Optimizing Water Management in Waste-To-Energy Through Water Conservation And Efficiency

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The Solid Waste Authority (SWA) of Palm Beach County's new 3,000-ton-per-day (tpd) advanced technology mass burn Renewable Energy Facility #2 (REF2) will utilize municipal solid waste to generate up to 100 megawatts (MW) of gross electrical power. The new facility will be located in SWA's Renewable Energy Park adjacent to the existing Renewable Energy Facility #1 (REF1). This location provides a unique opportunity to develop a process design that minimizes water consumption and virtually eliminates the need to discharge wastewater from either facility. Waste-to-energy (WTE) power facilities typically consume a significant amount of water for boiler makeup, steam condensing, ash quenching, air pollution control, and other uses, including wash down and irrigation. The design for REF2 utilizes three integrated water supply and distribution systems to maximize the reuse and recycling of process wastewater, resulting in a reduction in projected water use of more than 85 percent compared to other existing WTE facilities.

This article provides an overview and quantification of the water balance elements designed into SWA's new WTE facility and details the key features that contribute to the optimized water management approach. The design includes the selection of an air-cooled condensing system (as opposed to a more conventional evaporative cooling system), as well as implementation of a hierarchy of alternative sources of water to supply the new facility. The hierarchy of water sources includes cooling tower blowdown from the adjacent REF1, harvested rainwater, and nonpotable surficial well water. Ultimately, this approach will result in a more reliable, flexible, and sustainable water management system for the WTE facility that will largely eliminate the need for potable makeup water and minimize wastewater disposal requirements.

Background

Water is of critical importance to many industrial processes, including municipal solid waste processing in WTE facilities. The WTE process reduces the volume of solid waste by approximately 90 percent, while beneficially producing electricity. WTE facilities can consume a significant amount of water, with the majority of the water being used for condensing steam, boiler feedwater makeup, and flue gas cooling. Due to the large amount of water consumed, the use of nonpotable sources for cooling water and boiler water makeup is a key component of efforts to reduce a facility's dependence on potable water resources.

Early in the planning stages of the new mass burn WTE facility, SWA recognized the importance of providing a sustainable solution that would maximize water conservation and reuse. Since reclaimed water was not a viable alternative for this particular facility, innovative design and water supply sources had to be incorporated to address these goals. The solution included specifying the use of an air-cooled condenser to be used for condensing steam, instead of a traditional evaporative cooling tower, significantly reducing the amount of water needed in the new facility. In addition, SWA specified a hierarchy of alternative water sources to be used as supply water in the new facility.

An overview of the water balance elements for the new facility and details of the key features that contribute to the optimized water management approach are presented. The selection of a dry-cooling system to maximize water conservation and the various water usage efficiency methods using the hierarchy of alternative sources of water to supply makeup to the new facility are discussed.

Air-Cooled Condenser

Currently, there are 86 WTE facilities operating in the United States. In the typical WTE process, municipal solid waste is combusted and the heat generated is used to convert water into high-pressure steam. The steam is passed through a turbine that spins an electrical generator to produce electricity. After leaving the turbine, the exhaust steam is then converted back to water so it can be reused in the boiler feedwater system to produce more electricity. The steam is condensed in a heat exchanger (condenser) that has multiple tubes representing a large surface area. A large volume of cooling water flowing through the tube bundles absorbs heat from the steam. The heat that has been transferred to the cooling water in the heat exchanger must then be dissipated so the water can be reused in the steam cooling system.

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This wet recirculating cooling system is the most common type used at WTE facilities. In these systems, the warm cooling water from the condenser is pumped to an evaporative cooling tower consisting of a large, baffled structure. The water is cooled as it descends through the interior by gravity while contacting ambient air that passes up through the tower. The heat from the cooling water is dissipated to the atmosphere and a significant portion of the cooling water is evaporated in the process. The cooled water is collected in a basin at the bottom of the cooling tower where it can then be reused to absorb heat in the steam condenser. Because a considerable amount of water is evaporated during the process, a portion of water, referred to as "blowdown," needs to be discharged to prevent a buildup of salts and minerals in the system. Makeup water is therefore needed to replace the amount of water that is lost in the system due to evaporation, blowdown, and other losses. In a WTE facility employing a wet recirculating cooling tower, upwards of 600 gal of water may be consumed to process 1 ton of waste and to produce approximately 550 to 650 kilowatt-hours of electricity. The majority of this water consumption is used in the cooling system.

