Putting the principles of sustainability and resiliency into practice—GLSD's organics to energy project

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ABSTRACT | The Greater Lawrence Sanitary District (GLSD) has developed and implemented an innovative project that captures the core principles of sustainability and resiliency. The project also shows that these are not just aspirational goals but also tangible principles that can be applied on a large scale to create major local and regional benefits. GLSD's Organics to Energy Project takes two materials that have traditionally been viewed as wastes—food waste and wastewater sludge—and converts them to a clean energy source. This energy will, largely, meet the energy needs of the GLSD facility. The project demonstrates the transformation of water reclamation facilities from a mission of treatment and disposal to one of recycle and reuse. As the value of nutrients and organics in wastewater, biosolids, and food waste is recognized and utilized" as a resource rather than a waste product, similar projects will become the norm instead of "cutting-edge. This paper provides an overview of the project, reports the benefits over the first few months of operation, and uses initial results to project this groundbreaking project's long-term environmental, economic, and resiliency benefits.

KEYWORDS | Climate change, resilience, adaptation, resilience planning, resilient design, wastewater utility

PROJECT BACKGROUND

Like many states, the Commonwealth of Massachusetts has banned disposal of food waste by incineration or landfilling. This new regulation resulted from a Solid Waste Master Plan by the Massachusetts Department of Environmental Protection (MassDEP) in 2010. Statewide goals identified in the plan include reducing solid waste disposal by 2,000,000 tons (1,800,000 metric tons) per year by 2020, reducing disposal of organics by 350,000 tons (320,000 metric tons) per year (17 percent of total solid waste reduction goal), and developing infrastructure to support organics diversion processes. A goal of developing 250,000 to 300,000 tons (225,000 to 275,000 metric tons) per year of processing capacity along with supporting organics collection infrastructure was set.

GLSD has long been an innovator in biosolids treatment and energy recovery. It operates one of the few anaerobic digestion facilities in New England with digester gas used as the primary fuel for a thermal biosolids drying operation and building and process heat. GLSD recognized that bans on disposal of food waste presented an opportunity to further its net-zero energy goal for its wastewater treatment facility. These organics can be used, along with biosolids, to augment generation of biogas within the anaerobic digestion facility as a fuel for renewable energy production.

GLSD completed an Organics to Energy Feasibility Study in June 2013 with specific goals in mind. The feasibility study evaluated the viability of expanding the digestion system to allow for co-digestion of biosolids and food waste. It also identified a need to add a new biogas fired cogeneration system to produce renewable energy (both heat and power) for use at the facility. The study found that the installation of a fourth anaerobic digester and utilization of the excess capacity for co-digestion of food waste would improve the facility's resiliency and reduce operating costs. As conceived, the project would greatly reduce or eliminate GLSD's reliance on utility-supplied power. Based on the results of this study, GLSD proceeded with design and construction of the project, with new facilities becoming fully operational in January 2020.

