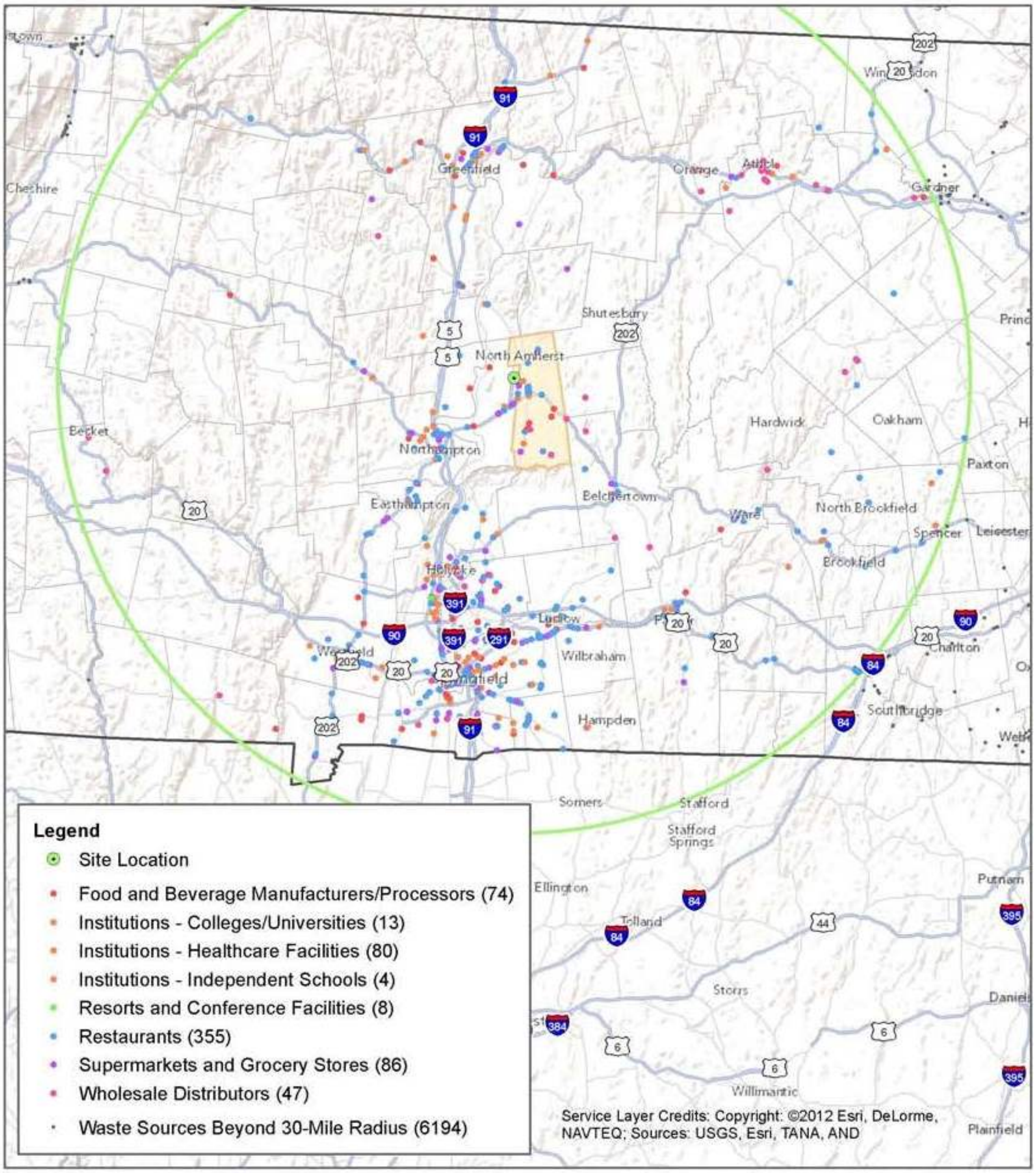
Generally, the feasibility of collection and hauling of waste is evaluated on the basis of a 30-mile radius around the disposal destination. As a starting point for this evaluation, the quantity of anticipated waste in this 30-mile region was extracted from the organic waste survey data generated for MassDEP. The spatial distribution of the anticipated sources in this region is shown on Figure 3-1 while Table 3-4 provides a summary of the distribution of these sources between the various industry sectors. Note that for this analysis, CDM Smith assumed that the SSO materials available through the colleges and universities outlined in Table 3-3 above were not included.

Table 3-4
Regional SSO Materials Source Distribution (Not Including Colleges and Universities)

Institution/Facility Type	Generation (Tons Per Year)
Institutions -Healthcare Facilities	3,300
Institutions -Independent Schools	100
Supermarkets and Grocery Stores	13,500
Restaurants	14,400
Resorts and Conference Facilities	100
Food and Beverage Processors	50,300
Wholesale Distributors	7,000
TOTAL	**88,700**

Note: "Regional" is considered to be within a 30-mile radius of the site. Food and beverage processions and Wholesale Distributors are CDM Smith estimates.

Figure 3-1
Regional Organic Waste Sources within a 30-Mile Radius of Site



3.5 Current Organics Diversion Efforts

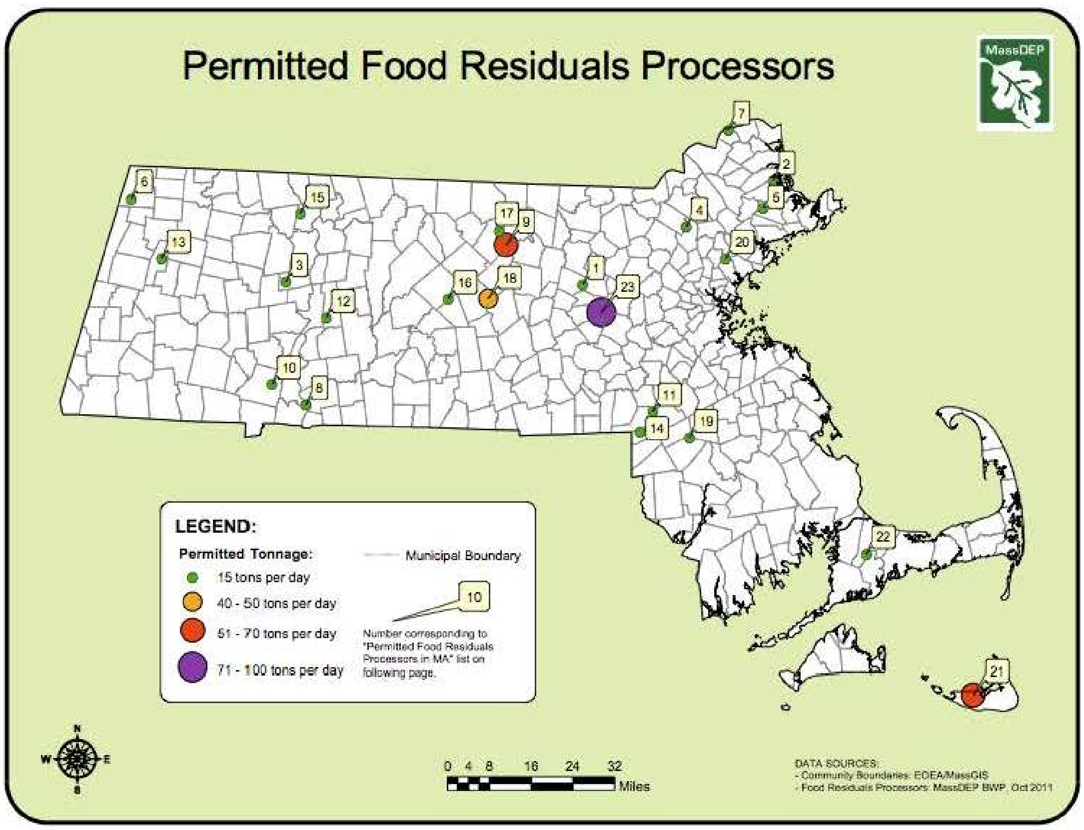
MassDEP estimates that there are approximately 950,000 wet tons of organics currently in the waste stream, and that currently only about 100,000 wet tons of pre-consumer food wastes are being diverted, mostly by supermarkets, institutions, and other large generators. The SSO materials that are currently diverted is managed in any of the following ways:

- Edible food is provided to food banks – this is the highest priority use, if appropriate;

- Animal feed (e.g. at pig farms);
- Commodity processors, such as Baker Commodities (recycles high value grease and oil);
- Anaerobic digestion – a very limited amount is processed in anaerobic digesters at food production facilities or stand-alone commercial operations, such as the Jordan Dairy Farm digester; and
- Composting – at municipal composting sites or the several commercial and/or on-farm composting operations in Massachusetts or in neighboring states. The SSO materials collected by UMass are currently composted.

Figure 3-2 depicts the general location and relative size of the existing permitted food waste processors throughout the Commonwealth. For comparison, the largest of these (located in Marlborough) is currently permitted to accept 100 TPD of waste while the majority of the smaller processors are generally local leaf and yard waste facilities permitted for up to 15 TPD of SSO co-composting. Note that all of the existing SSO facilities located in western Massachusetts near the UMass site are small (less than 15 tons per day).

Figure 3-2



3.6 Summary of Proposed Volumes – SSO Materials and Biosolids

Based on the information developed for the available biosolids and SSO tonnages available in the vicinity of the UMass site, CDM Smith held several discussions with MassDEP and UMass to determine potential alternative tonnage scenarios of available materials that will be evaluated in this assessment. Based on these discussions, two base scenarios were developed based on the following assumptions:

- Biosolids from the Amherst and Hadley biosolids will be accepted at the AD facility since the site is located in Hadley and the Amherst WPCF is a direct abutter;
- The UMass SSO materials are assumed to be accepted at the facility;
- Biosolids from other WPCF's will be limited; and
- Approximately 10% and 20% of the remaining SSO materials available within a reasonable hauling distance (30 miles) of the UMass site would be available for acceptance at the facility.

The two scenarios for accepting SSO materials and biosolids that were selected for evaluation are summarized on Table 3-6.

Table 3-6
Summary of Annual SSO and Biosolid Tonnages Scenarios for Further Evaluation

Alternative	Total Wet Tons Per Year			Annual Wet Tons Per Year from UMASS and Amherst WPCF			Net Additional Wet Tons Per Year			Net Additional Average Wet Tons Per Day		
	Biosolids	SSO	Total	Biosolids	SSO	Total	Biosolids	SSO	Total	Biosolids	SSO	Total
Alternative A	18,500	11,500	30,000	15,400	1,200	16,600	3,100	10,300	13,400	12	41	53
Alternative B	30,000	20,000	50,000	15,400	1,200	16,600	14,600	18,800	33,400	58	75	133

TPY: Tons per Year

UMass SSO is currently 1,200 TYP

Assumption

Days per year accepting materials 250

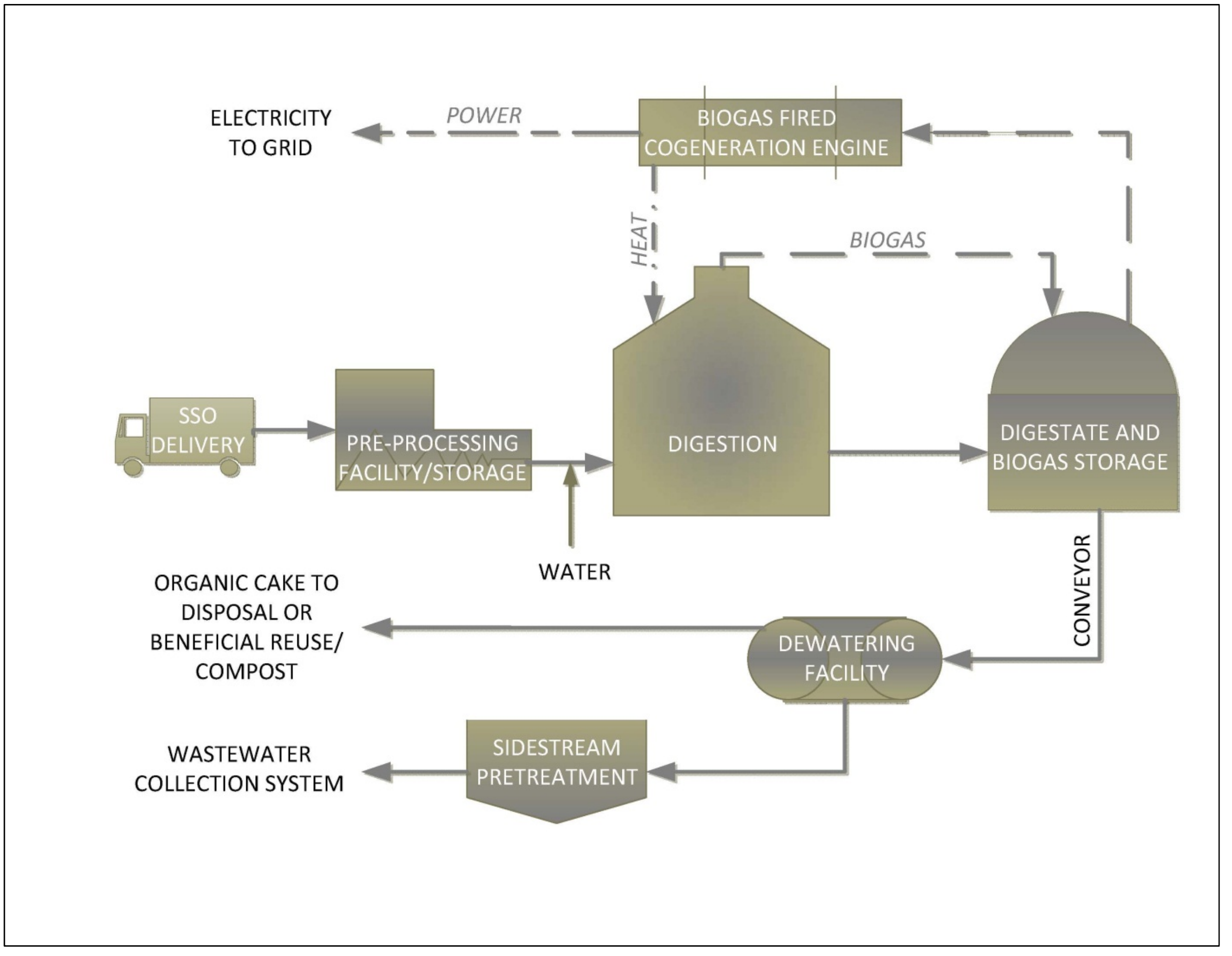
Section 4

Conceptual Organics Processing Facilities

4.1 Introduction and AD Facility Schematic Layouts

There are numerous technologies available today for the development of AD facilities that can accept both biosolids and/or SSO materials. These technologies typically include several standard components that each proprietary vendor may modify to accommodate different feedstocks or other design preferences. A schematic of a typical AD facility is shown on Figure 4-1.

