Develop a Micro-Grid Using Energy Produced at Your Wastewater Treatment Facility

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ABSTRACT

Communities with water resource recovery facilities (WRRF's) have the opportunity to utilize its benefits to offset a portion of their community's energy cost and improve their operating budget. One example of how a WRRF can process waste into energy to reduce both electric and natural gas grid consumption is through utilization of anaerobic treatment, taking advantage of a fuel that can be produced onsite – biogas!

Biogas, produced as a result of anaerobic treatment, is a renewable resource that is often flared off, vented or otherwise ignored. Utilization of this fuel can beneficially impact the energy needs of a community.

This paper will describe how a municipal WRRF addressed this opportunity and now has the ability to produce sufficient electric power for their WRRF operations, and – potentially - export energy for other municipal operations. While connecting to an external electric grid may come with many expensive requirements, the benefits can outweigh these costs. If a municipality develops a mini-grid, the energy produced can be supplied to community operations (a municipal campus of buildings) which could reduce energy costs. Specific to biogas, beneficial use of this renewable energy source provides for electric generation and heat offsetting natural gas consumption.

A specific project completed in recent years will be highlighted to present the features needed to best utilize existing conditions at a WRRF, resulting in successfully implementing biogas recovery. Characteristics of interest range from influent quality to the types of industrial wastes in the area to the infrastructure at the WRRF.

Suggestions will also be made on how to continue to improve this opportunity. Examples include: combining the biogas from the WRRF and landfills to increase distributed energy generation, assessing the location of biogas electric generation systems so the waste heat can be beneficially utilized as a heating district, assessing the utilization of the solids remaining as a soil enhancer, and utilizing the exhaust gases from the generation process as an attribute for green houses. Overall community planning should also include evaluation of incorporating municipal solid waste incineration for material and energy recovery with the evaluation of utilizing biogas since the combination could produce the majority if not all the electric and heat energy a municipality requires.

Introduction

Communities with wastewater resource recovery facilities have the opportunity to expand the beneficial utilization of their systems. For example, anaerobic digesters - beyond just being a biosolids treatment process at their WRRF - can enable facilities to be a net energy producer with energy "export" capability. Thus, anaerobic digestion systems can become a community and regional benefit. Anaerobic treatment systems can accept business, commercial and industrial high-strength wastes (auxiliary feed stocks) as a fuel source. All of this can occur at a point source location, in the anaerobic digesters, resulting in increased biogas production that could provide electric and – if sufficient – could provide heat for a community's or utility's buildings. This holistic approach by a municipality could provide regional solutions to a variety of growing problems communities and the surrounding businesses are facing. Such systems are considered "micro-grids".

A variety of progressive actions are required to occur to develop conditions that could lead to a successful micro-grid. The following is a listing of major actions required to 1) increase biogas production which will increase electric generation and 2) promote the development of a micro-grid campus to utilize the additional generated electricity:

- Utilize existing "oversized" infrastructure – for example, many water resource recovery facilities are sized and constructed for 20-year design conditions yet are only operating at 30 to 35 percent design conditions.
- Utilize all biogas produced at the water resource recovery facility to fuel generators to meet all water resource recovery facility electric needs (become self-sustaining) and then export to a micro-grid (to provide energy for additional functions beyond the water resource recovery facility) rather than flaring or venting the unused yet produced biogas into the atmosphere.
- Construct a designated receiving station to accept high-strength business, commercial and industrial wastes to be treated by the water resource recovery facility rather than hauled to land spreading locations that are continually getting further from relevant cities.
- Coordinate a number of municipal departments to be located in a campus setting so municipal or utility facilities are located contiguously to one another.
- Utilize the municipal or regional water resource recovery facility as the energy generator and central driving force of an electric and possible heating micro-grid.
- Identify the value to the community in making the water resource recovery facility become self-sufficient and self-reliant, not requiring any energy from outside sources to operate the treatment facility or energize the micro-grid.
- Become an energy self- sustaining municipality through utilization of other industrial or commercial waste materials that would otherwise be thrown away (fats, oils and grease), released to the atmosphere (biogas), or land spread for disposal (high organic strength wastes).