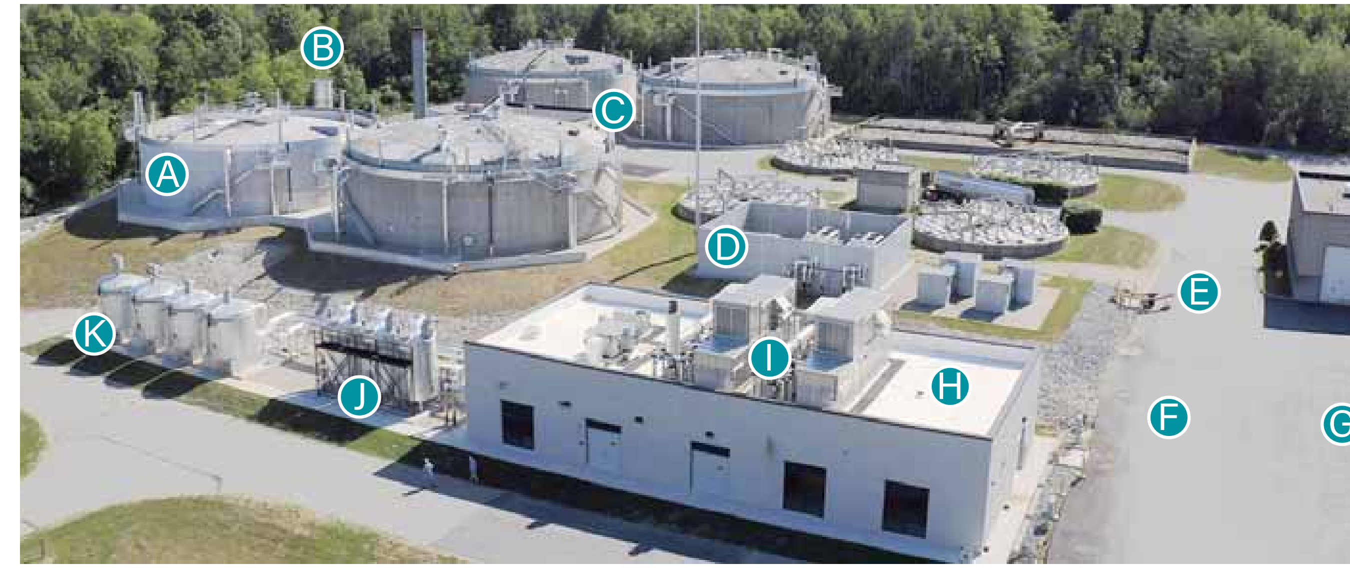

Figure 1. GLSD organics to energy project components

- A Digester #4
- B Waste Gas Burner
- C Digester Equipment Upgrades
- D Radiators and Chillers
- E Organic Waste Receiving Station
- F Organic Waste Receiving Tanks *(below grade)*
- G Organic Waste Pump Station *(below grade)*
- H Cogeneration Building
- I CHP Exhaust Treatment (Oxidation Catalysts & Selective Catalytic Reduction)
- J Siloxane Removal
- K H_2S Removal

THE PROJECT

The project added new infrastructure to allow for acceptance and conveyance of food waste material for co-digestion and use of the additional biogas generated. With the new system, biogas will continue to be the primary fuel for the thermal drying process and for providing digester and building heat. The increase in digester gas will also support a combined heat and power (CHP) system. The project's major elements include the following:

- Organic waste receiving tanks. Two new source-separated organic (SSO) receiving tanks provide approximately 238,000 gal (900 m^3) of storage. A pump/jet nozzle mixing system and SSO pumps mix and transfer the material to an existing sludge blending tank.
- Anaerobic digester No 4. A new 1.4 MG (5.3 ML) digestion tank adds digestion capacity. Similarly to the other three digester tanks, digester No. 4 uses draft tube mixers and a steel gasholder cover.
- Anaerobic digestion ancillary equipment. Additional equipment installed within the digester equipment building supports the new digester, including two digester recirculating pumps, one concentric tube heat exchanger (1.7 MMBtu/hr [1,800 MJ/hr]), and one hot glycol recirculation pump. Space for this equipment was provided in the digester building as part of the original digestion system design completed around 20 years ago.
- Biogas conveyance and waste gas burner. Additional biogas conveyance capacity was added between various biogas treatment systems and points of use, in addition to a second waste gas burner (flare). This allows the biogas conveyance system to handle the significant increase in gas production from SSO co-digestion.
- Hydrogen sulfide and siloxane treatment system. A high level of digester gas treatment is required to protect the CHP engines and exhaust treatment equipment from damage. The biogas cleaning system includes a fixed media hydrogen sulfide treatment system and a carbon media-based siloxane treatment system.
- Biogas pressure boosting. Treated biogas is boosted to between 3.5 and 5.0 psi (24 to 35 kPA) to accommodate the cogeneration engines and digester heating boilers.
- CHP engines. Additional biogas is used in reciprocating CHP generators with a capacity of approximately 3.2 MW. The power produced is fed to the site electrical system and can be net metered back to the utility grid. Heat from the engines and exhaust is captured to supply process and other on-site heating demands. The CHP engines are dual fuel burning engines and can also use natural gas.