Figure 4-1
Schematic of Typical AD Facility for SSO Materials



Generally, AD facilities like those potentially proposed for the UMass-Amherst site, include facilities to accept and pre-process as needed incoming SSO materials and biosolids that are typically delivered in sealed truck containers. The pre-processed materials are then temporarily stored in a tank that feeds on a constant basis another tank where the anaerobic digestion occurs. Anaerobic digestion is defined in MassDEP's solid waste management regulations as "….a process of accelerated biodegradation of organic materials using microorganisms under controlled conditions in the absence of oxygen."

Anaerobic digestion generates a biogas (consisting of 50 to 60% methane) and liquid end-product of remaining material that is not digested. This "digestate" will likely require dewatering with the water needing further treatment to remove constituents such as ammonia while the solid can be composted or landfilled. Note that the incorporation of biosolids into the facility will create specific requirements for the re-use of the digestate. The biogas can be utilized to either generate electricity or heat in a separate engine. The intent of the technology in this application is to utilize what is currently considered a waste stream (SSO materials) with biosolids from local WPCF's that are currently being transported significant distances for disposal to generate power as well as potentially a reusable product from the solid portion of the digestate.

4.2 Conceptual Facility Sizing and Approach

In this section, CDM Smith will present the assumptions about each of the components of the AD facility for the feedstock scenarios that were developed in Section 3. This information will form the basis for developing estimates of capital and operating costs for the AD facility that will become the basis for conducting an initial screening of project feasibility. For cost estimating pruposes, CDM Smith has assumed equipment and appurtenant systems that have a minimum useful life of 15 years to correspond to the proposed facility operating life and the pro forma estimates. These estimates are presented at the end of this section.

As outlined in Section 3, after completing an analysis of the available SSO materials within a reasonable hauling distance as well as biosolids from the Amherst and Hadley WPCF's, the MassDEP and CDM Smith selected two scenarios to be evaluated further as to their feasibility for implementation at the proposed UMass-Amherst site. The two proposed scenarios are summarized on Table 4.1 below.

Table 4-1
Summary of Annual SSO and Biosolid Tonnages Scenarios

Scenario	Biosolids			SSO Materials			Total TPY
	Wet TPY	Percent Solids	Basis	TPY	Percent Solids	Basis	
A	18,500	6%	Hadley and Amherst current generation	11,500	30%	UMass SSO plus approximately 10% of remaining regional SSO	30,000
B	30,000	6%	Scenario A plus additional biosolids	20,000	30%	UMass SSO plus approximately 20% of remaining regional SSO	50,000

TPY: Tons per Year; UMass SSO is currently 1,200 TPY

4.2.1 Incorporation of Pre-Processing for SSO Materials

One of the key considerations in the capital costs for this type of facility that will accept a significant quantity of SSO materials is the pre-processing required prior to their insertion into the AD unit. These costs are not just related to the pre-processing operations but also to the appurtenant site work, material storage, control systems and odor control systems that are required for the unloading and pre-processing operations.

Because the proposed project at the UMass-Amherst site is proposed to accept a significant amount of biosolids with relatively low solids (high water) content, the AD technology has to be a "wet" technology similar to that utilized at many wastewater treatment plants. With wet technologies, the AD unit requires that the SSO materials be processed into a slurry form that can be pumped and mixed within the digestion tank. SSO materials may be generated in a slurry form (typical with materials from food processing and manufacturing operations); be processed at an off-site location and delivered to the AD facility; or be accepted in a raw form and processed at the proposed UMass-Amherst facility.

To fully evaluate these alternatives, CDM Smith included an alternative for each feedstock scenario that assumes that pre-processing facilities will either be incorporated on-site or that the SSO materials will be received in a form that can be directly discharged into an on-site storage tank and fed into the AD unit. For the purposes of this discussion, CDM Smith will evaluate two types of facilities (with and without pre-processing of SSO) that will be designated 1 and 2. The four potential facility scenarios are summarized in Table 4-2.

Table 4-2
Summary of Annual SSO and Biosolid Tonnages Scenarios for Further Evaluation

Scenario	*Biosolids Wet TPY*	*SSO Materials TPY*	*Basis*
A-1	18,500	11,500	UMass SSO plus approximately 10% of remaining regional SSO – With Pre-Processing
A-2	18,500	11,500	UMass SSO plus approximately 10% of remaining regional SSO – Without Pre-Processing
B-1	30,000	20,000	UMass SSO plus approximately 20% of remaining regional SSO – With Pre-Processing
B-2	30,000	20,000	UMass SSO plus approximately 20% of remaining regional SSO -Without Pre-Processing

CDM Smith notes that UMass currently has an effective program for the collection of SSO materials from dining halls throughout the campus. This program uses "toters" to collect the source material that are then delivered to the University's central solid waste facility. This facility does not have the ability to pre-process the collected SSO materials into an appropriate slurry material and constructing such a facility will not be cost-effective. Therefore, CDM Smith has assumed that in all scenarios, the UMass collected SSO materials will be delivered directly to the proposed AD facility and the operator will incorporate the capabilities to unload them into a pit where they will be processed into a slurry directly by smaller equipment as a sufficient quantity is received. The facility will also have to include a facility to unload the toters and clean them, similar to the existing operation.

4.2.2 On-Site Use of Biogas and Electricity

The proposed AD facility can generate a significant amount of biogas that could be utilized at an off-site boiler to generate heat or electricity or sent directly to an on-site CHP unit to generate electricity.

There is also some excess heat that will be generated from the process that could be utilized. One of the apparent advantages of the proposed UMass Amherst site is the presence of the UMass Combined Heat & Power (CHP) Plant and the Amherst WPCF who could potentially utilize both the net electricity generated and the heat. The UMass CHP Plant could potentially also accept the biogas directly and utilize it as an additional fuel source.

CDM Smith met with the operator of the UMass CHP facility as part of this project. At the meeting and during subsequent discussions, information on the existing operation was collected and evaluated.

The CHP facility currently generates between 70 and 75% of the electricity used by the University with the remainder being purchased from Western Massachusetts Electric Company (WMECO). The operator intends on increasing the percentage generated to approximately 90% of the University's needs. The CHP facility also generates a significant amount of steam for use at the University. The fuel source for the CHP facility is now primarily natural gas delivered by both a pipeline as well as by truck through a recently constructed liquefied natural gas (LNG) facility. The blended rate (both on-site generated and purchased from WMECO) for electricity is approximately $0.07/kw-hour with the WMECO purchased electricity averaging $0.14/kw-hour. The current peak load is 26.5 MW which is expected to increase to 42 MW by 2017 when the new buildings under construction and planned are completed. Note that this load is significantly greater than that anticipated to be generated by the proposed AD facility[1].

CDM Smith discussed the potential for the acceptance of the biogas from the AD facility directly at the CHP facility. The operator raised concerns about the quality of the gas (need for pretreatment for the removal of siloxanes, moisture and hydrogen sulfide). In addition, the significantly lower heating value for biogas compared to natural gas that would likely necessitate the operation of a dedicated engine. In any scenario for the AD facility, the biogas will have to be pretreated prior to being used in an engine so the costs and requirements for the pretreatment have been included in this analysis. Because of the likely need for a dedicated engine for the biogas (potentially supplemented with diluted natural gas), CDM Smith has included the cost for a standalone biogas engine located at the AD facility in our analysis. However, given the trained workforce at the CHP facility, it may make sense for the biogas engine to be located and operated there.

The Amherst WPCF does not currently have the ability to generate electricity from the biogas without constructing an engine similar to the one the private operator of the AD facility would have to install and operate. Since the AD facility will be a private operation constructed on state land, CDM Smith feels that if Amherst was to utilize any generated electricity, this private operator would have to construct and operate the engine.

Therefore, for the purposes of our evaluation, CDM Smith has assumed that the AD facility will incorporate an engine that will generate electricity on-site. Some of the generated electricity will be assumed to be utilized by either the Amherst WPCF or the UMass CHP system to offset their current electrical usage.

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[1] Preliminary estimates indicate that the proposed AD Facility could generate up to 1 MW of electricity.

4.3 SSO Materials Receiving and Pre-Processing

As discussed above, this section will present the pre-processing equipment requirements for the two scenarios (A-1 and B-1) where the SSO materials received require pre-processing in the analysis.

Though few facilities presently exist nationwide for the pre-processing of SSO materials, there are some operational facilities in Canada and Europe. A facility of this nature would include equipment to process in-coming materials in order to produce a product that can be easily pumped. Processing could include machinery to screen and pulp the materials, remove contaminants (e.g., glass, plastics, metals, and cardboard), and produce a uniform pumpable material that is readily digestible. The type and capacity of the equipment will be determined not only on the feedstock quantity but also on the types of SSO materials that are accepted.

4.3.1 Pre-Processing System Sizing

It has been assumed, based on industry research, that the SSO materials would be delivered to the facility at an approximate solids percentage of 30% (70% water). At this high percentage of solids, even following pre-processing, the resultant product is not conducive to pumping to or mixing within AD tanks. As a result, it has been assumed that the materials would be diluted to approximately 13% solids content prior to being introduced to the digestion facility. This resultant product is sometimes referred to as Engineered Food Waste (EFW).

As shown in Table 4-3, this would translate to approximately 48,800 and 85,200 gal/day of EFW being fed to digestion with between 16,800 and 29,500 gal/day of dilution water being required. It should also be noted that, though public water supply is a potential source for this dilution water, rain water, effluent from the Amherst WPCF and/or other liquid organic wastes can also be used for this purpose and would be more cost effective. For the cost evaluations provided in this report, CDM Smith has assumed no cost for dilution water as a alternative source (Amherst WPCF effluent) is readily available.

Table 4-3
Summary of SSO Dilution and Pre-Processing Volumes

SSO Pre-Processing and Storage Design Component	*Scenario A-1*	*Scenario B-1*
Potentially Available SSO Waste (wet tons/year)	11,500	20,000
Potentially Available SSO Waste (wet tons/day)	32	55
SSO Pre-Processing Rate (8 hrs/day, 5 days/wk) (wet tons/hr)	5.5	9.6
Assumed as-collected SSO water content	70%	70%
Dry Solids Content (dry ton/day)	13.3	23.1
Dry Solids Content (dry lbs/day)	26,500	46,200
EFW Diluted to 13% (gal/day)	24,400	42,600
EFW Storage Volume (2 days) (gal)	48,800	85,200
Water Required for Dilution (gal/day)	16,800	29,500

Table 4-3 (Cont'd)
Summary of SSO Dilution and Pre-Processing Volumes

SSO Pre-Processing and Storage Design Component	*Scenario A-1*	*Scenario B-1*
Biosolids Storage		
Biosolids Annual Average (gallons/day)	12,200	19,700
Daily Receiving Rate (5 days/wk schedule) (gallons/day)	16,804	27,656
Storage Volume (2 days) (gal)	33,608	55,312
Total Incoming Waste Storage		
Storage Volume (2 days) (gal)	82,000	141,000

4.3.2 Pre-Processing Equipment

Figure 4-2
Example Receiving and Pre-Processing Equipment
(Courtesy of Komptech)

One of the limited examples of preprocessing systems that has been utilized to-date within the United States is the "CORe" (Centralized Organics Recycling equipment) system developed by Waste Management (WM). This system is a SSO material processing and blending system designed to remove the non-degradable contaminants. The major components of this system include an organic material feed hopper, hopper auger feed, bio-separator (cylindrical screen) and bio-slurry tanks. It is intended to utilize a small footprint and provide a totally enclosed solution for SSO preprocessing transfer station, landfill, or on a partner's property. Using this system, the received material is blended into a consistent feedstock. Pilot testing of the CORe system was completed at Victor Valley Water Reclamation Authority in CA with reportedly positive results. However, it is noted that this system is currently proprietary and costs for installation are not currently available.

A second known example of a pre-processing system is that currently offered by Komptech USA of Westminster, Colorado (though headquartered in Germany). The pre-processing system that they offer includes shredding, pulping, screening/pressing, sand separation and hygienisation stages. Though they do not currently have any US installations, the equipment they offer has been used extensively in Europe.

Costs presented later in this section include costs for this type of pre-processing system at the UMass-Amherst site. For the purpose of equipment sizing, it has been assumed that SSO material will be received 8 hrs/day, 5 days/wk.

4.3.3 Pre-Digestion Storage and Feed

The efficiency of anaerobic digestion is contingent upon the ability to feed it at a relatively constant rate. Highly variable loading or 'slugs' of feed material being introduced into the process creates a potential for upsets (significant decrease in biogas production), foaming and/or an overall reduction in volatile solids destruction efficiency.

SSO materials are expected to be received on a 40-hour per week schedule but the digestion process will operate continuously. As a result of the continuous feeding needs in comparison with the receiving schedule, it is expected that a pre-digestion EFW storage tank(s) would be required. In addition, this storage would serve to address variations in SSO supply and potential system operational issues. It would also provide storage for the biosolids received from outside sources. For the purpose of this study, it is assumed that a total of 2 days of EFW storage would be required. As shown in Table 4-3, this equates to 82,000 and 141,000 gallons of total for the two options being evaluated. Note that comparable volumes of storage capacity will have to be built into the proposed facility even if the SSO materials are received pre-processed or with an appropriate water content.

4.4 Anaerobic Digestion Process

Anaerobic digestion has been practiced for decades and is one of the most common technologies used for the stabilization of biosolids utilized in the United States. Some of the major benefits of this process for biosolids include the following:

- Quantity reduction for biosolids can commonly exceed 40 percent;
- Digester gas produced (biogas) can be used to generate to electricity;
- Digested materials produced exhibit less odor than the undigested feedstocks; and
- The carbon footprint of facilities with anaerobic digestion is significantly less than competing management technologies.

Previous and continued research in the area of anaerobic digestion has generally focused on improved solids pre-treatment, improved digestion efficiency and maximization of digester gas production. In addition, there are many technologies that are being developed to improve feedstock quality, making it more amenable to digestion. These technologies disrupt the cell membranes with chemical, heat or pressure to accelerate the digestion process and improve biogas production. There are also several variations of the anaerobic digestion process itself which have been employed by some municipalities. These include staged systems (acid-phase digesters followed by gas-phase digesters), high temperature thermophilic digesters (140°F) and other combinations which are also intended to improve the efficiency of the digestion process.

More recently, as discussed in Section 2, there has been a significant increase in the emerging area of SSO materials digestion and co-digestion of SSO materials with biosolids. There are a number of ongoing studies in this area including work with the Department of Defense and the Massachusetts Water Resources Authority to help refine data pertaining to the expected volatile solids (VS) reduction and biogas production from digestion of SSO materials.

4.4.1 Digester Tank Sizing

Anaerobic digesters are sized based upon solids retention time (SRT) and hydraulic retention time (HRT). For the conceptual AD facility at UMass-Amherst, it has been assumed that the process would utilize a conventional mesophylic process (95°F process temperature) and would be sized for an average SRT of 20 days. This retention time is industry standard and is based on allowing adequate time for the biological process within the digester to optimize the volatile solids destruction and associated biogas production. It is further assumed that this high rate digester system will not include supernatant decant and therefore, the HRT is equivalent to the SRT and the terms may be used interchangeably.