Due to the large amount of water consumed using traditional evaporative cooling systems—and because reclaimed water, a viable alternative water source for such systems, was not available to the new facility—SWA needed to consider alternatives for steam cooling. Environmental and aesthetic considerations were

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also a priority. A direct dry-cooling system was ultimately selected that uses air instead of water as the medium of heat transfer in the steam condensing process. Since an air cooling system uses no water, this design decision will significantly minimize total water consumption in the new facility. The use of a dry-cooling system will also result in no wastewater discharge attributable to the cooling system from blowdown. Other drawbacks associated with wet recirculating cooling towers will also be avoided; for example, no visible plume will be emitted and no carryover of water droplets that may contain salt and other contaminants will occur.

The new facility will use an air-cooled condenser comprised of modularized finned tube bundles mounted on an A-frame structure. Steam from the turbine will flow through the finned tubes, where it will be cooled using a high flow rate of ambient air directed by fans across the outside surface of the tubes. Heat from the steam will be transferred directly to the ambient air. The condensed steam will be collected and returned to the boiler feedwater system to be reused. The new direct dry-cooled WTE facility will use less than 15 percent of the water required for a wet-cooled plant of similar size. Although the air-cooled condenser will be significantly more expensive to build and result in slightly lower power cycle efficiency than a wet-cooling system, it represents an innovative and sustainable solution that will minimize water usage and virtually eliminate the need to discharge wastewater from the new facility.

Cascading Water Management System

For the same reasons and goals described, innovative water sources had to be identified for use as supply water to REF2. As a result, SWA specified a hierarchy of alternative water supply sources to be used in the new facility, in the following order of decreasing priority:

- Existing REF1 cooling tower blowdown water
- Harvested rainwater
- Industrial supply well (ISW) water
- Dechlorinated potable water
- Potable water, when needed

The new mass burn facility will be located directly adjacent to an existing 2,000 tpd refuse-derived fuel WTE facility (REF1). The REF1 uses a wet recirculating cooling system and generates a significant amount of cooling tower blowdown. A portion of the blowdown is reused in the existing plant, but the excess has been discharged for disposal via deep well injection. The SWA recognized that this excess could be beneficially reused in the new facility as a source of supply water. This synergistic arrangement will reduce and perhaps eliminate the amount of wastewater disposed through deep well injection from REF1 and, along with the use of harvested rainwater and ISW water as sources of supply water to the new facility, conserve potable water that would otherwise have to be used.

The design approach developed by the project team of B&W, KBR, and CDM Smith uses a cascading water management system (CWMS) to supply water to the facility processes using the following separate, integrated systems:

- Recycle Water System
- Wastewater Reuse System
- Ash Quench Water System

The wastewater from the processes supplied by the recycle water system is recovered and reused in the wastewater reuse system. Wastewater from the processes using both the recycle water and the wastewater reuse systems is recovered and reused in the ash quench water system. The ash quench water system (via a settling basin) recovers all of the wastewater that is high in minerals and suspended solids, along with other process water sources, so that it can be reused in the facility as quench water for the bottom ash.

As a result of the cascading system design, along with appropriately-sized storage tanks and basins, the new facility will effectively operate as a zero-wastewater-discharge facility under normal operating conditions. The system allows for storage of excess water in the three primary water storage systems for later use during peak demand periods, minimizing the need for the higher-quality and more-expensive sources of water during those periods. Figure 1 provides a simplified overview of the CWMS, showing the sources of supply to each system and the cascading hierarchy design.

The Recycle Water System

The recycle water system consists of a 2-mil-gal (MG) recycle water storage tank, three service pumps and associated controls, and a piping network that provides clean water to various processes within the new facility (including boiler water makeup and lime slaking). This upper rung of the cascading water reuse system is designed to accept and blend sources of clean water with low minerals and suspended solids. The sources of water supplying the recycle water system are:

- Harvested rainwater
- ISW water
- Dechlorinated potable water (backup supply only)

Harvested Rainwater

Harvested rainwater is a clean source of water that is low in minerals and suspended solids. This supply is variable and intermittent with the largest quantities anticipated during the rainy season, which runs from June to September. The first 2 in. of rainfall from each rain event will be harvested from approximately 7 acres of rooftop from a portion of the existing REF1 and most of the new mass burn facility (refer to the buildings labeled in Figure 1).