Figure 1 shows the general layout for the upgraded biosolids and organics processing systems.

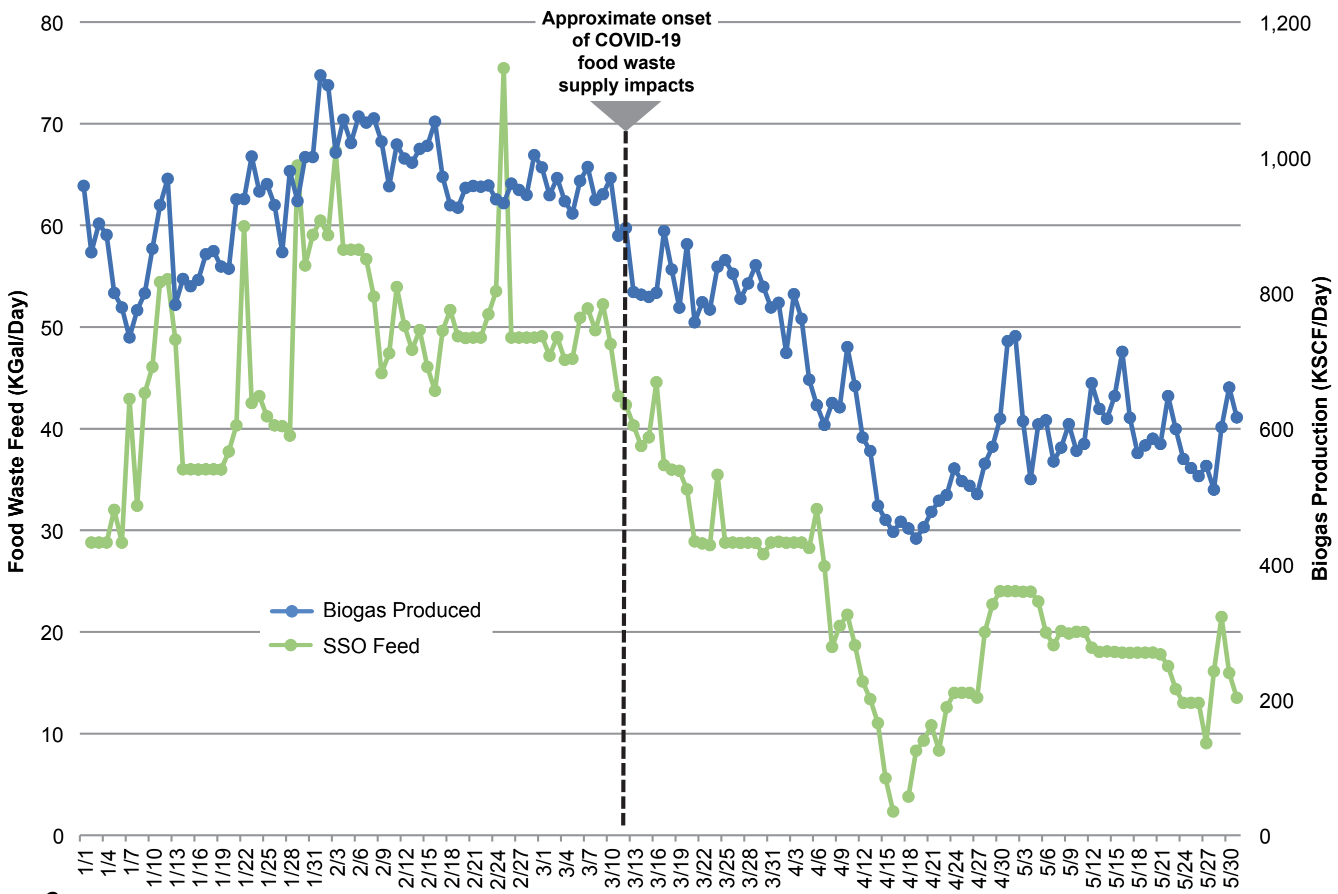

Figure 2. GLSD co-digestion system, 2020 food waste addition and biogas production