Although the SRT generally dictates digester volumetric sizing for most biosolids applications, the amount of volatile solids (VS) fed per unit digester volume becomes an increased concern when highly concentrated wastes such as SSO are fed to a digester at high percentages. The limitation of this loading is important to ensure stable operations and biogas production and to reduce the potential for process upset. Based on recent studies, laboratory testing and full-scale co-digestion applications, the recommended upper bound of this loading is currently believed to be approximately 0.20 pounds of volatile solids per cubic foot of digestion capacity per day (lb VS/CF/day). As is the case for all alternatives evaluated here, when VS loading is above this criteria, the digester volume is commonly increased above that determined by SRT sizing criteria to reduce the VS loading.

Table 4-4 summarizes the recommended basis of design used to size the digester system under each acceptance alternative. As shown below, it is anticipated that required digestion volume would range from approximately 0.8 Mgal to 1.0 Mgal of volume.

Table 4-4
Anaerobic Digestion Conceptual Sizing Calculation Summary

Design Criteria/Calculation	*Alternative A-1 & A-2*	*Alternative B-1 and B-2*
Biosolids Loading[1]		
Flow (gal/day)	12,200	19,700
Solids (lbs/day)	6,100	9,900
VS Reduced (lbs/day)	2,704	4,389
Solids Remaining (lbs/day)	3,396	5,511
Biogas Produced (cf/day)	40,567	65,838
SSO Feedstock Loading[2]		
Flow (gal/day)	17,436	30,323
Solids (lbs/day)	18,904	32,877
VS Reduced (lbs/day)	13,176	22,915
Solids Remaining (lbs/day)	5,728	9,962
Biogas Produced (cf/day)	179,196	311,645
Total Loading		
Flow (gal/day)	29,636	50,023
VS Reduced (lb/day)	15,881	27,304
Digestate Solids (lbs/day)	9,123	15,472
Digestate Solids Concentration (%)	3.7%	3.7%
Biogas Produced (cf/day)	219,763	377,483
Digester Sizing		
Digester Volume for 0.20 lb/cf/day VSLR (gal)	786,264	1,345,892

[1]Assumes TS of 4.3%, VS/TS of 81.2%, VS reduction of 54.6% and biogas production of 15 cf/lb VSR.

[2]Assumes TS of 13%, VS/TS of 85%, VS reduction of 82% and biogas production of 13.6 cf/lb VSR.

It should also be noted that the materials of construction for digestion tanks under municipal ownership and operations is commonly either cast-in-place or pre-stressed concrete. This selection of material is typically made due to considerations including service life and reduced maintenance costs when compared to other options. Concrete also provides the most flexibility with respect to biogas pressures and cover options. Concrete tanks can also be partially buried or obscured to improve aesthetics. However, in industrial settings, steel digestion tanks tend to be selected more commonly due to the associated capital cost savings. Steel tanks can be provided with welded or bolted steel and coated with epoxy coatings or fused glass materials. For the purpose of this conceptual analysis, it has been conservatively assumed that the tanks(s) will be constructed of concrete since the proposed facility will be required to be aesthetically similar to the Amherst WPCF.

4.4.2 Biogas Production Estimate

Based on recent studies , it has been shown that the ratio of volatile solids to total solids and the biogas production per pound of volatile solids reduced for SSO materials is relatively similar to that of municipal biosolids. However, it was also shown that the reduction of the volatile solids in the SSO stream within an anaerobic digester is significantly greater than is typically seen with municipal biosolids (82% VS reduction for SSO vs. 55% VS reduction of municipal sludge). This, combined with the fact that SSO materials are generally fed to digesters at higher solids concentrations, enables the biogas yield from a gallon of SSO to significantly exceed that of from a gallon of biosolids. When this difference in gas production is considered on a unit basis, the yield from SSO materials are approximately four times that of municipal sludge (10 cf biogas/gal SSO vs. 2.5 cf biogas/gal sludge).

Using the anticipated incoming feedstock volumes, along with theoretical digestion performance parameters for digestion of SSO and biosolids, the total anticipated biogas yield under each scenario was calculated. As shown in Table 4-5, the total theoretical biogas production under these loading conditions would be between approximately 220,000 and 377,000 cf/day.

It should also be noted that heating value of digester biogas typically ranges from 500 to 650 BTU/cf, with 600 BTU/cf (lower heating value or LHV which net is the heat available after evaporating the moisture content in the gas) being used in this estimate. For comparison, natural gas typically contains an average heating value of approximately 1,000 BTU/cf.

Table 4-5
Summary of Biogas Production Estimate

Calculation Component	Alternatives A-1 & A-2	Alternatives B-1 & B-2
Volatile Solids Reduced (lbs/day)	15,881	27,304
Biogas Production (cf/day)	219,763	377,483
Biogas Production (scfm)	152	262

4.5 Ancillary Equipment

Anaerobic digestion systems require a significant amount of ancillary equipment to ensure proper process operations and safety. The following includes a brief discussion on each of the major ancillary systems, which include:

- Heating system;
- Mixing system;
- Digester covers;
- Digester biogas handling equipment;
- Biogas storage system; and
- Biogas treatment and boosting systems.

4.5.1 Digester Heating

Anaerobic digesters are heated to maintain an environment conducive to methane forming microorganisms and to ensure greases and fats within the digester remain in an emulsified state so they can be broken down biologically.

There are two main types of heating systems:

- ***Internal:*** With an internal arrangement, heat is applied to the digester materials while it remains in the digester tank. Older digester heating arrangements included mounting pipes to the interior of the digester wall in which hot water circulates and installing draft tube mixers equipped with hot water jackets. In recent years, these arrangements have become less popular due to operational issues, including the buildup of digester materials on the heating surface and access restrictions. Because all internal heating systems rely on the digester mixing system to circulate heat within the digester, the mixing system must be operated on a continuous basis. Without continuous mixing, a thermal gradient will develop in the tank and create biologically inactive zones.

- ***External:*** Newer digesters typically use external heating systems that recirculate sludge through external heat exchanger(s) using a recirculation pump. Most external heating systems incorporate means to heat the digester materials before it enters the digester (i.e. influent heat exchanger). The feedstock is typically interlocked with digester materials recirculation pumps, allowing the blending and preheating of the feedstock and digester materials before it enters the tank.

Hot water for the digester heating systems is typically supplied by either waste heat from a cogeneration system and/or a boiler that utilizes biogas from the anaerobic digester. Natural gas can be used as a supplemental fuel when insufficient biogas is produced to heat the digester or if all of the digester gas is used in cogeneration and the waste heat is not sufficient to meet heating demands.

For this conceptual analysis, is has been assumed that external heat exchangers will be utilized and cogeneration waste heat will serve to supply the process heating needs. The energy balance and cogeneration sizing will be discussed later.

4.5.2 Digester Mixing

Mixing in high rate digestion systems is important to maintain uniformity within the digester and to prevent potential scum accumulation in the digester tank. Digester mixing is a crucial component and poor mixing typically results in lower volatile solids destruction and decreased biogas production. Presently, the most common mixing systems are:

- ***Recirculation Pumps:*** Pump systems use external pumps to recirculate the sludge for mixing. Biosolids are pumped from the digester tank and are typically reintroduced through several ports located around the circumference of the digester or discharged through nozzles. Depending on tank diameter and flow rate, pumping rates typically turn over the contents of the digester every 3 to 12 hours.

- ***Compressed Biogas:*** The four major gas mixing systems are gas-discharged lances, floor-mounted diffusers, confined draft tubes, and "bubble-gun" gas mixers. On each of these systems, the gas compressor and control valves are the major mechanical pieces of equipment. In each system, biogas is taken from the headspace of the digester tank, compressed, and distributed to multiple mixing devices.

- ***Mechanical Mixing:*** These systems consist of a propeller, drive shaft and drive. Most mechanical mixing systems are mounted in a draft tube to direct digester materials flow within the digester, while others are simply installed through tank wall penetrations with the motor and gear external to the tank and with the propeller shaft penetrating though and generally perpendicular to the tank wall. When installed in a draft tube, drives are typically reversible, allowing the digester materials to discharge at the top or bottom of the draft tube. Mixer/draft tube assemblies may be located at the center of the digester tank, at the mid-radius point or outside the digester tank.

A pump recirculation mixing system is assumed for the proposed AD facility based on preliminary operation and maintenance considerations. With these systems, pumps are located inside an enclosure along with other equipment and are easily accessed. In comparison, mechanical draft tube motors are located on top of the digester tanks creating a difficult maintenance environment especially during winter conditions. In addition, due to the inability to grind the recirculation flow with a draft tube mixer, rags and other fibrous materials could accumulate within the digesters and create a maintenance concern. Further, due to the configuration of draft tube mixers, a crane would be required for any significant maintenance procedures. Gas mixing systems were removed from consideration due to cost and the historical maintenance concerns associated with the biogas compressor systems and general safety concerns associated with biogas handing. It should also be noted that a mixing system will also be required for the digestate storage tank discussed later in this section.

4.5.3 Digester Cover

Digester tanks require a solid cover to maintain anaerobic conditions in the tank, contain and assist in collecting biogas produced during the digestion process, reduce odors, retain heat to maintain internal temperatures, and support some types of mixing equipment (e.g. internal draft tube mixers supported from fixed covers). There are four basic types of digester covers:

- ***Floating Covers:*** Floating covers have been widely used for years. They have typically been used to provide for some liquid storage (conventional floating covers), as well as some gas storage (gas holding covers). Conventional floating covers float directly on the digester materials surface, which provides for fluctuations of levels with minimal change in biogas pressure.

- ***Fixed Covers:*** Fixed concrete and steel covers are also widely used. They have historically been the option with the lowest cost and least potential for operation and maintenance problems in comparison to floating covers. However, fixed covers offer minimal biogas storage and limited flexibility with regard to liquid levels.

- ***Submerged Fixed Covers (SFC):*** One variation on the fixed concrete cover design is the submerged fixed cover (SFC). Compared to flat fixed cover designs, the submerged fixed cover is effective at utilizing the upper portion of the tank volume by inhibiting the buildup of floating foam and scum and directs mixing energy for better efficiency. These are similar in costs to flat roof digesters and less costly to construct than domed roofs. The key to the submerged fixed cover digester is a sloped roof that leads to a centrally located gas dome. In a SFC design, the liquid level is allowed to rise into the gas dome above the side wall, submerging the underside of the cover. Submerging the cover provides a gradual transition at the cover side wall connection, directing mixing patterns more effectively. Operating the liquid level in the gas dome minimizes the gas to liquid interface. By minimizing this interface, foam and scum can be removed more effectively. With minimal gas storage volume, a fixed cover system must either rely on storage spheres, piping, flares, vacuum and pressure relief valves, or some other means of gas storage to keep the pressures consistent inside the tank.

- ***Gas Membrane Covers:*** Gas membrane covers are a relatively new product that was first used in the U.S. in the early 1990s. They provide a large volume of digester gas storage using a double-membrane design and may be installed on digester tanks or storage tanks. The outer membrane maintains a consistent dome shape, while the inner membrane moves up or down depending upon gas storage requirements. Ambient air fans and valves add or release air from the space between the inner and outer membranes to maintain the consistent outer membrane shape and constant biogas pressure. This also allows for substantial changes in the depth of materials in the digester.

For cost-estimating purposes, it has been assumed that SFCs will be used at the proposed UMass-Amherst facility, as SFC's minimize forming which is often expensive and difficult to control and contain. It is further recommended that the digestate storage tank, as discussed further below, be installed with a gas membrane cover to store excess biogas before it is used in cogeneration.

4.5.4 Gas Handling Equipment

Gas handling equipment consists of gas storage, conveyance and safety equipment. The conveyance system brings biogas from the digesters to equipment for consumption, storage, or wasting. Most biogas conveyance systems are low pressure and operate at approximately 12 inches of water column (< 0.50 psig). Biogas may be stored based on production and utilization demands of the boiler or cogeneration equipment. Storage devices include digester tank gas holder covers which are part of the digester itself and membrane gasholders that are external to the digester and are typically located in close proximity to the digester on a concrete pad.

As biogas is explosive at low concentrations of approximately 1 volume of gas to 15 volumes of ambient air, it is of the utmost importance that the biogas handling system be fitted with appropriate gas-safety equipment, to protect against the risk of ignition and a potentially catastrophic explosion.

The digestion and gas equipment must be protected against flashback through the piping with a flame arrestor or flame traps from any potential source of ignition. A flame arrestor works to quench the flame by dissipating any heat from a potential explosion in the piping. A flame trap is a combination of a flame arrestor and a thermal shutoff valve. If a propagating flame is stopped by the arrestor but continues to burn in the piping, a thermal element in the thermal shutoff valve will melt and seal off the remainder of the upstream piping from the fuel source.

Anaerobic digesters are provided with pressure/vacuum relief valves, typically mounted directly on top of the digester tank. These valves release any biogas to the atmosphere when the pressure rises above a set-point to protect the tank from over-pressurization. Additionally, a vacuum relief valve will allow entry of ambient air into the tank during any vacuum conditions, to protect the tank from imploding. Costs for these systems have been incorporated into the project.

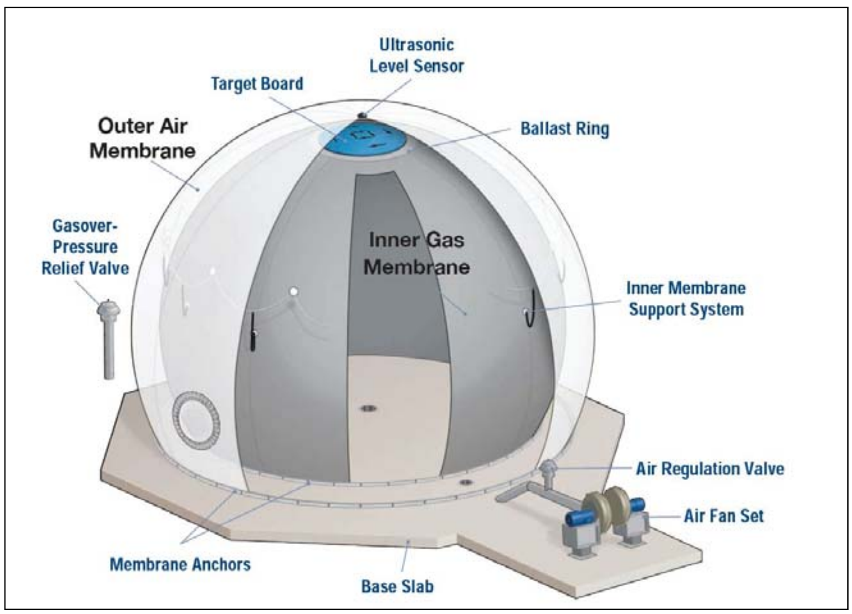

Figure 4-2
Typical Gas Membrane Storage System
Figure Courtesy of WesTech

4.5.5 Biogas Storage Systems

As previously noted, because digesters do not produce biogas at a constant rate, biogas storage is often recommended to maximize the biogas capture rate and increase the efficiency of the overall system. The most likely and viable alternative for providing storage capacity in this application would be the use of a double membrane gas holder. Storage of biogas is similar to the short-term storage of natural gas at numerous facilities. In general, there are several safety controls that the operator willhave to incorporate to meet building codes. These will include installation of flame arresters, a device generally installed in pipelines that prevents the flame from travelling into a gas storage tank; and appropriate pressure, temperature and gas concentration controls in all biogas storage and conveyance systems. A flare will be provided to combust any excess gas or when the power generating system is not operating.