Each of these items will be described in further detail below:

Utilize existing infrastructure. Most municipal water resource recovery facilities are required by State regulatory agency's code or guidelines to develop a facility plan prior to any major improvement, expansion, or construction at a water resource recovery facility. Such regulatory codes often require "sizing" for a forecasted 20-year peak organic and hydraulic loading (WEF 2010). The proposed facility modifications must be able to treat the forecasted amount to meet regulatory issued effluent discharge limits. Additionally, such regulations often require redundant basins and equipment to assure that the facility can continually meet the effluent limits - even if a unit is out of service. These planning, design, and equipment selection requirements have led many water resource recovery facilities to be operated at a fraction (often only 30 to 35 percent) of their treatment capacity. Thus, many facilities, although meeting their effluent limits, are operating inefficiently. Such conditions can provide opportunities for communities to utilize the existing infrastructure for anaerobic digesters to produce additional biogas in quantities to meet the electric power requirements of the facility. In some cases, production will have sufficient energy surplus to interconnect with the local electric grid and be able to supply the utilities grid with energy.

In addition, the "mode" of operating anaerobic digesters, see Figure 1, has progressed to being able to feed the digesters at a greater loading of organics per unit of volume, thus, leading to increased biogas production. With increased biogas available to generate additional electricity, the water resource recovery facility may generate enough to energize additional municipal facilities and lessen the need to utilize grid provided energy.

A byproduct of increased organic loading is not only additional electric generation but also additional heat from the increase in electric generation. This captured heat can be beneficially utilized to meet the process demands at the water resource recovery facility, but in some cases it is adequate to support heating facilities adjacent to the water resource recovery facility through a heating district. At times there may be adequate generation of biogas to directly utilize it in fueling a boiler to provide heat for additional beneficial use.

Figure 1. Anaerobic digester with a new mixing system

Utilize all biogas produced. Many water resource recovery facilities that have anaerobic digesters were constructed with limited or no biogas treatment systems. Without biogas treatment systems, the "raw" biogas often damages the systems' boiler and/or engine. By so doing, these "raw" gases often cause the system to be shut down. Biogas utilization traditionally has received low to no interest in its use, resulting in it being vented or flared. This approach to managing biogas has been in existence for a number of years but in recent years much more attention has been placed on biogas conditioning, see Figure 2, resulting in beneficially utilizing it to offset external energy purchasing.

The best approach to maximize the beneficial utilization of biogas is to assess how to treat all the gas that is produced and, then, develop a strategy that would utilize the volume of biogas produced to best offset energy costs. This approach generally implies not using biogas to meet the process needs but, rather, utilize the total volume of the biogas produced to generate electricity and capture the heat from the generation system to meet process heating needs and building heat needs (traditionally called combined heat and power, or CHP). Depending on the size of the system, there may be sufficient excess heat to supply the water resource recovery facility and if sufficient volume of heat remains it could be distributed to adjoining facilities resulting in developing a heat district micro-grid if all of the regulatory requirements, discussed below, are met.

Figure 2. Biogas conditioning system

Accept high-strength wastes. Most water resource recovery facilities, when constructed, did not include a separate high-strength waste receiving station. This is because the facilities were constructed to serve the immediate community for which they were built. In recent years, there has been an awareness and acknowledgement that the existing water resource recovery facility was designed for substantially higher loads than those experienced under current conditions. As a result, there is anaerobic digester capacity available to accept additional organic wastes (Pirnie 2007; EPA 2016). This increase in biological load allows an increase in biogas production. Thus, allowing it to be beneficially utilized to offset purchased energy costs.

A receiving station can benefit many neighboring commercial, business, and industrial facilities' that discharge high-strength wastes (wastes discharged that are greater than domestic strength usually in range of 500 mg/l biological oxygen demand BOD or greater)by receiving these wastes at (or directly connected to) the water resource recovery facility . These organic loads enhance the operation of the existing anaerobic digesters. The additional biogas produced can lead to sufficient electric generation that could meet all onsite needs and have excess available to be exported through development of a micro-grid. Additionally, the water resource recovery facility having the capability to accept surrounding high-strength wastes benefits the generators of the waste who now have a controlled process to manage their waste. Prior to being able to have the water resource recovery facility accept the waste, the waste generators often need to continually "work at" locating and acquiring locations to dispose of the waste. With guidelines associated with land disposal sites becoming continually more restrictive, the location of many sites has constantly become further distances to travel resulting longer haul and disposal times (NY State DEC 2011; Parry 2012; CBC 2012).