Figure 1. Proposed Rendering of Renewable Energy Facility #2

Approximately 60 in. of rainfall occurs in the Palm Beach area on a yearly average. The past 40 years of historical data were analyzed, and it is estimated that 89 percent of the annual rainfall can be harvested using the rooftop areas. Of the 89 percent, 72 percent will be harvested from rainfall events less than 2 in. and 17 percent from rainfall events greater than 2 in. Assuming all of the first 2 in. of rainfall from each rain event will be captured from the rooftops, 10.1 MG of rainwater will be harvested annually. Harvested rainwater will supply approximately 16 percent of the total annual water requirements for the new facility (REF2).

Industrial Supply Well Water

The ISW water is a clean source of water that is low in minerals and suspended solids. This supply is a variable source of water that originates from a network of existing surficial groundwater wells located throughout the Palm Beach County Renewable Energy Park. The wells are used to draw down the groundwater table at the landfill site to maintain an inward gradient, eliminating the potential for off-site groundwater contamination. Approximately 39.7 MG of ISW water (based on an annual facility availability of 92 percent) will be used to meet the water requirements of the new facility, or approximately 61percent of the total annual water demand under normal conditions. The ISW water is subject to daily and monthly withdrawal limitations. Under normal conditions, 153 gal per min (gpm) of ISW water will be available to the new facility. The availability of the ISW water source is affected by weather, as well as the demands imposed on the system by the existing REF1 (makeup to the cooling tower and irrigation system) and other SWA uses throughout the renewable energy park. When REF1 has one or two units down, more ISW water will be available to the new facility.

Dechlorinated Potable Water

Dechlorinated potable water (city-supplied water that is filtered and dechlorinated at the existing SWA water treatment facility located south of REF1) is a source of water that is low in minerals and suspended solids. The supply of dechlorinated water available to the new facility is dependent, in part, on permitted daily and monthly allotments. This supply will not be used in the new facility during normal operating conditions; however, this source may serve as a backup source during peak demand periods if the tank inventory requires supplemental makeup.

The availability of the dechlorinated water source is also affected by the demand imposed on the system by REF1. The estimated maximum available dechlorinated water supply is 150 gpm.