Gas membrane covers were first used in the U.S. in the early 1990s. They provide a large volume of digester gas storage using a double membrane design. The outer membrane maintains a consistent dome shape while the inner membrane moves up or down depending upon gas storage requirements. Ambient air fans and valves add or release air from the space between the inner and outer membranes to maintain the consistent outer membrane shape and constant biogas pressure. The exterior membrane is typically made out of polyester fiber fabric that is coated with microbial and abrasion resistant PVC. The internal membrane is also typically manufactured from PVC coated polyester fiber fabric, which is microbial, abrasion and biogas resistant. Some of the key drivers for this technology have been the need for large gas storage volumes and/or large fill and draw capacity in the tank.

There are several suppliers of membrane covers in the U.S. including WesTech, Ovivo, Siemens and JDV. WesTech, Siemens and JDV have several installations in the U.S. and most of the JDV and WesTech membrane systems are standalone on a concrete pad as opposed to on top of a tank.

Membrane covers have proven to be reliable systems with the older installations having a life expectancy of 10 years. However, suppliers indicate that the technology has improved in recent years and newer membranes should have a service life of approximately 15 years.

It is conceptually estimated that a total biogas storage volume equating to 8 hrs of average production would provide adequate storage capacity to enable a high biogas capture percentage. As such, the additional storage required to be supplied by this new storage system would range from approximately 72,000 to 104,000 cf.

4.5.6 Biogas Treatment and Boosting Systems

Biogas Treatment

Prior to being utilized in a cogeneration system, some level of biogas treatment is typically required to remove contaminants. The level of treatment depends on the concentrations of contaminants and the end use of the gas. In addition to a high moisture content, contaminants often found in digester gas produced from wastewater treatment residuals include hydrogen sulfide (H_2S) and siloxanes.

Figure 4-3
Representative Biogas Booster System

Hydrogen sulfide in biogas is formed by the reduction of sulfates by anaerobic bacteria within the digester. Sulfates occur naturally in wastewater from the decomposition of urine and protein in the influent feedstock. Siloxanes are often used in the manufacture of personal hygiene, health care and industrial products and eventually end up in wastewater. Siloxanes volatilize into the biogas during the digestion process and when this biogas is combusted, siloxanes are converted to silicon dioxide (SiO_2), which is then deposited in the combustion or exhaust stages of the equipment. In reciprocating engines, the presence of hydrogen sulfide and/or siloxanes can lead to premature deterioration and excessive maintenance of the equipment components.

As noted above, this experience with biogas quality and treatment is based on biogas from wastewater biosolids. In the case of an AD facility that also accepts SSO materials, there is limited data relative to biogas quality and contaminants. However, based on the limited data and experience that exists, biogas from an AD facility accepting only SSO materials is likely of much higher quality and likely contains very low levels of the above contaminants. Because the proposed AD facility will accept biosolids, CDM Smith has assumed incorporation of a hydrogen sulfide removal system. However, at this time it has been assumed that siloxane treatment will not be required or could be added at a later time if necessary.

Biogas Pressure Boosting

Biogas pressure boosting is generally required in CHP applications due to the relatively low gas pressures at which anaerobic digesters typically operated. The pressure of the biogas from anaerobic digesters is generally 12 inches of water column (< 0.50 psig) or less. This pressure is not sufficient for internal combustion engines which generally require an inlet pressure of between 2–5 psig of inlet gas pressure. As a result, the biogas utilization system at this facility would require a biogas booster system. In this system, the digester gas would first be filtered through a blower inlet filter to remove any free moisture and particulates prior to being compressed with a blower. The blower would compress the gas to about 5 psig prior to entering a heat exchanger which would reduce the dew point of the gas to 40°F and reheat the gas to 80°F. All condensed moisture would be removed inside the heat exchanger and drained through a no-gas-loss drain. The heat exchanger would be supplied with cold glycol from a remote mounted glycol chiller.

4.6 Energy Recovery

Digester biogas is commonly used to heat the digester and facility buildings using the biogas in hot water boilers. However, in recent years, the prevalence of biogas fueled cogeneration systems have increased in popularity due to their ability to produce electricity and heat simultaneously, thereby increasing the overall efficiency of the system. These are commonly referred to as Combined Heat and Power (CHP) systems. The following includes a brief description of available CHP technologies, and a conceptual evaluation as to the anticipated heat and electrical balance between production and on site use.

4.6.1 CHP Technology Alternatives

Currently, the most common technologies used for cogeneration are microturbines and reciprocating engines. In addition, other innovative technologies may become competitive in the future by reducing the need for biogas cleaning prior to use, therefore reducing overall complexity and equipment cost. For general background and potential future consideration, both established and innovative CHP technologies are briefly described below.

Internal Combustion Engines

Internal combustion (IC) engines are the most widely used CHP technology. They are often the most economical CHP technology and have combined electrical and heat recovery efficiencies higher than any other currently available CHP technology. Heat can be recovered from the engine jacket and the exhaust gas. The technology is reliable and available from a number of reputable manufacturers. IC engines are less sensitive to biogas contaminants than most other CHP technologies, reducing the gas cleaning performance requirements.

One disadvantage of IC engines is their relatively high emissions, as compared to other CHP technologies, such as microturbines and fuel cells. IC engine emissions can cause permitting difficulties in areas with strict air quality limits and may require additional emissions control, such as selective catalytic reduction to meet emission requirements. However, most IC engines installed since 2005 are lean-burn engines, with higher fuel efficiency and lower emissions than rich-burn engines which were more commonly used historically.

Combustion Gas Turbines

Combustion gas turbines are often a good fit for very large biogas production facilities. Like IC engines, combustion gas turbines are a reliable, well-proven technology available from several manufacturers. Large WPCF's often use biogas-fueled combustion gas turbines. Heat can be recovered from the exhaust gas. Combustion gas turbines are relatively simple, containing few moving parts and consequently requiring little maintenance. While infrequent, the maintenance of combustion gas turbines requires specialized service.

Microturbines

As the name suggests, a microturbine is a much smaller version of a combustion gas turbine. Microturbine capacities range from 30 kW to 250 kW and are often a good fit for smaller WPCF's with anaerobic digestion. Microturbines are relatively new, introduced about 15 years ago. Despite their somewhat recent development, microturbines have become the second most widely used technology at WPCF's for harvesting electricity and heat from biogas energy due to their small capacity and clean emissions. However, microturbine electrical efficiency is considerably lower than that of IC engines. Microturbines require relatively clean fuel, increasing the performance requirements and cost of biogas treatment, but their exhaust emissions are among the lowest of all CHP technologies. Microturbines are currently available from two manufacturers.

Fuel Cells

Fuel cells are unique in that they do not combust biogas to produce power and heat. Instead, fuel cells convert chemical energy to electricity using electrochemical reactions. Their benefits include high electric efficiency and extremely clean exhaust emissions. However, fuel cells are one of the most expensive CHP technologies in terms of both capital and operation and maintenance (O&M) costs. In addition, they are extremely sensitive to impurities in the biogas, requiring the highest level of biogas cleaning of all CHP technologies. For these reasons, fuel cell installations are typically limited to locations with strict air quality regulations and fuel cell-specific grants or incentives.

Stirling Engines

While Stirling Engine technology is well established, their application to biogas is innovative. There has been increased interest in this CHP technology in recent years due to its reduced biogas cleaning requirements. A Stirling Engine is an external combustion process. Biogas is combusted outside of the prime mover. The heat generated by the combustion process expands a working gas (generally helium), which moves a piston inside a cylinder. Because combustion occurs externally to the cylinder and moving parts, very little biogas cleaning is required.

Pipeline Injection

For pipeline injection biogas must have extremely low concentrations of contaminants and must be compressed to match the natural gas transmission line pressure. Biogas contaminants that must be removed include foam, sediment, water, siloxanes, hydrogen sulfide, and carbon dioxide. Biogas cleaning to pipeline quality has high capital and O&M costs. In most situations, generation of pipeline quality biogas is not cost-competitive with CHP. This biogas use is a better fit for large biogas producers (to take advantage of economies of scale) near a natural gas pipeline. If financial incentives are available, pipeline injection can become attractive. There are currently only a few facilities cleaning biogas to pipeline quality in the US.

CNG or LNG Vehicle Fuel

Biogas can be upgraded to displace CNG or LNG in vehicles capable of using these fuels. In Europe, upgrading biogas to fuel vehicular fleets is a well-established practice. In the US, there are only a few installations. Purity requirements for vehicular fuel are lower than those for pipeline injection. The biggest barriers to CNG or LNG conversion are the lack of a widespread infrastructure for gas filling stations and the cost of vehicle conversion for CNG or LNG use. Small scale packaged CNG conversion systems and filling station equipment are available from a single manufacturer and includes sulfur removal in a vessel with proprietary media, siloxanes removal in an activated carbon vessel and membrane carbon dioxide removal. There are currently three biogas CNG installations in the US, two at landfills and one at the Janesville, Wisconsin, WPCF. Note that UMass does not have any CNG vehicles currently in use.

Cogeneration Technology Selection

As previously noted, reciprocating internal combustion engines are the most widespread, economical and efficient of all CHP technologies currently used for biogas cogeneration. Though the selection of CHP technology should be revisited during later stages of development for this project, internal combustion engines were selected for use in the following system sizing as well as the cost estimates included later in this section.

Figure 4-4
GE Jenbacher 850 kW IC Engine

For the purpose of engine sizing, it was assumed that engine selection would be based on ensuring that the average biogas production rate under each alternative would be capable of being utilized by the selected engine(s). Biogas feed rate to the engine less than the total rated capacity would be utilized by either running the engines at a reduced rate. It was further assumed that a parasitic load of 5% of the total electrical output is needed to provide energy for compression, gas boosting and gas treatment. For example, a 400 kW unit will produce 380 kW assuming 5% of the power produced is consumed by the parasitic load of the equipment used to operate the cogeneration system.

4.6.2 Projected Energy Balance

As noted previously, the digestion of organics yields biogas production and associated energy recovery opportunities. However, the processing of solids yields energy consumption in the following areas:

- Heat required for preheating incoming waste;
- Heat to replace energy lost to the environment through tank walls, cover, etc;
- Electrical energy for the digestion system components (pumps, mixers, etc); and
- Electrical energy for the downstream processing of digestate (effluent from the digester).

The above demands need to be considered along with the anticipated CHP energy production in order to yield a realistic estimate of net energy which would be available for other purposes.

CHP Energy Production

As noted above, in order to realize an environmental and financial benefit from this biogas, it would need to be utilized in a CHP cogeneration system. The internal combustion engine assumed for this analysis would have an average electrical generation efficiency generally between 30- and 40-percent. However, when the waste heat produced by this equipment is recovered and reused for process or facility heating requirements, an overall system efficiency of over 80% can generally be realized.

Table 4-6 summarizes the amount of power and heat produced if the biogas is utilized in a reciprocating engine. As shown, the total estimated electrical output using average biogas production rates and assuming a 95% capture rate is estimated to range from 530 kW to approximately 1,100 kW.

Table 4-6
CHP Sizing and Energy Balance

Biogas Production and CHP Sizing	*Alternatives A-1 and A-2*		*Alternative B-1 and B-2*	
	Summer	*Winter*	*Summer*	*Winter*
Biogas Production (cf/day)	219,763	219,763	377,483	377,483
Biogas Production (scfm)	153	153	262	262
Average Biogas Captured (95%)(scfm)	145	145	249	249
Equivalent reciprocating engine size (kW at full load)	800	800	1,550	1,550
Total Recoverable Heat (MMBtu/hr at full load)	2.9	2.9	5.7	5.7
CHP Capacity Utilization with Average Biogas (%)	80%	80%	79%	79%
Heat Balance				
Recoverable Heat from Average Biogas (MMBtu/hr)	2.30	2.30	4.5	4.5
Design Temperatures				
Minimum Ambient Design Temperature (deg F)	60	0	60	0
Incoming EFW Temperature (assumed) (deg F)	60	50	60	50
Internal Digester Temperature (deg F)	95	95	95	95

Table 4-6 (Cont'd)
CHP Sizing and Energy Balance

Biogas Production and CHP Sizing	Alternatives A-1 and A-2		Alternative B-1 and B-2	
	Summer	Winter	Summer	Winter
EFW Feed Heat Requirement				
Flow Rate (gpm)	21	21	35	35
Total Feeding Heat Required (MMBtu/hr)	0.36	0.46	0.61	0.78
Maximum Conductive Heat Loss (MMbtu/hr)				
Cover (Insulated, U=0.28)	0.03	0.09	0.05	0.12
Wall (Insulated Above Grade, U=0.14)	0.03	0.09	0.05	0.12
Bottom (Uninsulated, U=0.50)	0.06	0.15	0.08	0.22
Total Maximum Conductive Heat Loss	0.12	0.33	0.17	0.47
Building Heat Requirements (MMBtu/hr)				
New Process Buildings (~25 Btu/sf)	0.6	0.6	1.0	1.0
Total Potential Heat Demand (MMbtu/hr)	1.1	1.4	1.8	2.3
Net Remaining Heat Energy (MMBtu/hr)	1.2	0.9	2.7	2.2
Electricity Balance				
CHP Electrical Output at Average Biogas (kW)	640	640	1,230	1,230
New Process Equipment	80	80	100	100
Biogas Boosting (5% of Production)	32	32	62	62
Total Demand	112	112	162	162
Net Remaining Electrical Energy (kW)	530	530	1,100	1,100

Heat Balance

In this application, the waste heat from the CHP equipment would be recovered and applied to influent preheating and to maintain mesophylic digestion tank temperatures. The theoretical energy use for these heating needs was calculated and included in Table 4-4. It should be noted that these heat demand values are based on the noted temperatures and could be significantly less during the warmer seasons and/or with warmer incoming waste temperatures. In addition to process heat, the new buildings required to house the equipment are assumed to utilize CHP waste heat for facility heating demands.

Electricity Balance

The expected electrical production from the CHP system is currently estimated to range from 0.53 to 1.1 MW, depending on the feedstock acceptance quantity. Conceptual estimates of electrical demand from the new systems were also completed. This demand would originate from the equipment required for the pre-processing equipment (if required), digestion process, biogas treatment, dewatering systems and side stream treatment (discussed later in this section).

4.7 Solid and Liquid Products and Byproducts

Though the potential benefits of accepting and processing biosolids and SSO materials can be significant due to the biogas production potential, the digestate flow from the process is roughly equivalent to the hydraulic input and contains significant inert and undigested solids that must be dealt with. In some facilities, this digestate is simply land applied as a soil amendment. However, for the conceptual UMass-Amherst facility, it is currently assumed that further onsite processing will be required prior to beneficial reuse or disposal.