The cost to construct and oversee the project was around $31 million. Owing to the project's significant environmental and energy benefits, credits and grants were available to help fund the construction cost of the proposed facilities. Some $5 million in grants and $26 million in State Revolving Fund (SRF) assistance were committed to the project, with grant funding provided by the MassDEP, the Massachusetts Department of Energy Resources, the Massachusetts Clean Energy Center, and National Grid. Additionally, GLSD will receive about $1.6 million in SRF loan principal forgiveness from the MassDEP Clean Water Trust due to GLSD's Environmental Justice designation.

INITIAL RESULTS

Since January 2020, clean energy generated and the associated savings from the reduction of purchased utility power have been impressive, particularly given that many system components were still being optimized during this time. The mid-January to mid-March period was of interest, as regular food waste material deliveries were available following a slowdown over the holiday period and before COVID-related delivery interruptions. Highlights of period include the following:

- A strong relationship between food waste acceptance and increased gas production was shown. Gas production often exceeded 1,000,000 ft³ (28,000 m³) per day based on acceptance of around 50,000 gpd (189,000 L/d) of SSO (reference Figure 2). This is more than 3 times the volume of biogas typically produced prior to initiation of the co-digestion process. The additional biogas allows the CHP system to produce clean energy while maintaining biogas as the primary fuel for on-site thermal drying and the primary fuel for digester heating.
- The CHP system, using biogas as its primary fuel, can fully meet the treatment facility's power needs. Additionally, net metering offsets around 60 percent of the power consumption at the Riverside pump station (RSPS). The RSPS conveys virtually all of the flow to the treatment facility and represents around 30 percent of GLSD's power demand. As SSO acceptance increases, the GLSD treatment plant and RSPS are expected to be fully powered by this renewable energy source (see Figure 3).
- During this period, the CHP system operated at approximately 60 percent of capacity with generator operations limited by food waste availability. As the available supply of SSO increases, both generators should operate regularly, increasing the export of clean energy back to the local utility grid.
- The CHP system's typical recovery of between 4 and 5 MMBtu/hr (4,200 and 5,200 MJ/hr) of thermal energy under the current loading has offset the prior use of heat provided by natural gas-fired boilers to the digestion process and some building spaces. Future growth of SSO co-digestion and expansion of this heat recovery system will provide further opportunities for heat recovery.
- No negative impacts with biogas or Class A fertilizer pellets have been observed as a result of the co-digetsion operation.
- On average, approximately 50,000 gpd (189,000 L/d), or an estimated 210 tpd (190 tonne/d) of food waste organics have been diverted from landfills, with the potential to increase that to 90,000 gpd (341,000 L/d), or an estimated 380 tpd (345 tonne/d), of SSO. This would greatly reduce greenhouse gas emissions from landfills and further the goals of the MassDEP Solid Waste Master Plan.
- While operating as an emergency generator is not its primary purpose, the CHP system can operate during utility power outages; this operation has been successfully simulated in the field. This operational flexibility provides the GLSD facility with additional resiliency to withstand short- or long-term interruptions in utility power supply, provided that the supply of SSO material or natural gas can be maintained.

Figure 4 (next page) provides an overview of the production, use, and export of clean energy (power and heat) realized during the early months of system operation.

In sum, all anticipated benefits of the Organics to Energy Project have been demonstrated during the initial operating period. Some of these benefits are tangible and quantifiable. For example, the Alternative Energy and Renewable Energy credits, combined with meeting the energy demands of the treatment facility and some of the RSPS energy needs, save GLSD more than $2 million annually—while operating at only 60 percent of the CHP system design capacity. Future growth of SSO co-digestion will further expand the ability to export power and yield significant financial net-metering benefits. In other instances, the benefits are less quantifiable but real. Starting the generators and powering the facility during power outages, for instance, provides operational resiliency. By expanding the field of vision traditionally used to scope water reclamation projects, GLSD has developed and implemented a project that addresses not only a short-term need but will provide various long-term environmental, economic, and resiliency benefits to itself and the communities it serves.