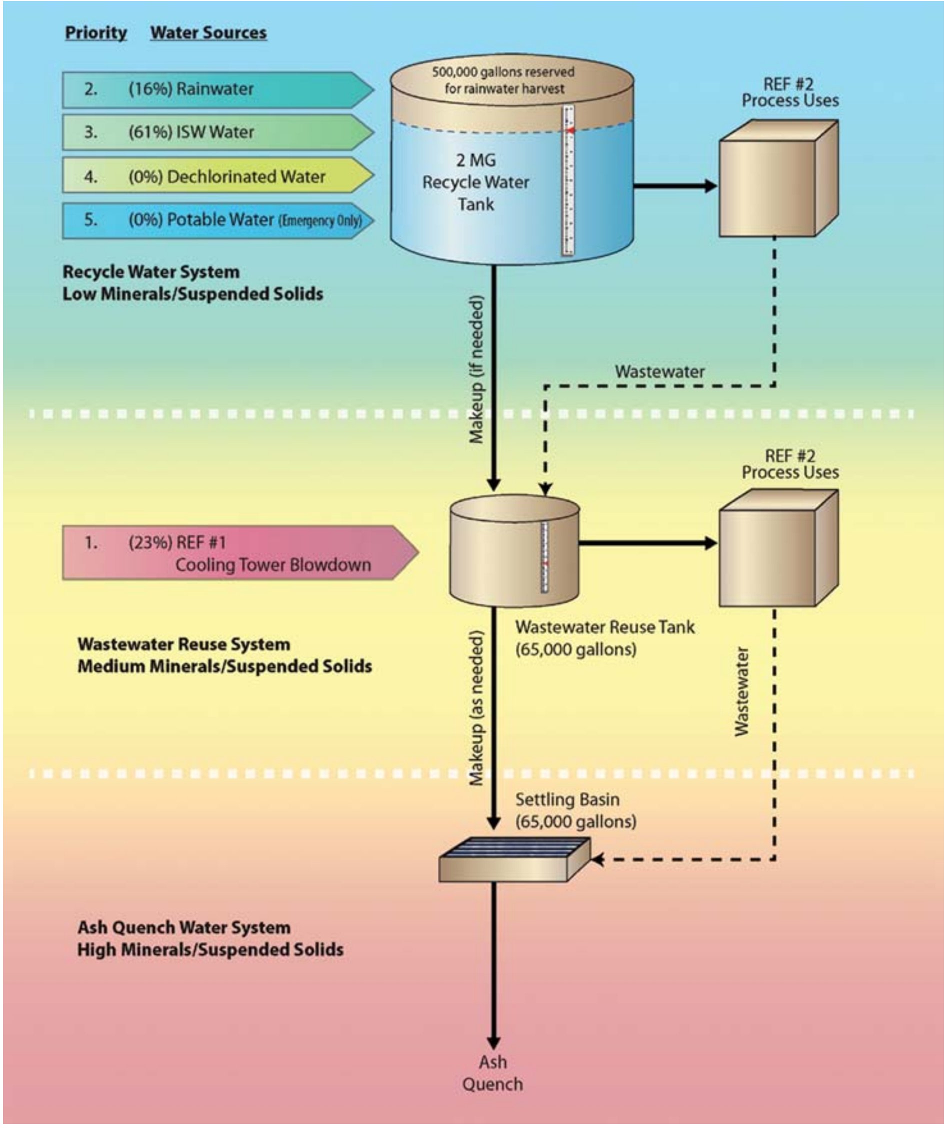

Figure 2. Overall Cascading Water Management System

Wastewater Reuse System

The wastewater reuse system consists of a 65,000-gal storage tank, two service pumps and controls, and a piping network that provides water to various processes within REF2, including scrubber dilution and fly ash conditioning. The wastewater reuse system is the middle rung of the cascading water reuse system and is designed to accept and blend several sources of water with high dissolved solids including:

- Existing REF1 cooling tower blowdown (primary source of water supply)
- Reverse osmosis (RO) reject water from boiler makeup water treatment
- Auxiliary cooling tower blowdown

The RO reject water and auxiliary cooling tower blowdown sources are wastewater streams from the processes served by the recycle water system that will be reused within the facility.

Renewable Energy Facility #1 Cooling Tower Blowdown

The REF1 cooling tower blowdown is a source of water that is high in minerals and relatively low in suspended solids. This supply serves as the primary source of water to the wastewater reuse system of the new facility, depending upon the status of operation of the existing facility. The REF1 can supply up to 146 gpm of cooling tower blowdown to the new facility. It is estimated that15 MG (based on an annual facility availability of 92 percent) of cooling tower blowdown from REF1 will be used annually to meet the water requirements in the new facility, or approximately 23 percent of the total annual water demand under normal conditions.

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An underground pipe will transfer the cooling tower blowdown from REF1 to the wastewater reuse storage tank at the new facility for use as process water. It should be noted that when REF1 is not in operation (an infrequent condition), there will be no cooling tower blowdown available to the new facility. At the same time, however, the use of ISW water in REF1 will be greatly reduced during these periods, so more ISW water would be available to the new facility under such conditions.

The current cooling tower blowdown system at REF1 operates continuously and is driven by the pressure of the circulating water. A booster pump will be provided at the existing facility site to convey cooling tower blowdown to the 65,000-gal wastewater reuse tank located at the new facility. The booster pump will be designed to allow 100 percent of the available cooling tower blowdown supply water to be pumped to the new facility. This will enable the full transfer of available cooling tower blowdown water for later use during peak demand periods (such as the initial fill of the wastewater reuse tank and settling basin) if other water sources are not available.

Under normal operating conditions, a bypass line around the booster pump will be installed to allow REF1 circulating water system pressure to transfer the estimated average demand of 31 gpm of cooling tower blowdown water to the new facility. A throttle valve will be provided in the supply line on the new facility site to regulate the flow to the amount needed to maintain required inventory in the wastewater reuse storage tank. Strainers will be provided on the supply line just prior to the inlet of the wastewater reuse tank, removing any larger particles of suspended solids.

This arrangement will allow the new facility to accept only the amount of cooling tower blowdown water that is needed. Under this mode of operation, the new facility will operate as a zero-wastewater-discharge facility. The disposal of any nonrecycled blowdown water would remain in the control of REF1 staff, but the benefit is that there would be reduced frequency and volume of wastewater discharges.