The major additional downstream processes that would be required include the following:

- Temporary storage of digested solids;
- Concentration of the digestate solids using a dewatering process; and
- Treatment of the dewatering sidestream prior to discharge into the municipal sewer system or off-site disposal.

Because of space constraints, a dewatered solids composting facility could not be located on-site. It is assumed that there is not enough available land area at the site to support a composting operation and that the dewatered digestate will be disposed of at an off-site location.

4.7.1 Digestate Storage

The dewatering system for the digestate would likely be operated on a similar daily schedule as the receiving and pre-processing system. As the digester(s) would be fed and would discharge continuously, digested sludge storage volume would be required during the hours when the dewatering system is not in operation. CDM Smith has assumed two days of digestate storage. Note that the AD facility may want additional storage depending onoperating days and the flexibility of the digestion operations.

With the use of submerged fixed covers over the digestion tank(s) and the need for biogas storage volume (discussed previously), the need for digestate storage tanks provides a good opportunity to cover this tank with a biogas membrane and use the headspace of the tank as the storage mechanism. This also enables any additional biogas production resulting from methanogenesis within the storage tank to be captured and utilized. Costs included below incorporate this concept of dual purpose storage.

4.7.2 Dewatering Technology Selection and Sizing

There are a variety of technologies available for the dewatering of digested sludge. A brief description of the leading and most proven technologies is as follow:

- ***Belt Filter Press:*** A conventional belt filter press (BFP) is a dewatering device that applies mechanical pressure to a chemically conditioned sludge, which is sandwiched between two tensioned porous belts. By passing those belts through a serpentine of decreasing diameter rolls, the digestate is gradually compressed by increasing pressure which presses water out while leaving a drier cake behind. Belt filter presses offer numerous advantages over comparable dewatering technologies including: Rapid start-up and shut-down of equipment; less noise and low electrical power consumption compared to centrifuges; low polymer consumption; relatively low maintenance to operate; and low staffing requirements. Conversely, major disadvantages of a belt filter press unit include; odor release during dewatering requires high rate ventilation and odor control; extensive manual cleaning at the end of an operating cycle is necessary for wash down, and moderate to high water demands for belt wash system.

- ***Rotary Press:*** Rotary presses offer moderate to high degree of dewatering with minimal equipment foot print, minimize odor control and room ventilation requirement by fully enclosing the dewatering process and provide a fully automated cleanup cycle minimizing staffing needs for cleanup. The basic operating principal of a rotary press is to feed digestate between twin perforated plates that simultaneously compress and dewater it. Major advantages of rotary presses over belt filter presses and centrifuges include automated wash down cycle, low housekeeping maintenance requirements and minimal odor generation. Major disadvantages include poor dewatering performance on thin low fiber materials and operating performance varies considerably amongst existing installations.

- ***Centrifuge:*** Centrifugal solids dewatering of digestate is a high speed process that utilizes the centrifugal forces generated during high speed rotation of a cylindrical bowl assembly to physically separate and dewater solids from liquid in wastewater sludge. Liquid digestate is pumped into stainless steel bowl that is spun at very high speeds producing gravity accelerations between 2,500 -3,500 G. The heavier solids accumulate at the bowl wall and are then discharged by means of a helicoidally shaped screw known as a scroll, which pushes the solids from the cylindrical section of the bowl, up through the conical section and towards the discharge ports. The liquid phase, known as the centrate, finds its way back down the centrifuge bowl where it flows out to the discharge pipe. Centrifuges offer numerous advantages including high loading capacity, smaller equipment footprint, minimal operator attention and minimal odor emissions. Disadvantages include high energy costs, lengthy shut-down period and generally require special structural considerations due to weight and dynamic loading concerns.

It has been assumed that belt filter press technology will be used as a result of its low energy cost and proven reliability in dewatering.

Table 4-7 summarizes the assumed operating parameters and anticipated performance of this system under the two loading scenarios.

Table 4-7
Digestate Dewatering

	Alternative A	*Alternative B*
Flow to Dewatering (gal/day)	29,636	50,023
Flow to Dewatering (8 hrs/day, 6 days/wk) (gpm)	72	122
Solids to Dewatering (lb/day)	9,123	15,472
Solids to Dewatering (8 hrs/day, 6 days/wk) (lb/hr)	1,300	2,300
Digestate Storage Volume (assuming 2 days) (gal)	59,000	100,000
Dewatering Feed Concentration (%)	3.7%	3.7%
Assumed Dewatered Cake Solids (%)	25%	25%
Assumed Dewatering Solids Capture (%)	95%	95%
Dewatered Cake Water Content (gal/day)	4,400	7,400
Dewatered Cake Requiring Disposal (wet tons/day)	17	29
Centrate Requiring Disposal (gal/day)	25,000	42,600

4.7.3 Side Stream Treatment Considerations

As noted above, the dewatering process would concentrate the digested solids while producing a side stream flow that would require further treatment. The amount of side stream to be disposed of is estimated to range between 25,000 and 42,600 gal/day. Though limited data is available pertaining to the quality of this flow from an exclusively SSO digester, it is known that typical side stream downstream of anaerobic digestion can have significant ammonia concentrations.

The presence of ammonia in wastewater can significantly increase secondary wastewater treatment process oxygen requirements along with the associated aeration costs. This results from the biological nitrification process where approximately four times the oxygen is required to treat one pound of ammonia as compared to one pound of typical oxygen demand. For this reason, many municipal treatment facilities enforce ammonia pretreatment limits which must be achieved prior to discharge to the municipal collection system.

The proximity of the Amherst WPCF to the UMass site could potentially provide a nearby location for the treatment of the liquid sidestream generated from the digestate. Currently, the Amherst WPCF is updating their facilities plan to determine current needs for potential plant upgrades. These upgrades include items such as increasing the amount of plant effluent that is beneficially reused (currently some effluent is used for production by the UMass CHP after further treatment); equipment upgrades required to continue operations; and potential impacts of lower discharge standards in future permits issued by USEPA and MassDEP for the plant. Given the permits issued at other plants, CDM Smith anticipates that any future permit for the Amherst WPCF could have a lower standard for total nitrogen (which includes ammonia). Therefore, any significant increase in the nitrogen loading from a proposed AD facility, and given the anticipated concentrations of ammonia of between 1,000 and 2,000 mg/l from the AD facility sidestream compared to the typical municipal wastewater concentrations of 25 to 50 mg/l, the AD facility flows could represent a significant additional loading on the plant.

The Amherst WPCF does not currently have an Industrial Pretreatment Program (IPP) in-place. An IPP is typically implemented by the treatment plant to set appropriate discharge standards for the large flow and loading users in the system to control the incoming loadings into the plant. There are currently no such significant industrial users (SIU) discharging into the Amherst collection system. In meetings with the WPCF operator, they voiced strong concern to implementing an IPP for their WPCF.

Implementation of an IPP requires significant effort by the plant operator and regular effluent sampling and reporting by the SIU. An IPP is required by regulations if either (1) the AD facility discharges more than 25,000 gpd into the Amherst system; (2) the loading of nitrogen or any other constituent is more than 5% of the incoming loading on the Amherst WPCF; or (3) the town determines that one is needed. CDM Smith notes that the volume of sidestream estimated for the two feedstock scenarios will exceed the 25,000 gpd and potentially exceed the 5% loading threshold requiring an IPP.

There are several alternative methods for pretreatment of the sidestream from the AD facility. For the purposes of this evaluation, CDM Smith has assumed that the sidestream would be treated on-site to remove nitrogen with eventual discharge into the Amherst WPCF or transportation to an off-site facility. Since the final vendors will determine the quantity of centrate, generated as well its relative strength, the final decision on the approach will need to be determined as part of the response to the anticipated RFP.

4.8 Schematic Site Plan

As part of this analysis and based on the preliminary sizes for the two proposed feedstock scenarios, CDM Smith developed a proposed conceptual site plan for the facility at the UMass-Amherst site (see Figure 4-5).

4.9 Capital Cost Estimates

As generally reflected in Figure 4-5, the major new facility components that would be required for this facility and which serve as the basis for the conceptual capital costs summarized in Tables 4-8 through 4-11, inclusive include the following:

- ***Pre-Processing Facility:*** The components and design of this system would be intended to process the incoming waste into a pumpable and digestible material free from foreign objects. The equipment associated with this system is assumed to be housed inside a building with all required ancillary systems including adequate ventilation and odor control. The processing capacity of the system considered here could range between 5.5 wt/hr to 9.6 wt/hr.

- ***Pre-Digestion Food Waste Storage Tanks and Pump Station:*** As a result of the continuous feeding needs in comparison with the receiving schedule noted previously, it is expected that pre-digestion engineered food waste storage tank(s) would be required. The estimated size of this storage would equate to between 82,000 and 141,000 gallons for the two options being evaluated.

- ***New Anaerobic Digester(s) and Ancillary Digestion Equipment:*** The two options evaluated yield a need for approximately 0.8 and 1.4 million gallons of digestion capacity. It has been assumed that this would be provided inside of cast-in-place concrete tanks with submerged fixed covers. In addition, a digester equipment building would be provided to house the mixing, heating and other ancillary digestion equipment. Biogas Collection, Safety and Boosting Equipment would also be provided in the form of collection headers, foam separator, sediment trap, flame arrestors, condensate traps, emergency relief valves, as well as a waste gas burner system to combust any biogas not utilized in the CHP system. In addition, a pressure boosting system would be required to increase the gas pressure being fed to the CHP system.

- ***Digestate and Biogas Storage:*** Due to the assumed dewatering schedule relative to the constant effluent rate from the digester, digested sludge storage volume would be required. In addition, biogas storage would be required to help maximize the CHP utilization by adsorbing fluctuations in biogas production and CHP operation. It is recommended that these two components be combined into a new concrete tank covered by a gas holder membrane and associated costs have been included.

- ***New Cogeneration Engines:*** As previously noted, reciprocating internal combustion engines are the most widespread, economical and efficient of all CHP technologies currently used for biogas cogeneration. Though the selection of CHP technology should be revisited during later stages of this project, internal combustion engines were selected for use in the system sizing as well as the economic evaluation included in the previous tables.

Figure 4-5
General Conceptual Site Plan for All Alternative Scenario

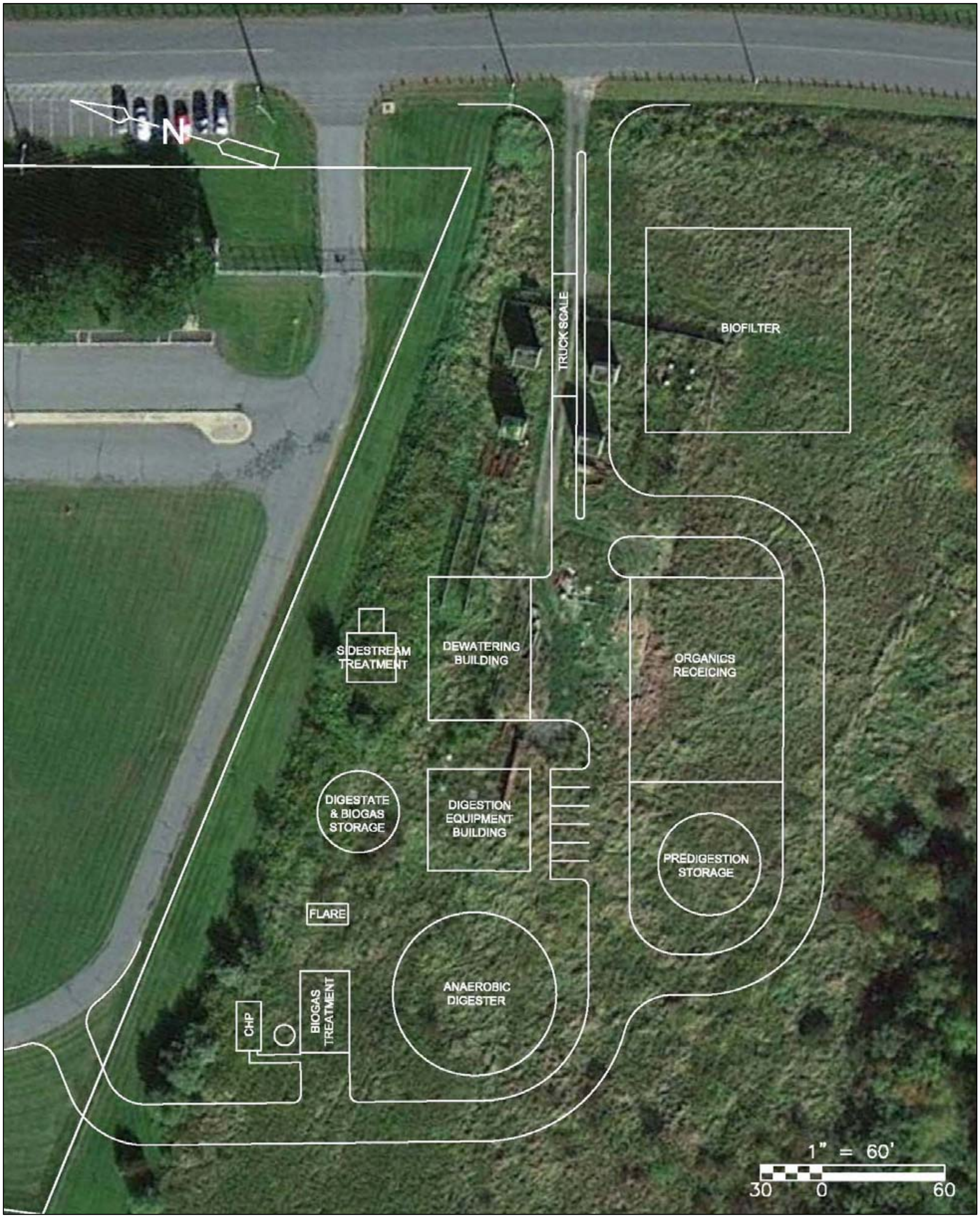

Table 4-8
Summary of Estimated Capital Costs
Alternative A-1 – 30,000 TPY AD Facility with On-Site Pre-Processing

Capital Cost Item	*Unit Size*	*Equipment*	*Install and Buildings*	*Subtotal Equipment & Install*
Pre-Processing (Based on 24-hour process operation)	5.5 wt/hr	$4,250,000	$2,852,000	$7,102,000
Pre-Digestion Storage Tank	80,000 gal	$100,000	$190,000	$290,000
Digestion Tank	0.8 MG		$ 875,000	$875,000
Digestion Support Building and Ancillary Equipment	~4,000 sf		$2,576,000	$2,576,000
Digestate/Biogas Storage Tank	60,000 gal, 70,000 cf gas	$310,000	$85,000	$395,000
H_2S Removal System	200 scfm max mo	$487,000	$340,000	$827,000
CHP Internal Combustion Engine and Electrical Infrastructure	800 kW	$984,000	$75,000	$1,059,000
Dewatering Facility (8 hrs/day, 6 day/week)	1,300 lb/hr	$325,000	$1,265,000	$1,590,000
Sidestream Treatment Equipment	30,000 gal/day	$185,000	$300,000	$485,000
Odor Control Biofilter	40,000 cfm		$2,700,000	$2,700,000
Truck Scale		$75,000	$150,000	$225,000
Rolling Stock (Loader, Trucks, Other Equipment)	-	$300,000	-	$300,000
Sitework and Yard Piping			$100,000	$100,000
Subtotal - Direct Costs				**$18,524,000**
Insurance, Construction Permits, Bonds, etc..			4%	$741,000
Contractor's Overhead and Profit			8%	$1,482,000
General Construction Conditions Allowance			10%	$1,852,000
Subtotal - Direct and Indirect Costs				**$22,599,000**
Construction Contingency			25%	$5,650,000
Subtotal - Construction Cost				**$28,249,000**
Allowance - Engineering Costs			15%	$4,237,000
Escalation to Mid-Point of Construction (two years)			6%	$1,695,000
TOTAL ESTIMATED CONSTRUCTION COST				**$34,181,000**

*All structures assumed to require 12-ft over excavation and replacement with structural fill.