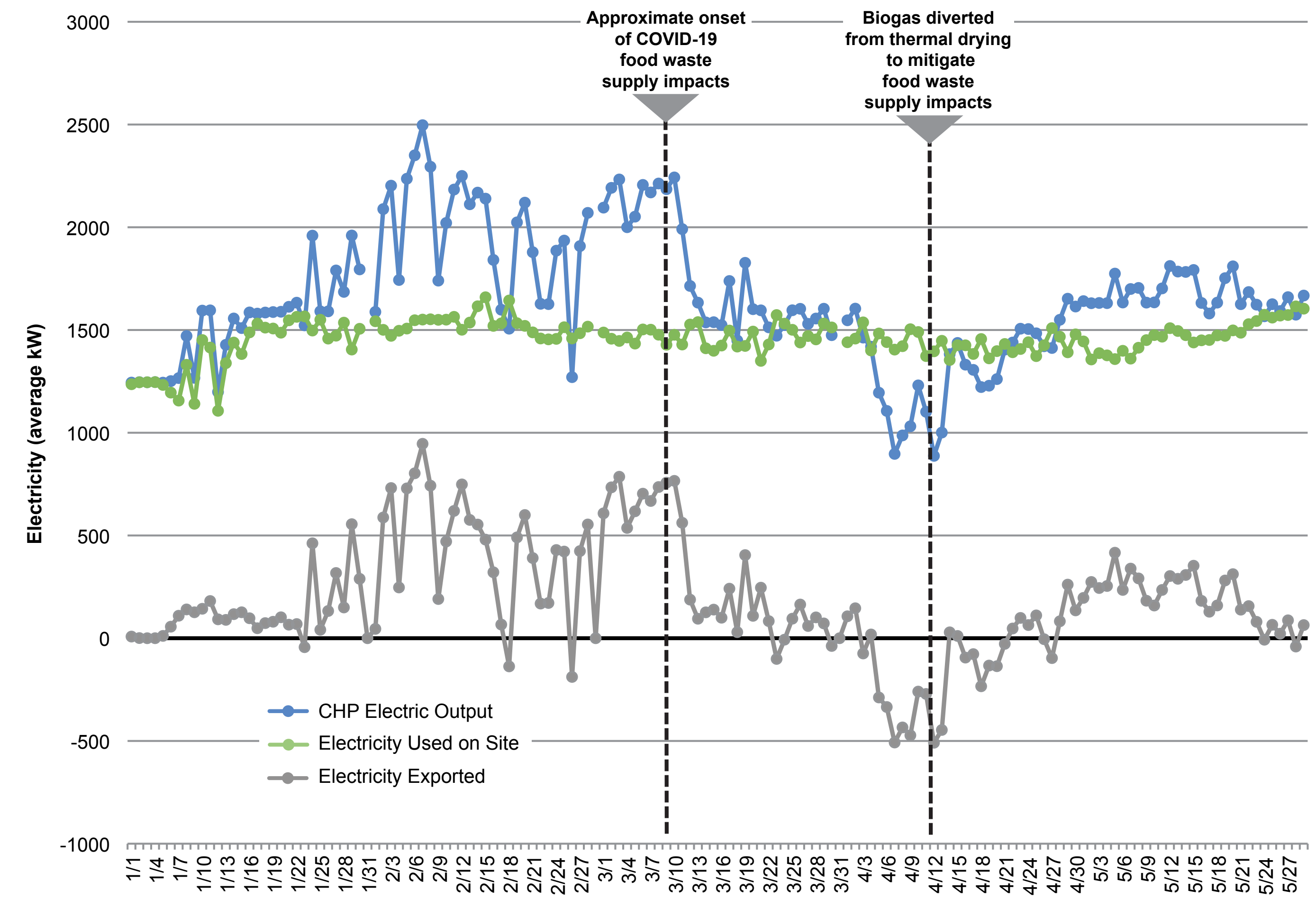

Figure 3. GLSD co-digestion system, 2020 electric power production and export