Ash Quench Water System

The ash quench water system consists of a 65,000-gal settling basin, two pumps and controls, and a distribution piping network. This system occupies the last rung on the water reuse ladder and provides water that is high in minerals and suspended solids.

The supply sources to the settling basin system include wastewater streams from the processes served by the recycle water and the wastewater reuse systems that will be reused within the new facility. The sources of water supplying the settling basin system are collected in floor drains and u-trenches, then routed via gravity and pumping to the setting basin for storage. After some physical treatment (skimming of floatables and settling of suspended solids), the water from the settling basin is reused as quench water in the ash dischargers and grate siftings conveyors. Regular makeup from the wastewater reuse system may be required to meet the water demands from the settling basin system under normal conditions.

Highlighting the Innovative Aspects of The Design

The innovative design of the cascading water management system minimizes the amount of makeup water needed in the new facility. The estimated water input requirement to the new facility is 64.8 MG per year under normal conditions. Approximately 15.5 MG of annual process water demands will be met by the reuse of process wastewater within the cascading water management system. The internal reuse of wastewater will also result in a zero-discharge operation under normal conditions.

The cooling tower blowdown water from the existing REF1 is an unconventional source of supply water for the new facility. Since REF2 will be located adjacent to the existing REF1, this allows for a synergistic relationship between the two facilities. What sets this apart from other WTE facilities is essentially a "better than zero-discharge" concept. The use of cooling tower blowdown as a source of supply represents the beneficial reuse of a wastewater stream that otherwise would be sent for disposal by deep well injection. As such, REF2 will not only operate as a zero-discharge facility, it will also reduce the amount of wastewater currently being discharged by REF1.

The rainwater harvest system is another unique aspect of the design. This intricate collection system will harvest rainwater from the following roof areas:

- Northern half of REF1 tipping building
- REF2 main processing buildings (tipping, refuse, boiler, and air pollution control buildings)
- REF2 ash building
- REF2 maintenance building
- REF2 recycle water storage tank roof
- REF2 visitor center

Harvested rainwater as a priority source of supply water to a WTE facility is unique. The volume of water harvested from rain will vary widely throughout the year, but the variations should not have a significant impact based on the designed flexibility of the system. The seasonal variation of harvested rainwater will affect the daily and monthly demands for water from the other sources available to the new facility. Figure 3 represents the estimated supply expected from each source of water by month under normal operating conditions.

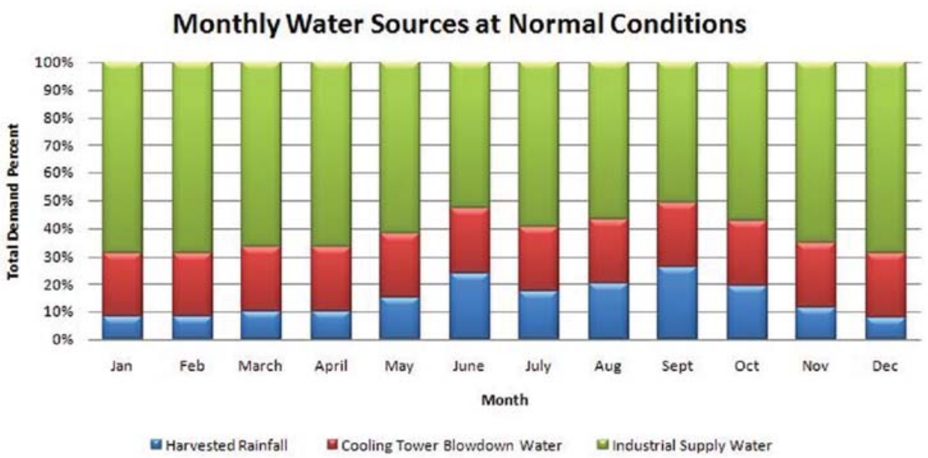

Figure 3. Monthly Water Supply Sources at Normal Conditions

Conclusion

The use of innovative design and water supply sources at SWA's new WTE facility will significantly reduce the amount of water needed in the new facility and maximize potable water conservation. The CWMS uses three integrated water supply systems to maximize reuse and consumption of process wastewater within the facility. The result is a reliable, flexible, and sustainable water management system at the new facility. Because the water sources are sustainable and the design minimizes wastewater discharge, this new facility will operate at "better than zero-discharge" conditions, a novel concept and perhaps the first facility to do so.