LAWPCA - Lewiston-Auburn (ME) Water Pollution Control Authority - recent digester CHP project by CDM Smith.

Table 4-9
Summary of Estimated Capital Costs
Alternative A-2 – 30,000 TPY AD Facility without No On-Site Pre-Processing

Capital Cost Item	*Unit Size*	*Equipment*	*Install and Buildings*	*Subtotal Equipment & Install*
Pre-Processed SSO and UMass SSO Acceptance Facilities	Allowance	$200,000	$300,0000	$500,000
Pre-Digestion Storage Tank	80,000 gal	$100,000	$190,000	$290,000
Digestion Tank	0.8 MG		$875,000	$875,000
Digestion Support Building and Ancillary Equipment	~4,000 sf		$2,576,000	$2,576,000
Digestate/Biogas Storage Tank	60,000 gal, 70,000 cf gas	$310,000	$85,000	$395,000
H_2S Removal System	200 scfm max mo	$487,000	$340,000	$827,000
CHP Internal Combustion Engine and Electrical Infrastructure	800 kW	$984,000	$75,000	$1,059,000
Dewatering Facility (8 hrs/day, 6 day/week)	1,300 lb/hr	$325,000	$1,265,000	$1,590,000
Sidestream Treatment Equipment	30,000 gal/day	$185,000	$300,000	$485,000
Odor Control Equipment Allowance	Allowance	$500,000	$250,000	$750,000
Truck Scale		$75,000	$150,000	$225,000
Rolling Stock (Loader, Trucks, Other Equipment)	-	$300,000	-	$300,000
Sitework and Yard Piping			$100,000	$100,000
Subtotal - Direct Costs				**$9,872,000**
Insurance, Construction Permits, Bonds, etc..			4%	$395,000
Contractor's Overhead and Profit			8%	$790,000
General Construction Conditions Allowance			10%	$987,000
Subtotal - Direct and Indirect Costs				**$12,044,000**
Construction Contingency			25%	$3,011,000
Subtotal - Construction Cost				**$15,055,000**
Allowance - Engineering Costs			15%	$2,258,000
Escalation to Mid-Point of Construction (two years)			6%	$903,000
TOTAL ESTIMATED CONSTRUCTION COST				**$18,216,000**

*All structures assumed to require 12-ft over excavation and replacement with structural fill.

Table 4-10
Summary of Estimated Capital Costs
Alternative B-1 – 50,000 TPY AD Facility with On-Site Pre-Processing

Capital Cost Item	*Unit Size*	*Equipment*	*Install and Buildings*	*Subtotal Equipment & Install*
Pre-Processing Equipment (Based on 24-hour process operation)	9.6 wt/hr	$4,250,000	$2,863,000	$7,113,000
Pre-Digestion Storage Tank	140,000 gal	$150,000	$250,000	$400,000
Digestion Tank	1.4 MG		$925,000	$925,000
Support Building and Ancillary Equipment	~5,000 sf		$3,220,000	$3,220,000
Digestate Storage Tank	100,000 gal, 100,000 cf	$400,000	$90,000	$490,000
H_2S Removal System	340 scfm max mo	$584,000	$340,000	$924,000
CHP Internal Combustion Engine and Electrical Infrastructure	1,550 kW	$1,338,000	$100,000	$1,438,000
Dewatering Facility (8 hrs/day, 6 day/week)	2,300 lb/hr	$475,000	$1,270,000	$1,745,000
Sidestream Treatment Equipment	50,000 gal/day	$318,000	$485,000	$803,000
Odor Control Biofilter	40,000 cfm		$2,700,000	$2,700,000
Truck Scale		$75,000	$150,000	$225,000
Rolling Stock (Loader, Trucks, Other Equipment)		$400,000	-	$400,000
Sitework and Yard Piping			$100,000	$100,000
Subtotal - Direct Costs				**$20,483,000**
Insurance, Construction Permits, Bonds, etc.			4%	$819,000
Contractor's Overhead and Profit			8%	$1,639,000
General Construction Conditions Allowance			10%	$2,048,000
Subtotal - Direct and Indirect Costs				**$24,989,000**
Construction Contingency			25%	$6,247,000
Subtotal - Construction Cost				**$31,236,000**
Allowance - Engineering Costs			15%	$4,685,000
Escalation to Mid Point of Construction (two years)			6%	$1,874,000
TOTAL ESTIMATED CONSTRUCTION COST				**$37,795,000**

*All structures assumed to require 12-ft over excavation and replacement with structural fill.

Table 4-11
Summary of Estimated Capital Costs
Alternative B-2 – 50,000 TPY AD Facility without Pre-Processing

Capital Cost Item	*Unit Size*	*Equipment*	*Install and Buildings*	*Subtotal Equipment & Install*
Pre-Processed SSO and UMass SSO Acceptance Facilities	Allowance	$200,000	$300,0000	$500,000
Pre-Digestion Storage Tank	140,000 gal	$150,000	$250,000	$400,000
Digestion Tank	1.4 MG		$925,000	$925,000
Support Building and Ancillary Equipment	~5,000 sf		$3,220,000	$3,220,000
Digestate Storage Tank	100,000 gal, 100,000 cf	$400,000	$90,000	$490,000
H2S Removal System	340 scfm max mo	$584,000	$340,000	$924,000
CHP Internal Combustion Engine and Electrical Infrastructure	1,550 kW	$1,338,000	$100,000	$1,438,000
Dewatering Facility (8 hrs/day, 6 days/week)	2,300 lb/hr	$475,000	$1,270,000	$1,745,000
Sidestream Treatment Equipment	50,000 gal/day	$318,000	$485,000	$803,000
Odor Control Equipment	Allowance	$700,000	$300,000	$1,000,000
Truck Scale		$75,000	$150,000	$225,000
Rolling Stock (Loader, Trucks, Other Equipment)		$400,000	-	$400,000
Sitework and Yard Piping			$100,000	$100,000
Subtotal - Direct Costs				**$12,170,000**
Insurance, Construction Permits, Bonds, etc..			4%	$487,000
Contractor's Overhead and Profit			8%	$974,000
General Construction Conditions Allowance			10%	$1,217,000
Subtotal - Direct and Indirect Costs				**$14,848,000**
Construction Contingency			25%	$3,712,000
Subtotal - Construction Cost				**$18,560,000**
Allowance - Engineering Costs			15%	$2,784,000
Escalation to Mid Point of Construction (two years)			6%	$1,114,000
TOTAL ESTIMATED CONSTRUCTION COST				**$22,458,000**

*All structures assumed to require 12-ft over excavation and replacement with structural fill.

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- ***Dewatering Facility:*** Due to the low solids concentration of the digestate, a solids dewatering system would be required. The system is assumed to include feed pump system, belt filter press dewatering equipment, cake truck storage bay and other ancillary systems – all housed in an enclosed superstructure due to environmental (freezing) concerns as well as odor control considerations.

- ***Sidestream Treatment Facility:*** The dewatering process would concentrate the digested solids while producing a side stream flow that would require further treatment. The amount of side stream to be disposed of is estimated to range between 25,000 and 42,600 gal/day. Though limited data is available pertaining to the quality of this flow from an SSO digester, it is known that typical side stream downstream of anaerobic digestion can have significant ammonia concentrations. Conceptual costs for a separate deammonification treatment system have been included in the analysis.

- ***Rolling Stock:*** Various pieces of equipment would be required for receiving of materials and maintenance of the facility. As such, an associated allowance has been included.

All capital costs include a 25% allowance for construction contingencies and an additional 15% for engineering of the associated improvements.

4.9.1 Summary of Capital Costs

The capital costs for each alternative facility are summarized on Table 4-12 below.

Table 4-12
Summary of Estimated Capital Costs for Different AD Facilities at UMass-Amherst Site

Alternative		*Estimated Capital Cost*
A-1	30,000 TPY AD Facility with On-Site Pre-Processing	$34.2 million
A-2	30,000 TPY AD Facility with No On-Site Pre-Processing	$18.2 million
A-3	50,000 TPY AD Facility with On-Site Pre-Processing	$37.8 million
A-4	50,000 TPY AD Facility with No On-Site Pre-Processing	$22.5 million

Operation of an organics processing facility at the site would carry with it significant costs which need to be considered in the conceptual financial analysis. Based on discussions with MassDEP and the high costs related to pre-processing at the proposed AD facility, it was decided to not include pre-processing costs in the overall capital costs for the analysis of the overall project costs outlined as part of this feasibility study. Therefore, for future cost analysis, CDM Smith assumes that only options A-2 and B-2 will be evaluated further. Note that all the future scenarios assume that the UMass generated SSO materials and possibly a small amount of the other SSO materials may require some minor processing as discussed above prior to being input into the AD unit. The determination of the level of pre-processing that is financially viable will have to be part of the RFP being prepared for the private developers of the facility.

4.10 Estimated Annual Operation and Maintenance Costs

The second component of the financial analysis is the annual operation and maintenance (O&M) costs for each facility. Table 4-13 and 4-14 includes the O&M costs for scenarios A-2 and B-2, respectively, based on the following general assumptions:

- ***Labor:*** The maintenance and operation of both of the proposed AD facilities is assumed to require three full-time (40 hours per week) employees. As such, the associated total labor costs were developed based on a blended rate of $50/person hour (including fringe benefits).

- ***Dewatering Chemicals:*** Dewatering of digestate will require polymer for proper operation and solids capture. It was assumed that this chemical would be consumed at a rate of 50 lbs polymer per dry ton of organic solids and would cost approximately $1.50/lb Polymer.

- ***Offsite Digestate Disposal:*** The residual solids from the facility would require disposal. Though there may be an opportunity for reuse of this material for animal bedding or agricultural fertilizer, as there have not been any specific outlets identified at this time, it has been assumed that disposal will be required at a rate of $50/wet ton.

- ***General System Maintenance:*** Systems and equipment of this magnitude will inherently carry with it ongoing costs for operations and maintenance. For general maintenance activities, it has been assumed that this annual cost would equate to approximately 2% of the equipment capital cost. All equipment assumed for this facility is anticipated to have a minimum useful lift of 15 years and this O&M cost item does not included any equipment replacement.

Table 4-13
Summary of Estimated Annual O&M Costs for Alternative A-2
30,000 TPY AD Facility without On-Site Pre-Processing

Costs/Revenues	Quantity	Units	Unit Cost	Subtotal Cost
Labor	120	Hours/week	$50	$312,000
Dewatering Process Chemicals	160	Tons per year	$3,000	$480,000
Off-Site Digestate Disposal	6,200	Tons per year	$30	$186,000
General Facility O&M	2%	Subtotal Construction Cost	$11.2 million	$236,000
On-Site Liquid Sidestream Treatment	25,000	gpd	$0.03	$274,000
Total Estimated Annual O&M Costs				**$1,488,000**

Costs rounded to nearest thousand dollars and are for first year of operation (2015)

Table 4-14
Summary of Estimated Annual O&M Costs for Alternative A-2
50,000 TPY AD Facility without On-Site Pre-Processing

Costs/Revenues	Quantity	Units	Unit Cost	Subtotal Cost
Labor	120	Hours/week	$50	$312,000
Dewatering Process Chemicals	270	Tons per year	$3,000	$810,000
Off-Site Digestate Disposal	10,600	Tons per year	$30	$318,000
General Facility O&M	2%	Subtotal Construction Cost	$ 13,870,000	$277,000
On-Site Liquid Sidestream Treatment	42,600	gpd	$0.03	$466,000
Total Estimated Annual O&M Costs				**$2,183,000**

Costs rounded to nearest thousand dollars and are for first year of operation (2015)

4.11 Anticipated Additional Traffic

Based on several conversations with MassDEP and UMass, one of the primary potential concerns with the development of an AD facility is any increase in truck trips on the roadways around the proposed site. Based on these conversations, CDM Smith developed preliminary estimates of potential increases in truck traffic related to the proposed facility.

As a basis of comparison to current traffic levels, UMass provided CDM Smith with recent total peak vehicle trips (trucks and cars) collected around the UMass campus by Vannasse Hangen Brustlin Engineers (VHB) during the weekday morning and evening peak travel hours in March 2012. Based on this information, there was no data collected during the weekday morning at the intersection of North Hadley Road and Mullins Way but there was approximately 500 trips per hour travelling eastbound on North Hadley Road at the intersections immediately adjacent to Mullins Way. Approximately 100 vehicle trips were recorded at the same intersections moving westbound during the same period. During the afternoon peak hour, there were counts collected at the Mullins Way/North Hadley Road intersection that showed 28 vehicle trips existing Mullins Way onto North Hadley Road and 300 and 560 vehicles travelling westbound and eastbound, respectively, on North Hadley Road.

The proposed AD facilities to be evaluated are based on the SSO materials being pre-processed (e.g. in a form that can be pumped into a storage tank). Therefore, CDM Smith has anticipated that this feedstock stream will be delivered in larger capacity vehicles. The biosolids will also be delivered in larger tanker trucks as is typically done at WPCFs due to the significant distances that these materials are currently being hauled. The specific assumptions used to develop the additional truck trips to the facility are summarized in Table 4-15 below. Note that in addition to the truck trips, there would be a minimal amount of additional vehicle trips for the employees and visitors to the AD facility.

Table 4-15
Summary of Assumptions Utilized to Estimate Additional Truck Trips to Proposed AD Facility

Average Gallons Per Truck for Biosolids	3,000 gallons
Assumed Solids Concentration - Biosolids	6%
Average Tons Per Truck Trip – SSO Materials	12 tons
Assumed Peaking Factor (Daily Trips)	1.5
Operating Days Per Year	250 days

There are currently truck trips generated from two sources of feedstock to the proposed AD facility on the UMass campus. The biosolids from the Amherst WPCF are currently transported in a large tanker truck from the WPCF to their off-site disposal facility and the SSO materials collected by UMass in "Toter" containers are consolidated and transported to the solid waste facility on the eastern side of the campus. To estimate the assumed net additional truck trips, CDM Smith deducted the volume of SSO materials from the UMass campus and the Amherst WPCF from the materials from "off-site" sources. These calculations are presented in Table 4-16.

