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SUPPLIER PERSPECTIVE

Brewery Water and Process Water Management: The Golden, Green Opportunity Found in Anaerobic Treatment Solutions

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ABSTRACT

As the number of craft breweries in the United States continues to grow, concerns about input water and spent process water become increasingly prevalent. Many breweries—particularly in drought-stricken regions and in small towns where aging municipal treatment infrastructure is nearing capacity—are implementing strategies around water consumption and process water discharge to avoid business

interruption and mitigate supply and cost concerns. It is no surprise that craft brewers, consistent innovators in both product and process, are tackling input water and spent process water management challenges head on, implementing water conservation programs and investing in sustainable process water treatment technologies.

Water and process water management challenges continue to present economic and environmental barriers to growth for breweries across the United States. Brewery process water is significantly higher strength than domestic wastewater. Its strength is typically measured in terms of chemical or biochemical oxygen demand (COD or BOD, respectively), the amount of organic content in the process water. The BOD in brewery process water typically averages 6,000 mg of BOD/L but can run up to 20,000 mg/L. These streams overload municipal wastewater treatment facilities, designed around domestic waste strengths of 150–200 mg/L, pushing them to risk violating their National Pollutant Discharge Elimination System (NPDES) permit limits. This risk, combined with increased water scarcity and aging infrastructure, forces municipalities to set high effluent discharge fees and water supply restrictions for their constituents.

Escalating effluent costs depress profitability, and limited water supply caps production, preventing breweries from keeping pace with market demand. This puts them at a critical disadvantage in a rapidly growing, highly competitive market. To alleviate these challenges and ensure continued, sustainable growth, breweries of all sizes must be proactive and strategic about water and process water management.

Several solutions offer relief. Brewery process water is traditionally treated with aerobic solutions for which energy, operations labor, and sludge disposal are the largest cost drivers. For example, aerobic solutions use 1.5–2.5 kWh of electricity to remove 1 kg of biochemical oxygen demand (BOD). However, high-strength process water streams contain up to 3 kWh of energy per kilogram of BOD, making

anaerobic solutions particularly compelling for breweries. Anaerobic treatment solutions, such as Cambrian Innovation's EcoVolt® Reactor, are net-positive energy generators and achieve high treatment efficiencies (80–90% removal of BOD). They give breweries an economically viable case for onsite treatment and reuse of their process water to hedge against increased water supply and pricing concerns.

Biological Alternatives to Municipal Wastewater Treatment Facilities

Onsite biological treatment solutions can be split into two categories: aerobic solutions and anaerobic solutions. Both are effective alternatives to centralized municipal solutions. To select a solution that suits their needs, breweries should optimize around two key considerations:

- Treatment: address relevant major process water issues (pH, BOD, and solids).
- Economics: evaluate total lifecycle cost and overall environmental benefit.

Traditional Aerobic Treatment

Aerobic treatment involves adding oxygen to process water, facilitating a biological degradation process in which BOD is converted into biomass, carbon dioxide, and water. Breweries typically select from aerobic treatment solutions ranging from simpler treatment ponds to more advanced membrane bioreactors (MBRs) and activated sludge processes.

Treatment ponds are a low capital option for treatment. They accomplish low effluent levels, are relatively easy to maintain, and incur relatively low maintenance costs. However, ponds require an enormous physical footprint, have high energy costs, and leave breweries at risk for odor issues while failing to capture the value trapped in brewery process water.

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MBRs and other advanced activated sludge processes require less physical space, treat process water efficiently and consistently, and are typically containerized. However, these solutions produce large volumes of wasted biosolids that require constant disposal, and they are energy intensive.

Traditional Anaerobic Treatment

Although anaerobic treatment solutions typically require a higher upfront capital investment than their aerobic counterparts, they compete on total lifecycle cost by offering lower operating costs, producing renewable energy, and generating significantly (around 80%) less biosolids. Anaerobic digestion systems efficiently clean process water while producing an energy-rich biogas, which can be converted into electricity and heat with a cogeneration system.

Anaerobic treatment proceeds through a diverse microbial community, culminating with methanogenic bacteria, to degrade organics in the process water in carefully designed reactors, simultaneously treating solids and/or BOD in process water while generating biogas. In recent decades, high-rate, soluble anaerobic treatment systems have been used extensively to treat industrial process water. Since the introduction of upflow anaerobic sludge blanket reactors in the early 1970s, advances have led to the introduction of other high-rate system designs such as expanded granular sludge blanket reactors and internal circulation reactors. These treatment systems are characterized as suspended growth anaerobic treatment systems and all rely on a delicate balance of reactor hydraulics and the formation of biomass granules to retain active biomass in the reactor and maintain the treatment process.