Figure 3. Waste receiving station

Coordinate municipal departments. The production of biogas at water resource recovery facilities can be increased to justify the installation of biogas conditioning systems and electric generation capability to achieve energy neutrality at the facility and to possibly export electric energy and capture and utilization of generated heat. However, identifying how to best utilize the available electric energy that can be exported remains a challenge. A variety of regulatory, physical, and cost barriers exist which can make a simple connect to the grid very challenging and often cost prohibitive. Developing a micro-grid which can utilize the exported energy is one potential solution.

A possible initial plan might be to locate municipal departments on a campus. An internal electric distribution system can be developed so the need to connect to the grid for utilization of the exportable energy is not required. This effort needs to be coordinated with the community's planning and land use departments so they can create a campus environment to jointly locate municipal facilities. This allows the exportable energy to be provided to facilities that have the same public ownership. This is a challenge with many existing water resource recovery facilities that have the ability to generate exportable energy because they are located in isolated areas with minimum setbacks to allow construction. These conditions need to be reviewed by planning and land use departments to assess how best to address the development of municipal facility campuses that then can utilize exportable energy.

Energy generation location. Water resource recovery facilities are receiving growing attention to become energy efficient and move toward energy self-sustaining capability (NACWA, WERF, and WEF 2013). Both of these attributes are achievable. There are existing water resource recovery facilities that have become energy efficient, are self-sustaining, and have the ability to export energy. The challenge associated with these achievements is justifying developing export capability responsive to the requirements associated with connecting to the grid. If the water resource recovery facility could develop a micro-grid and supply energy to other municipal facilities located contiguous to the water resource recovery facility through an onsite distribution system, it would meet payback guidelines that would allow the development of export capabilities.

Wastewater facility becoming self-sufficient. Municipal water resource recovery facilities are becoming proactive and making themselves energy efficient. They are beginning to assess their facilities to identify what they need to modify or construct to become self-sustaining. Most treatment facilities with anaerobic digesters are becoming aware of the value they can receive from developing their anaerobic digesters into fuel producers (biogas) to fuel the generation of electricity and heat. A number of facilities are realizing that they can achieve self-sufficiency and still meet all treatment and discharge quality effluent limits required by their regulatory agencies. Additionally, wastewater resource recovery facilities that have digesters and had accepted biogas utilization as a problem are now realizing it is an attribute they need to explore and resuscitate to maximize its ability to offset energy costs, which are usually in the range of 30 to 35% of a utility's budget (NACWA, WERF, AND WEF 2013). The ability to offset energy purchase costs can be expanded to additional municipal departments if the municipality has a campus arrangement and all exported energy is supplied to and utilized by other contiguous municipal facilities.

Municipal facilities become energy self-sufficient. Municipalities seeking self-sufficiency and responding to fiscal responsibility analyze many opportunities that will help them achieve these goals. Developing a municipal micro-grid to provide energy to most, if not all, municipal facilities would be a component to achieve the goal. Further utilizing the water resource recovery facility as a significant contributing energy source for the micro-grid this would further assist in achieving the goal.

It is possible to have energy generation capability located at the water resource recovery facility. This results in a major offset of energy costs and a major reduction in yearly operating energy costs. This progressive action also becomes environmentally attractive not only from the view of turning waste into energy but also by approaching municipal challenges in a holistic approach. The municipalities, by coordinating with high-strength waste generators, are:

- High strength wastes are going to the water resource recovery facility reducing the number of trucks hauling high strength wastes long distances to be disposed
- Providing the high-strength generators with a more cost controlled method of waste disposal management allowing them to stay in the community
- Accepting high-strength wastes directly into anaerobic digesters reducing the electric use of the aeration system

  Becoming more energy-efficient, assisting in reducing the volume of organic wastes being land spread, but rather utilizing the organic waste material to produce biogas, see Figure 4, (energy) at the water resource recovery facility to produce energy rather than just land disposing it and not extracting any energy value from it.