After these existing volumes are deducted, CDM Smith estimated the net additional truck trips as summarized in Table 4-15 and added a peaking factor of 1.5 to the daily average to account for variability in the deliveries typical of similar facilities. Using the peak factor and the operational assumptions discussed above, CDM Smith found that a maximum of 17 additional truck round trips would be generated by the facility at its peak proposed capacity.

Table 4-16
Summary of Estimated Tonnages Entering Proposed UMass Amherst Site

Alternative	Total Wet Tons Per Year			Annual Wet Tons Per Year from UMASS and Amherst WPCF			Net Additional Wet Tons Per Year			Net Additional Average Wet Tons Per Day		
	Biosolids	SSO	Total	Biosolids	SSO	Total	Biosolids	SSO	Total	Biosolids	SSO	Total
Alternative A	18,500	11,500	30,000	15,400	1,200	16,600	3,100	10,300	13,400	12	41	53
Alternative B	30,000	20,000	50,000	15,400	1,200	16,600	14,600	18,800	33,400	58	75	133

Assumption

Days per year accepting materials 250

Table 4-17
Summary of Estimated Average and Peak New Trucks Entering Proposed AD Facility

Alternative	Net Additional Average Wet Tons Per Day			Additional Average Truck Trips Per Day (1)			Estimated Peak Daily Truck Trips		
	Biosolids	SSO	Total	Biosolids	SSO	Total	Biosolids	SSO	Total
Scenarios A-1 & A-2	12	41	53	1	3	4	2	5	7
Scenarios B-1 & B-2	58	75	133	5	6	11	8	9	17

1. Additional truck trips shown do not include existing trucks related to UMASS SSO Materials and Amherst Biosolids.

Section 5

Project Pro Forma Financial Analysis

5.1 Overall Approach

In Section 4, CDM Smith developed the components of costs related to the development of an AD facility on the UMass campus based on several assumptions and for four potential development scenarios. Based on the preliminary analysis, two of the scenarios have been selected for further evaluation – Scenarios A-2 and B-2 – 30,000 and 50,000 tpy, respectively, with no on-site pre-processing of SSO materials. As part of the analysis of the potential feasibility of these alternatives, CDM Smith has developed a pro forma financial analysis including various elements related to the development of the AD facility by a private entity on the Commonwealth owned land.

The pro forma accounts for various factors including:

- Payment for payment of financing of capital costs based on the owner being a private entity.
- Benefits of various federal and state incentives and programs to assist private developers of AD facilities.
- Payments to the Town of Hadley for taxes on the privately-owned improvements to the property (e.g. the facility). Note that the Commonwealth or the private vendor could negotiate a Payment In Lieu of Taxes (PILOT) with the Town;
- Operating costs including labor, chemicals, general O&M and disposal of side streams; and
- Revenues including tipping fees from acceptance of biosolids and SSO materials as well as the generation of electricity.

The approach is to develop the pro forma for the two scenarios including all of the cost items and the revenues anticipated from the generation of electricity and disposal of biosolids and then calculate the necessary tipping fee for the disposal of SSO materials to cover any remaining total costs. This "break-even" SSO materials tipping fee can be compared to current solid waste disposal market costs as well as the tipping fee for the same materials currently being paid by UMass.

5.2 Summary of Assumptions

A summary of the significant general facility design and construction assumptions detailed in Section 4 is provided in Table 5-1. In addition to this information, the assumptions utilized to develop the specific pro forma include the costs developed herein are summarized on the attached Table 5-2. The capital cost and first year (2015) O&M costs for the facilities are summarized in Table 5-3. The assumptions used to develop the costs in Table 5-2 are detailed in Section 4.

Table 5-1
Summary of General Project Assumptions Used to Develop Pro Forma Cost Estimates

Description	Assumption
Aesthetics	New facilities will be similar architecturally to surrounding Amherst WPCF and UMass CHP Facility. Also will include additional screening and landscaping.
Foundation Requirements	Although the proposed site is on fill, costs have assumed standard foundations for all structures. Geotechnical requirements need to be confirmed.
Treatment of Liquid Sidestream from AD Facility	Costs for pretreatment of sidestream by AD facility operator with discharge of treated water to Amherst WPCF included in the estimates. Level of treatment and cost will be based on Amherst WPCF requirements as well as type of AD technology selected.
Wetland Resource Areas	There are no significant restrictions from regulations associated with wetland permitting at the site. Extent and type of on-site wetland resource areas needs to be confirmed.
Location of Power Generation Equipment	Assumed that AD facility operator will also install the power-generating equipment on-site for sale of electricity. Costs include preliminary estimate for pretreatment of the biogas for use in power generation.
Source of Dilution Water	Assumed that a no-cost water source such as treated effluent from the Amherst WPCF will be available to facility operator.
Pre-Processing of SSO Materials	Assumed that all SSO materials, except those from UMass operations, will be pre-processed and suitable (after the potential addition of dilution water) for pumping into the AD unit.
Use of Process Heat	All excess heat assumed to be utilized to maintain process temperatures.
Re-use/Disposal of Dewatered Solids	Included costs for transportation and disposal of dewatered solids at off-site location. There is significant variability in the costs for this given the incorporation of wastewater treatment plant residuals into the process.
Method for Dewatering	Preliminary assumption is that operator will dewater digestate on-site utilizing belt filter press technology.

Table 5-2
Summary of Pro Forma Economic Assumptions

Assumption	Value	Basis
Interest Rate for Capital Cost Financing	6%	Anticipated long-term borrowing rate in 2015
Length of financing of capital costs	15 years	Assumption
Percent Capacity Factor for Electricity Generation	95%	Similar operations operating capacity factor based on anticipated maintenance and repair
Annual Increase for O&M related costs including labor	3%	Assumed based on historic Consumer Price Index (CPI)
Annual Increase of Disposal Fee for Biosolids and Electricity Generation	3%	Assumed based on historic Consumer Price Index (CPI)
Town of Hadley Tax Rate per $1,000	$10	Approximate average tax rate based on Town web site
Useful Life of AD facility	15 years	Assumption based on similar facilities
Unit value for electricity generation	$0.10 per kw-hr	Assumption
Disposal Fee for Biosolids	$500 per dry ton	Current Amherst WPCF disposal cost

Table 5-3
Summary of Total Capital and First Year (2015) O&M Costs for Pro Forma Scenarios

Alternative		Estimated Capital Cost	First Year O&M Costs
A-2	30,000 TPY AD Facility with No On-Site Pre-Processing	$18.2 million	$1.49 million
B-2	50,000 TPY AD Facility with No On-Site Pre-Processing	$22.5 million	$2.18 million

For presentation purposes, the pro forma analysis was run for a period of ten years starting in 2015. While it is anticipated that the AD facility will have a useful life of at least 15 years which corresponds to the anticipated facility life. The ten-year span for the pro forma analysis was selected to demonstrate the estimated "breakeven" SSO materials tipping fee for each alternative over a set period.

Reference information on available state and federal tax incentives and how they were incorporated into the pro forma is provided on Table 5-4. Note that the availability of these programs will vary based on the private developers and funding availability.

Table 5-4
Summary of Potential Incentive Programs for Proposed AD Facility

Incentive	Description	Assumptions Used in Pro Forma
Net Metering/Power-Purchase Agreement	Under Department of Public Utilities (DPU) Net Metering Regulations (310 CMR 18.00) allows owner of a meter to be credited for the net value of electricity generated on-site and placed back into the grid.	Electricity assumed to be sold to UMass campus at $0.10/kw-hr which is higher than current net metering rate.
MassCEC Grant Opportunities	Organics to Energy program offers up to $400,000 in grants to private entities for construction related costs.	Not incorporated into pro forma.
Federal Investment Tax Credits (ITC)	Allows for private developers to offset a portion of a renewable energy project by up to 30%. Assume program will continue to be funded.	Assumed estimated capital costs were reduced by 30% for bond payments.
Modified Accelerated Cost-Recovery System (MACRS) plus bonus depreciation	Allows certain renewable assets, including those utilizing biomass, to be depreciated over a timeframe shorter than their usable life (e.g. 5 or 7 years). Assume program will be continued to be funded.	Assumed depreciation of adjusted capital costs (after ITC) over a 7-year period. Did not incorporate bonus depreciation.
Renewable Energy Credits (REC)	Credits for each MWh generated by specific renewable energy facilities (including AD) to assist utilities in meeting their regulatory Renewable Performance Standard (RPS) requirements.	Assume $30 per MWh REC (constant throughout 15 year pro forma life.

5.3 Pro Forma Analysis

Based on the assumptions and costs, CDM Smith developed a ten year cost starting in 2015 as presented in Tables 5-5 and 5-6 for scenarios A-2 and B-2.

For scenario A-2 (30,000 TPY without On-Site Pre-Processing), the "break-even" tipping fee starts in 2015 at a rate comparable to municipal solid waste at $69 per ton but increases substantially to $158. CDM Smith does not anticipate that this higher tipping fee will be competitive with the market rate for municipal solid waste disposal within the ten year period being evaluated as part of this analysis.

For scenario B-2 (50,000 TPY without On-Site Pre-Processing), the "break-even" tipping fee starts in 2015 at a rate of $39 per ton that is significantly lower than typical municipal solid waste tipping fees and is comparable to the rate that UMass currently pays as a tipping fee to compost their SSO materials at an off-site commercial facility. This tipping fee increases to $88 per ton once the tax credit benefits are completed. The $88 per ton tipping fee is approximately 25% higher than current solid waste disposal costs.

Table 5-5
Summary of Pro-Forma Costs and Revenues for Alternative A-2: 30,000 TPY without On-Site Pre-Processing

Costs/Revenues	Quantity	Units	Unit Cost	2015 First Year Cost	2016	2017	2018	2019	2020	2021	2022	2023	2024
Annual Costs/Depreciation													
Capital Costs - Annual Bond Payment (1)	N/A	Annual Payment	N/A	$(1,313,000)	$(1,313,000)	$(1,313,000)	$(1,313,000)	$(1,313,000)	$(1,313,000)	$(1,313,000)	$(1,313,000)	$(1,313,000)	$(1,313,000)
Town Property Taxes	N/A	N/A	N/A	$(180,000)	$(180,000)	$(180,000)	$(180,000)	$(180,000)	$(180,000)	$(180,000)	$(180,000)	$(180,000)	$(180,000)
O&M Costs (2)	N/A	N/A	N/A	$(1,488,000)	$(1,530,000)	$(1,580,000)	$(1,630,000)	$(1,680,000)	$(1,730,000)	$(1,780,000)	$(1,830,000)	$(1,880,000)	$(1,940,000)
Revenues/Offsets													
Tip Fee - Biosolids	1222	Dry Tons	$500	$611,000	$629,000	$648,000	$667,000	$687,000	$708,000	$729,000	$751,000	$774,000	$797,000
Depreciation (MACRS for 7 years)	N/A	N/A	N/A	$960,000	$960,000	$960,000	$960,000	$960,000	$960,000	$960,000	$ -	$ -	$ -
Renewable Energy Credits	4400	MWhr	$30	$132,000	$132,000	$132,000	$132,000	$132,000	$132,000	$132,000	$132,000	$132,000	$132,000
Net Electricity Generation	4,411,000	kw-hr	$0.10	$441,100	$454,000	$468,000	$482,000	$496,000	$511,000	$526,000	$542,000	$558,000	$575,000
Net Subtotal Costs and Revenues/Offsets				**$(836,900)**	**$(848,000)**	**$(865,000)**	**$(882,000)**	**$(898,000)**	**$(912,000)**	**$(926,000)**	**$(1,898,000)**	**$(1,909,000)**	**$(1,929,000)**
Required SSO Tipping Fee - Breakeven				**$69**	**$70**	**$71**	**$72**	**$74**	**$75**	**$76**	**$156**	**$156**	**$158**

Assumptions		
Tons Per Year - Biosolids (Wet)	18,800	
Assumed Percent Solids	6.5%	
Tons Per Year - SSO	12,200	
Capital Costs	$18,216,000	
Interest Rate for Bonds	6.0%	
Length of Bond	15	years
First Year O&M Costs	$1,488,000	
Net Electrical Production Capacity	0.53	MW
Percent Capacity Factor	95%	
CPI for Labor & Materials	3%	
Town of Hadley Mill Rate	$10.00	per $1,000
Renewable Energy Credit Value	$30.00	per MWhr
All dollar numbers rounded to nearest $1,000.		

Notes

1. Total Capital Costs decreased by 30% for bond payment for Federal Investment Tax Credit
2. O&M costs include labor, chemicals, digestate disposal, on-site liquids pretreatment and general equipment and facility O&M

Table 5-6
Summary of Pro-Forma Costs and Revenues for Alternative B-2: 50,000 TPY without On-Site Pre-Processing

Costs/Revenues	Quantity	Units	Unit Cost	2015 First Year Cost	2016	2017	2018	2019	2020	2021	2022	2023	2024
Annual Costs/Depreciation													
Capital Costs - Annual Bond Payment (1)	N/A	Annual Payment	N/A	$(1,417,000)	$(1,417,000)	$(1,417,000)	$(1,417,000)	$(1,417,000)	$(1,417,000)	$(1,417,000)	$(1,417,000)	$(1,417,000)	$(1,417,000)
Town Property Taxes	N/A	N/A	N/A	$(230,000)	$(230,000)	$(230,000)	$(230,000)	$(230,000)	$(230,000)	$(230,000)	$(230,000)	$(230,000)	$ (230,000)
O&M Costs (2)	N/A	N/A	N/A	$(2,183,000)	$(2,250,000)	$(2,320,000)	$(2,390,000)	$(2,460,000)	$(2,530,000)	$(2,610,000)	$(2,690,000)	$(2,770,000)	$(2,850,000)
Revenues													
Tip Fee - Biosolids	1950	Dry Tons	$500	$975,000	$1,004,000	$1,034,000	$1,065,000	$1,097,000	$1,130,000	$1,164,000	$1,199,000	$1,235,000	$1,272,000
Depreciation (MACRS for 7 years)	N/A	N/A	N/A	$890,000	$890,000	$890,000	$890,000	$890,000	$890,000	$890,000	$-	$-	$-
Renewable Energy Credits	9200	MWhr	$30	$276,000	$276,000	$276,000	$276,000	$276,000	$276,000	$276,000	$276,000	$276,000	$276,000
Net Electricity Generation	9,154,000	kw-hr	$0.10	$915,400	$943,000	$971,000	$1,000,000	$1,030,000	$1,061,000	$1,093,000	$1,126,000	$1,160,000	$1,195,000
Net Subtotal Costs and Revenues				**$(773,600)**	**$(784,000)**	**$(796,000)**	**$(806,000)**	**$(814,000)**	**$(820,000)**	**$(834,000)**	**$(1,736,000)**	**$(1,746,000)**	**$(1,754,000)**
Required SSO Tipping Fee - Breakeven				**$39**	**$39**	**$40**	**$40**	**$41**	**$41**	**$42**	**$87**	**$87**	**$88**

Assumptions		
Tons Per Year - Biosolids (Wet)	30,000	
Assumed Percent Solids	6.5%	
Tons Per Year - SSO	20,000	
Capital Costs	$22,500,000	
Interest Rate for Bonds	4.0%	
Length of Bond	15	years
First Year O&M Costs	$2,183,000	
Net Electrical Production Capacity	1.1	MW
Percent Capacity Factor	95%	
CPI for Labor & Materials	3%	
Town of Hadley Mill Rate	$10.00	per $1,000
Renewable Energy Credit Value	$30.00	per MWhr
All dollar numbers rounded to nearest $1,000.		