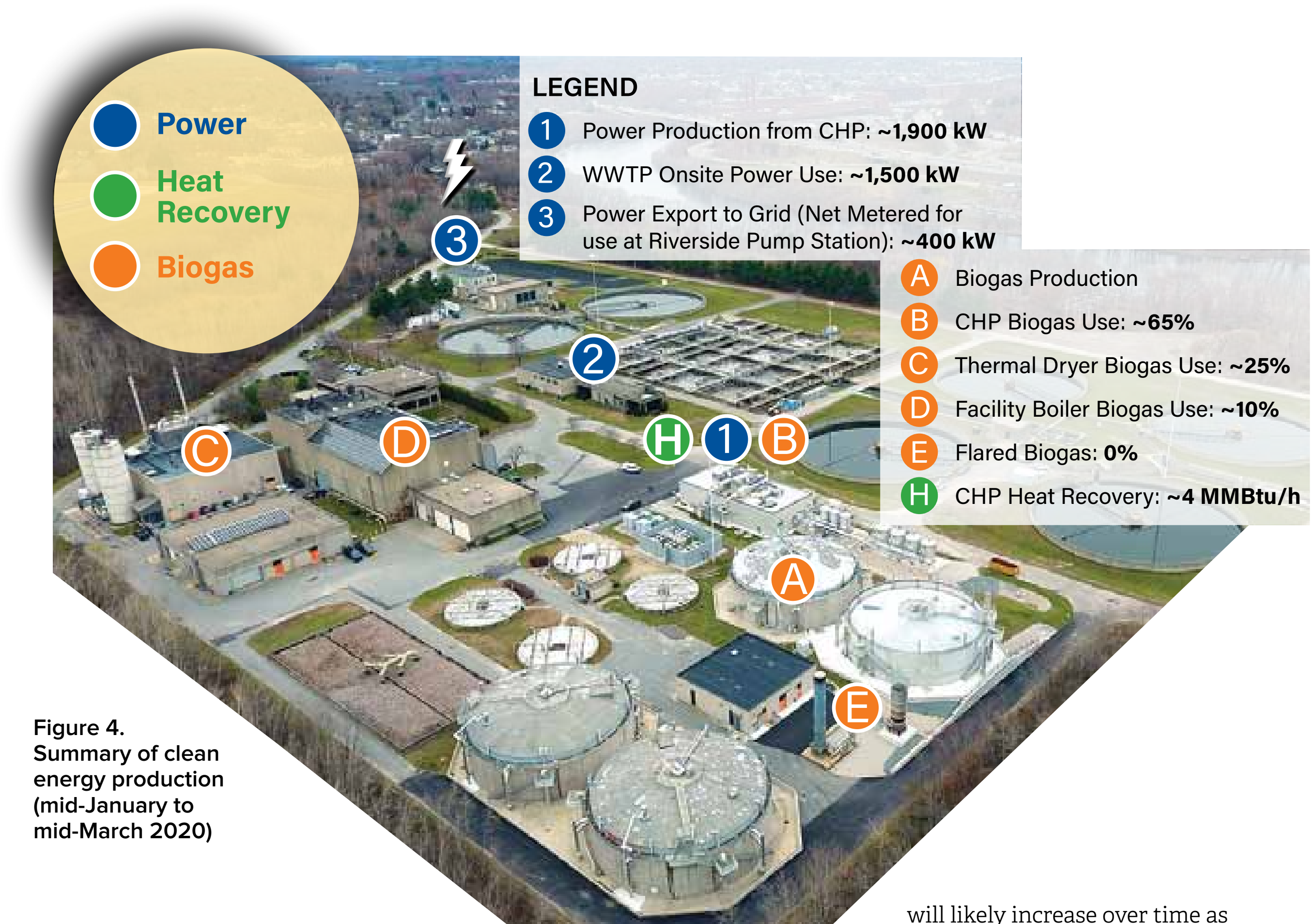

Figure 4. Summary of clean energy production (mid-January to mid-March 2020)