When the biogas production has been enhanced the water resource recovery facility, needs a complete and thorough energy efficiency diagnostic evaluation (ASHRAE Level 3 Audit) so it uses the minimum amount of energy required to meet all discharge permit requirements. By becoming energy-efficient it will also use the least amount of generated electricity, allowing more to be exported and supplied to a potential micro-grid.

Figure 4. Receiving station accepting trucked in material

Legal Issues

With sufficient biogas production available to fuel electric generators, see Figure 5, that will produce sufficient electricity to offset the energy the water resource recovery facility uses and has sufficient export capability to provide electric service to the contiguous municipal facilities, the focus shifts to the legal aspects of developing a micro-grid and who it can serve (Siemens 2014). Many states allow micro-grids to exist, but the legality of the existence is contingent on several stipulations usually different state to state. Some of the requirements, depending on the state, may include:

- The micro-grid's owner needs to be the primary customer.
- The consumer of the electricity must be physically located on the generation location or contiguous.
- The definition of contiguous may vary by state.
- The number of customers can be regulated.
- There is regulatory uncertainty associated with the legal standing of a micro-grid (is it a utility, a public utility or a franchise?).
- Uncertainty with regulatory requirements that may govern the micro-grid (federal, state or local).
- Can the micro-grid distribute energy across an easement or a public right-of-way and still be considered contiguous?
- Will the state utility commission regulate the unit cost charged for the distributed energy?

Figure 5. Biogas Fueled Electric Generator

There are a variety of legal issues, as listed, that need to be thoroughly researched and assessed to determine if a micro-grid is viable to develop at a water resource recovery facility. A community needs to be sure the micro-grid, if developed, is an attribute to the community, provide energy to a number of municipal facilities that are contiguous to the water resource recovery facility and can they manage and operate the system. The specific project presented addressed and resolved the legal issues associated with putting generated power onto the electric supplier's grid. It was a tedious process but one that was resolved but could have been less involved if the generated power did not go public.

Micro-grid Development

A variety of actions need to occur to develop a municipal micro-grid with the primary energy generation located at the municipal water resource recovery facility. The initial activity involves working with the municipal departments to be sure they are cooperative and understand the value a micro-grid can be to a community.

Initial actions would include coordinating with the planning and land use department of the municipality to assess if existing municipal facilities are located contiguous with the water resource recovery facility and what future municipal facilities will be. Distribution of the exportable energy does not need to be conveyed onto the grid but rather through a local energy conveyance system established to distribute the energy internally to only facilities that would have the same party responsible for the purchase of the sites energy. Locating facilities contiguously to the water resource recovery facility provides customers for the micro-grid.

It also needs to be determined that the municipal distribution system does not cross any public rights-of-way because a micro-grid is not a regulated utility. Therefore, its power distribution system cannot cross public rights of way (Siemens 2014). Some example customers could be the park and recreational department, municipal garage, water department, municipal hall, municipal bus station, public works garage, and other municipal departments so the exported energy is distributed to municipal facilities without entering public rights-of-way.

With the micro-grid boundaries and the electric export capability identified it is now necessary to identify and assemble the components of the micro-grid. The primary components necessary are transfer capability to switch to the micro-grid from the adjoining utility and connect to self-generation, electric generation capability (the size, type and configuration will be site specific), distribution system to convey the exportable energy to the end-users, and an automatic monitoring and control system to assure energy is continually delivered as required by the end-user.

Completed Project That Utilizes Biogas for Electric Generation

Many water resource recovery facilities could follow the steps one community did. This community beneficially utilized the equipment, structures, and treatment processes it had to attain the ability to be energy self-sufficient and also have the ability to export electricity.