Notes

1. Total Capital Costs decreased by 30% for bond payment for Federal Investment Tax Credit
2. O&M costs include labor, chemicals, digestate disposal, on-site liquids pretreatment and general equipment and facility O&M

5.3.1 Comparative Benefits to UMass Campus

As a basis of comparison, CDM Smith prepared a table summarizing the current costs for disposal of the University's SSO Materials and purchased electricity (in the amount that is generated by the AD facility) to the future cost should the University dispose of their SSO materials at the estimated tipping fees and purchase the generated electricity at the assumed net rate of $0.10 per kw-hr. The University currently purchases electricity from off-site sources at $0.14 per kw-hr and pays $34 per ton as a tipping fee for SSO materials. The comparison for scenario B-2 is summarized on Table 5-7. Note that this assumes that all of the electricity generated by the AD facility would be a direct substitute for the electricity currently purchased by the University.

This analysis shows that in its first year of operation, the AD facility would have a net estimated benefit of $356,000 to the University in comparison to the current costs for these items. If the tipping fee for SSO materials was to increase substantially as shown on the pro forma analysis, the University would continue to have a significant benefit (assuming the cost for their purchased electricity remains at the current rate).

5.4 Summary of Pro Forma Analysis

Based on this pro forma analysis, CDM Smith notes the following:

- The investment tax credit and the accelerated depreciation is a critical cost component in offsetting the significant capital costs for development of the AD facility. Note that different private developers will have differing potential benefits from this credit. As this credit requires renewal at the federal level, the status of the credit and the continued eligibility of AD technologies needs to be monitored as the Commonwealth completes the procurement process.

- In both scenarios, a significant amount of the revenues come from the disposal of biosolids. The operator will need to develop long-term agreements with WPCF's at close to current market rates and to secure this portion of the revenue stream. The Commonwealth should also consider allowing other local WPCF's to provide biosolids.

- The unit rate for the sale of electricity generated by the AD facility is significant. This rate could be enhanced with either a direct contract with the UMass CHP facility to off-set their purchased electricity, the Amherst WPCF, or potentially through "net-metering" provisions of the Green Communities Act.

- The break-even tipping fee required for SSO materials is marginally competitive with anticipated municipal solid waste disposal fees anticipated by CDM Smith over the life of the proposed AD facility. We note that the financial models presented herein for this pro forma analysis have many built in assumptions and the private vendors who have shown a significant interest in this project will have differing abilities to finance and move this project further.

Table 5-7
Summary of Potential Benefits to UMass Campus of Proposed AD Facility

Revenue Item	Current Unit Cost	Units	Quantity	Current Costs (2013)	Future Unit Cost (2015)	Units	Future Potential Costs (2015)	Net Benefits
SSO Materials Tipping Fee	$34	per ton	1,200	$41,000	$39	per ton	$47.000	
Electricity	$0.14	per kw-hr	9,154,000	$1,282,000	$0.10	per kw-hr	$915,000	
Totals				**$1,323,000**			**$962,000**	**$361,000**

Quantities shown are for amounts of SSO materials currently generated by UMass and net amount of electricity generated by AD facility. Costs are rounded to nearest $1,000.

Section 6
Conclusions

As the MassDEP moves to ban SSO materials generated by larger commercial entities from disposal in landfills and waste-to-energy facilities, there is a need to develop an infrastructure of new facilities to handle the diverted materials in a cost-effective, environmentally-sound manner. AD technology can accept the SSO materials anticipated to be diverted potentially with WPCF biosolids and generate electricity and/or heat as well as a potentially reusable solid product. The Commonwealth has numerous initiatives underway to promote AD and similar technologies including

- Revising the MassDEP's solid waste regulations to provide a clear permitting pathway for these types of facilities while maintaining protection of public health, safety and the environment;
- Providing financial incentives including grants to potential facility developers and municipalities to evaluate AD technology and implement pilot programs;
- Solicited public comment on the proposed waste ban for SSO materials and working to finalize the required regulations;
- Identifying state owned land where an AD facility may be appropriate to site and operate;

This feasibility study has been prepared to evaluate the potential development of an AD facility at a location on the western portion of the UMass-Amherst campus adjacent to the Town of Amherst's WPCF, North Hadley Road and Route 116. The land is owned by the Commonwealth.

CDM Smith understands that the Commonwealth through DCAMM is currently preparing a Request for Qualifications (RFQ) to be followed by a Request for Proposals (RFP) to be released to private vendors to develop an AD facility on each of three state owned properties including the UMass-Amherst site evaluated herein. The information collected as part of this feasibility study will be partially incorporated into the RFQ/RFP(s).

Based on the analysis conducted as part of this feasibility study, CDM Smith concluded the following:

1. ***Site Size*** - The proposed site is adequate in size and has no significant technical constraints that would limit the permitting and construction of an appropriately sized AD facility. Note that the site does not have additional space to handle the solid residual from the AD facility in a composting or similar operation.

2. ***Wetland Resource Areas*** - CDM Smith visited the site with a wetland scientist to conduct a preliminary review of wetland-related permitting requirements for the proposed AD facility. Based on this site walk, there are wetland resource areas on-site and additional investigations related to on-site wetland resources beyond the scope of this feasibility study need to be completed and incorporated into the final RFQ/RFP. CDM Smith recommends that this future work include the delineation of wetland resource areas on-site and filing and approval of an ANRAD with the

Hadley Conservation Commission. CDM Smith estimates that the cost to complete this process for inclusion in the procurement documents is between $5,000 and $8,000.

3. ***Proximity to Sensitive Receptors*** - Aside from the wetland resource areas, CDM Smith feels that there are adequate buffers to off-site and no on-site receptors that would be impacted by the development of the proposed AD facility and that the facility could be constructed and operated without any significant impact to human health, safety or the environment.

   Because the proposed site is directly visible from the UMass campus, the AD facility will have to include architectural and landscaping treatments compatible with the Amherst WPCF and the UMass CHP facility as well as the UMass campus. These treatments will add cost to the facility compared to the minimum operational components that have been utilized at similar operations.

4. ***Subsurface Conditions*** - From a review of historic aerial maps and other discussions, the proposed site is almost entirely constructed of several feet of soil fill. To provide information for the vendors to determine appropriate foundations, CDM Smith recommends that the RFQ/RFP incorporate subsurface borings sufficient to characterize geotechnical conditions CDM Smith notes that the source of the soil fill is unknown and the Commonwealth should consider collecting samples for laboratory analysis as part of the subsurface exploration program. CDM Smith estimates that the cost to complete the subsurface program and develop a corresponding geotechnical report is between $12,000 and $20,000.

5. ***Availability of Feedstock*** - For the feasibility study, CDM Smith identified a range of regionally available biosolids and SSO materials that could potentially be delivered to the AD facility. The incorporation of biosolids into the AD facility is an important aspect both from integration with the adjacent Amherst WPCF as well as providing a potential steady revenue stream for the operator. Based on discussions with MassDEP, two tonnage scenarios were identified for further evaluation as summarized in Table 6-1. Based on available information including MassDEP databases, there are adequate amounts of both biosolids and SSO materials within a reasonable hauling distance of the UMass site to provide the proposed feedstock amounts.

Table 6-1
Summary of Annual SSO and Biosolid Tonnages Scenarios for Further Evaluation

Alternative	Total Wet Tons Per Year			Annual Wet Tons Per Year from UMASS and Amherst WPCF			Net Additional Wet Tons Per Year			Net Additional Average Wet Tons Per Day		
	Biosolids	SSO	Total	Biosolids	SSO	Total	Biosolids	SSO	Total	Biosolids	SSO	Total
Alternative A	18,500	11,500	30,000	15,400	1,200	16,600	3,100	10,300	13,400	12	41	53
Alternative B	30,000	20,000	50,000	15,400	1,200	16,600	14,600	18,800	33,400	58	75	133

TPY: Tons per Year

UMass SSO is currently 1,200 TYP

Assumption

Days per year accepting materials 250

6. ***Capital Costs*** - For each tonnage scenario, CDM Smith developed conceptual estimates of capital costs for the AD facility assuming on-site pre-processing and that the materials are received pre-processed. These capital estimates are presented in Table 6-2.

Table 6-2
Summary of Estimated Capital Costs for Different AD Facilities at UMass-Amherst Site

Alternative		Estimated Capital Cost
A-1	30,000 TPY AD Facility with On-Site Pre-Processing	$34.2 million
A-2	30,000 TPY AD Facility with No On-Site Pre-Processing	$18.2 million
A-3	50,000 TPY AD Facility with On-Site Pre-Processing	$37.8 million
A-4	50,000 TPY AD Facility with No On-Site Pre-Processing	$22.5 million

CDM Smith made several assumptions in the development of the capital costs including that the AD facility would have to be similar aesthetically to the surrounding area and facilities and that the private developer would have to be state prevailing wage rates. Note that CDM Smith also assumed that the effect of the federal Investment Tax Credit would be to reduce the amount having to be borrowed for capital costs by 30%.

7. ***AD Technology*** - Because a significant portion of the incoming feedstock for the proposed AD facility is biosolids at an estimated 6.5% solids content, the AD technology for this project will be a “wet” technology. SSO materials that have been assumed to be at significantly higher solids content will have water added to be ready for the digestion process. Note that these AD technologies are generally proprietary.

   During preparation of this feasibility study, there was significant discussion on the incorporation of pre-processing of the SSO materials at the UMass site. The issue is that the incorporation of pre-processing equipment significantly increases both the capital and operating costs. For the financial analysis presented herein, all of the SSO materials except for those from UMass were assumed to be delivered to the AD facility in a form suitable for pumping into the digester unit. However, during the development of the RFP, the Commonwealth may want to consider allowing on-site pre-processing with the appropriate project controls, particularly for odors, from the vendors.

8. ***Operations Costs*** - Based on the development of an AD facility without any pre-processing on-site, CDM Smith developed preliminary operations costs including labor, purchase of chemicals and other supplies and facility maintenance allowance. The annual costs (2015 dollars) were $1.49 million and $2.18 million for scenarios A-2 and B-2, respectively.

9. ***Traffic and Site Access*** - Based on discussions with UMass, any increase in traffic to the area will be significant consideration. Estimates by CDM Smith indicate that there will be a maximum of 17 additional truck round trips per day to the proposed facility assuming all the feedstock materials are delivered in larger capacity trucks in a preprocessed condition. Note that peak hour traffic on North Hadley Road in the vicinity of Mullins Way is over 500 vehicles (trucks and passenger) per hour.

The procurement documents need to incorporate truck routes that limit access to Route 116 to North Hadley Road to Mullins Way.

10. ***Handling of Sidestreams*** - There are two potential sidestreams that will be generated from the AD facility – a solid component that cannot be digested further and a liquid component. For this analysis, CDM Smith has assumed the solid component will be removed from the Site and composted or otherwise disposed of at another location. The incorporation of biosolids into the AD facility will require that re-use of the solid sidestream comply with MassDEP's Land Application of Sludge and Septage regulations (310 CMR 32.00).

    CDM Smith anticipates that the liquid sidestream will be a high-strength wastewater with significant concentrations of ammonia. While the proximity of the adjacent Amherst WPCF is attractive, the WPCF will have limits on total nitrogen (including ammonia) on its effluent as well as a limited ability to accommodate the anticipated loading from the AD facility. Also, the Amherst WPCF does not have an Industrial Pretreatment Program (IPP) as would be required to accept flows from the AD facility. For this feasibility study, CDM Smith assumed that the operator of the AD facility will implement an on-site pre-treatment system to remove ammonia to a concentration that will be appropriate for discharge into the Amherst WPCF or similar facility.

11. ***Revenue Sources*** - The two potential revenue sources for the AD facility are disposal fees from the acceptance of biosolids and SSO materials and the sale of generated electricity. As discussed above, there are adequate quantities of both biosolids and SSO materials in the region to supply the AD facility. The Commonwealth should consider the addition of other WPCF's as a source of additional revenue from their biosolids.

    There are also several alternatives for the use of electricity including the UMass CHP facility, the Amherst WPCF or incorporation into the WMECO utility grid. The net sale value of the generated electricity will have a significant impact on the financial viability of the AD facility.

12. ***Pro Forma Financial Analysis*** - CDM Smith conducted an initial 10-year financial analysis of the two selected tonnage and scenarios (both without any on-site pre-processing of SSO materials) assuming a private development. This pro forma included re-payments of the financed amount for capital costs; assumed incorporation of the federal investment tax credit as an accelerated five-year depreciation; disposal fees for incoming biosolids; annual operating costs; increase of costs and revenues to account for future inflation; and payment of property taxes to the Town of Hadley. CDM Smith notes that private vendors may have very different considerations and financial conditions that will impact the financial viability of a proposed facility.

    This preliminary pro forma analysis found that:

    - The federal investment investment tax credit for renewable energy projects and the accelerated depreciation had a significant impact on the viability of the project as developed by a private entity. The Commonwealth should monitor the continuation of this credit program as it has a significant impact on the viability of the proposed AD facility.

    - The unit rate of electricity sold has a significant impact on the financial viability and should be secured with a long-term agreement.

- A major portion of the revenues is for the disposal of received biosolids at the AD facility. The operating vendor will likely have to tie down long-term agreements with WPCF operators to insure this revenue stream.

CDM Smith's analysis indicates that during the first five years of operations (assume to start in 2015), the "break-even" tipping fee for SSO materials disposal is close to the current market conditions for scenario B-2 (no on-site processing of SSO materials and 50,000 tons per year). This breakeven tipping fee increases significantly and is likely not competitive with either municipal solid waste disposal fees or other means of dealing with SSO materials (mixing with conventional leaf and yard waste compost operations) for scenario A-2. The costs may be marginally competitive with other SSO material processing alternatives for scenario B-2. However, CDM Smith notes that there are numerous assumptions made herein that have a significant impact on the viability. These assumptions need to be confirmed during the procurement process by the private firms who respond to the RFQ/RFP.

In conclusion, the proposed site on the UMass Amherst campus is technically viable for the development of an AD facility that can accommodate a reasonable portion of the available biosolids and SSO materials from the region. CDM Smith's initial pro forma found the larger (50,000 tpy) facility financially viable in the beginning but becoming less viable to operate in later years. However, given the interest in this location from private vendors as well as the different financial models that the private sector may have for this type of facility, CDM Smith recommends that the Commonwealth move forward with the development and issuance of the RFQ/RFP for the development of an AD facility with the appropriate project controls at the UMass-Amherst site.

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