PROJECT BENEFITS

The most obvious benefit is the savings from buying less electricity from the grid. Based on initial operation, the system has proven it can supply enough power to operate the GLSD treatment facility. The system is expected to generate enough clean energy to meet the combined needs of the treatment facility and the RSPS in the foreseeable future—provided the volume of food waste organics is available. This will save around $2.5 million annually based on current energy prices. While the cost savings are the easiest benefits to quantify, GLSD and the region will benefit further from the following:

- Protection against future increases in energy costs
- Greater facility resiliency and operational flexibility, including the ability to use the CHP engines during a loss of utility supplied power (i.e., islanding)
- Ability to provide an important service to the commonwealth and to local businesses that collect and process SSO material
- Greater system reliability, as the additional digester tank volume added as part of this project will make it easier to clean digester tanks
- Major reduction in net greenhouse gas emissions compared to previous organics disposal practices

The project will provide a long-term net economic benefit to GLSD and its member communities that will likely increase over time as the cost of traditional energy sources increases and the industry moves to renewable energy sources. Furthermore, the resiliency benefits will continue to increase in importance as the impacts of climate change and extreme weather events become more pronounced. In these and other ways, the Organics to Energy Project is a model for a smarter, more resilient approach to infrastructure needed to meet the challenges of the next several decades.

ACKNOWLEDGMENTS

GLSD acknowledges the tremendous support and cooperation from MassDEP, the Massachusetts Department of Energy Resources, the Massachusetts Clean Energy Center, and the Town of North Andover in developing this project over the past several years. This support—both financial and otherwise—allowed GLSD to advance the project from an initial feasibility study to preliminary and final design on an accelerated schedule while managing the challenges associated with what is, in many respects, a first-of-its-kind project. Without this commitment to innovation and partnership in advancing the state of the art for sustainable approaches to water quality, energy, and environmental issues, the GLSD Organics to Energy Project would not have been possible.

Biogas is treated for H_2S and siloxane removal prior to beneficial use

ABOUT THE AUTHORS

- Cheri Cousens has been executive director of GLSD since 2014. Before joining GLSD, Ms. Cousens was executive director of the Charles River Pollution Control District in Medway, Massachusetts. This District manages a tertiary, 5.7 mgd (21.6 ML/d) wastewater treatment facility serving the towns of Bellingham, Franklin, Medway, and Millis. She previously was an engineer/industrial pretreatment program coordinator for the District for 11 years and began her career as an environmental engineer for CDM Smith. Ms. Cousens holds a Bachelor of Science in environmental engineering from Wentworth Institute of Technology, and a Master of Science in civil engineering from Worcester Polytechnic Institute. She is a licensed Grade 7-C wastewater treatment plant operator, treasurer for the Massachusetts Coalition of Water Resources Stewardship, and a director of the North East Biosolids and Residuals Association.
- Richard Weare is the capital projects manager of GLSD. He has managed the implementation of all capital projects at the District over the past 20 years, including construction of the anaerobic digesters and thermal drying facility.
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- Michael Walsh is a vice president and client service leader based in CDM Smith's Boston office. He has over 30 years of experience in the planning and implementation of major water reclamation and biosolids projects, including application of innovative water reuse, alternative energy, nutrient removal, and energy recovery technologies both in the United States and overseas. Mr. Walsh is a Professional Engineer in multiple states and an Envision Sustainability Professional. Throughout his career, he has been involved with multiple projects for GLSD, including serving as project officer for the Organics to Energy Project featured in this article.