The community had a population of nearly 28,000, a wastewater treatment facility influent flow of 2.7 MGD, an organic loading of nearly 8,000 pounds of BOD per day, with a college and a brewery located within the community. The community began its move to energy self-sufficiency by first reducing the water resource recovery facility's energy use by approximately 35%. This was accomplished by the Superintendent of the WRRF contacting the State of Wisconsin's statewide energy efficiency and renewable energy program, Focus on Energy (Focus), to have an energy review and assessment developed to identify the energy efficiency opportunities the WRRF had to reduce its use. As a result of the assessment the Superintendent and staff implemented the following:

- Made staff aware of energy usage and cost's through review of the monthly water resource recovery facility energy bill
- Monitored electric demand and usage daily
- Installed new air compressor for air diaphragm pumps (50 horsepower to 10 horsepower)
- Changed exterior building lighting to LED technology
- Reduced set points on automatic dissolved oxygen (DO) concentration in the operation of the activated sludge treatment process from 2 ppm to 0.7 ppm
- Installed heat pumps for lab/office and garage heat, extracting heat from the final effluent
- Turned off unnecessary outside lighting
- Optimized waste activated sludge (WAS) thickening to reduce "water" entering the anaerobic digesters to improve energy efficiency of heating the digesters
- Purchased and installed a new more efficient technology blower
- Purchased and installed new flexible membrane diffusers
- Installed a new UV system with automatic cleaning
- Installed an updated SCADA system for managing on-peak demand
- Installed lower horsepower digester mixers 8.3 horsepower to 2.5 horsepower
- Installed new lower horsepower anoxic zone mixers

They then decided to improve their utilization of their anaerobic digestion system. They began by installing new mixing equipment in the existing digester to improve biogas production. They then proceeded to install a biogas conditioning system and an electric generator fueled by the biogas produced by the anaerobic digester. They then addressed how to further increase their biogas production to increase the production of electricity through the generator they installed.

They have developed the ability to produce sufficient electricity to meet 100% of the electric consumption of the water resource recovery facility and export any excess electricity to the grid. In 2015 the WRRF used 1,500,209 kWh and produced 1,276,109 kWh to offset 85% of the energy they used (WRRF Superintendent, pers. comm., June 13, 2016). The implementation of the modifications, energy efficiency and renewable energy, were funded by the community and financial incentives from the Focus program. The payback on the modifications, capital investment and operations, varied, most were less than five years, but all were within acceptance of the Community.

They have a limited time contract to export electricity to the grid so they are evaluating alternatives to identify the best option for them to continue to produce electricity to export. The development of a municipal micro-grid may be a potential opportunity to consider because they are fortunate to have other municipal facilities contiguous to them that could utilize the exportable electricity.

Conclusion

Water resource recovery facilities can serve as a contributing energy generation source for a community micro-grid, as shown in Figure 6. The distributed generation project presented in the case study attained success in utilizing the increased biogas produced to fuel an onsite generator to offset all of its electric use and convey excess generation onto the grid. This community's project demonstrates that a biogas fueled generator can offset grid provided electricity and provide the potential to a community to have a major energy user become self-sustaining. However, as can be seen in Figure 6, coordination and incorporation of additional distributed energy generation alternatives is also available to further increase energy production and have additional renewable resources available if needed. If developing a municipal micro-grid, a community needs to develop a coordinated effort amongst all municipal departments and distributed generation alternatives. The coordination should begin with the planning and land use departments to identify the best strategy to develop a community campus of municipal facilities so the generated electricity and captured heat can be distributed and utilized by the campus facilities. It is necessary to research and identify the relevant state regulatory requirements to develop a micro-grid as states have differing regulations that need to be met to develop a micro-grid.

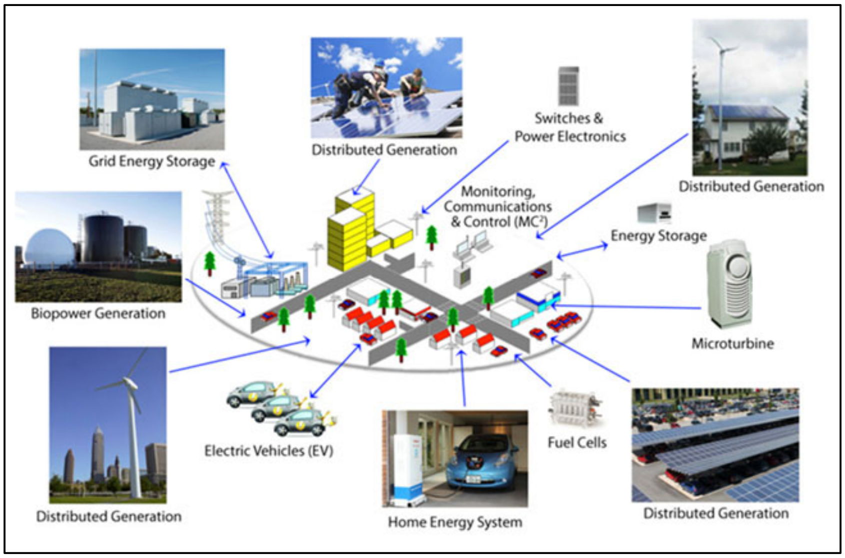

Figure 6. Community Micro-Grid Initative, August 2015

An additional component in the assessment of developing a micro-grid is the potential to incorporate the utilization of the municipally collected solid waste as an energy source to increase the renewable energy capability for the micro-grid. This overall approach is represented in Figure 7. Figure 7 represents an overall community-wide conceptual representation of utilizing often referred to “waste materials” and utilizing them as energy generation sources to beneficially utilize resources available to a community.

The analysis, evaluation and planning required to justify and support the creation of a micro-grid must carefully and completely address the many requirements associated with the development of a micro-grid: available energy sources , electric generation, heat capture, legal, technical, and financial to justify its development.

Municipalities should proactively assess their potential to develop a micro-grid as a holistic review of the benefits it can bring to their community, surrounding area, and the environment.

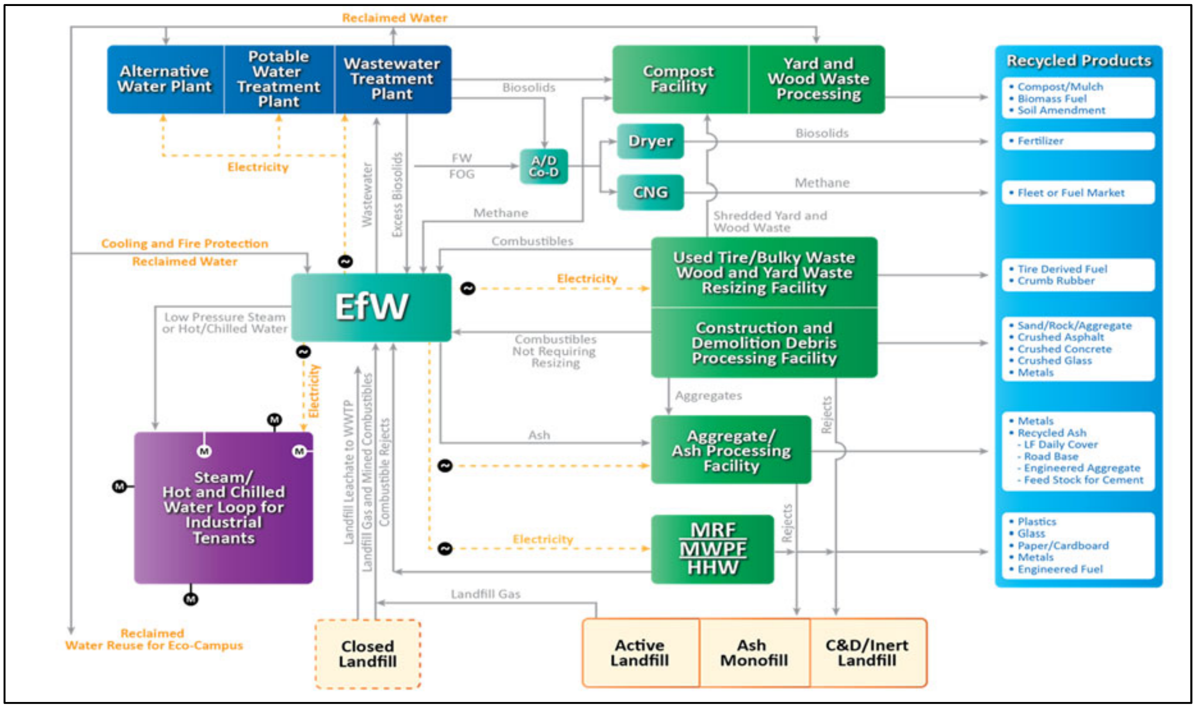

Figure 7. Integrated Campus for Management of Municipal Resources can Include Water Resources. (Paul Hauck/CDM Smith 2016)

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