Anaerobic treatment solutions exhibit relatively slow growth of the biomass compared to their aerobic counterparts. However, they also exhibit greater sensitivity to environmental conditions (pH, temperature, volatile fatty acids, ammonium, etc.). When combined with the proper pretreatment and control systems, many solution designs conquer this hurdle. But despite substantial advances, suspended growth anaerobic treatment technologies still suffer from challenges that hinder their widespread adoption in the brewing industry (1,2):

1. Washout of granular biomass can easily occur owing to upsets in process hydraulics or process water composition and loading fluctuations.
2. Anaerobic systems do not effectively treat low levels of BOD, requiring long hydraulic retention times and/or polishing steps to remove residual BOD.
3. High-rate anaerobic systems are generally operator-intensive due to the need for proper environmental conditions.
4. Custom system design typically requires large projects before economies of scale can be recognized.
5. Because of the bacteriostatic behavior of hops, breweries known for using high volumes of hops in the brewing process experience issues with traditional anaerobic treatment technologies.

Eager to capitalize on the opportunities presented by anaerobic solutions, some large-scale breweries turn to custom, on-site solutions. High equipment and installation costs coupled with complex and difficult-to-manage microbial communities that require constant oversight by trained operators make these solutions a major pain point for breweries. Additionally, these solutions are not scalable: as a brewery grows, they run the risk of overloading their onsite treatment solution.

Leveraging Bioelectrochemical Systems for Enhanced Anaerobic Treatment

Bioelectrochemical systems (BES), which include microbial fuel cells (MFCs) and microbial electrolysis cells (MECs), utilize newly discovered microbes to generate electricity via direct contact with electrodes. Traditional MFCs and MECs use chemical catalysts (such as titanium) that oxidize fuel (such as hydrogen) at anodes and reduce oxygen at cathodes. A circuit between the anode and the cathode captures electrical energy released in the process.

BES can be thought of as fuel cells with regenerative, living microbial catalysts. These microbial catalysts can oxidize and reduce a broad range of organic pollutants.

BES-enhanced process water treatment solutions have a number of advantages over suspended growth anaerobic solutions, particularly when energy efficiency, precise control, and reactor stability are high priorities. They allow for consistent, high-rate digestion in a fixed-film architecture, which not only offers robust treatment but also can be modular and does not require biomass replacement. This translates to lower operating costs for breweries. Additionally, multiple studies have demonstrated that the BES process is able to stabilize the treatment process, yielding significantly higher methane yield and BOD treatment rates (4), even with high organic loading rates (3).

Cambrian Innovation's EcoVolt Reactor: BES-Enhanced Anaerobic Treatment for Breweries

Cambrian Innovation is a commercial provider of distributed process water treatment and resource recovery solutions. The company's flagship product, the EcoVolt Reactor, is an MEC that leverages a process called electromethanogenesis to help breweries and other industrial businesses cost-effectively and sustainably treat their process water while generating renewable resources such as clean energy and clean water. Electromethanogenesis enhances the anaerobic treatment process, stabilizing system operation, improving biogas production, and enabling remote monitoring and automation of the treatment process.

In Cambrian's EcoVolt Reactor, biologically coated "anodes" consume pollutants in the water, converting them into electrons. Simultaneously, biological "cathodes" convert electrons and carbon dioxide into methane gas. The resulting biogas, a mixture of methane, carbon dioxide, and trace amounts of hydrogen sulfide, has one of the highest percentages of methane (70–80%) achieved in an MEC, significantly higher than that in a traditional anaerobic system. Similar in composition to natural gas, this fuel burns efficiently and with a low emissions footprint, allowing breweries to offset their energy consumption.

A typical EcoVolt solution includes a unit for process water conditioning and expandable 20,000 gal EcoVolt Reactors for process water treatment and biogas generation. An optional cogeneration system converts biogas into clean electricity and heat. The entire solution is prefabricated for ease of shipping, installation, and operation, and its modular and containerized architecture both requires a small physical footprint and allows for flexible capacity increase.

Figure 1 shows the performance of one EcoVolt Reactor over two months, through typical fluctuations seen at breweries.

Case Study: An EcoVolt Solution for Bear Republic Brewing Company

Faced with both water supply and process water discharge limits, Bear Republic began to explore onsite process water treatment solutions to both support their expansion plan and reduce the load on the city of Cloverdale's overworked treatment infrastructure. The brewery's desire to maximize sustainability led them to Cambrian Innovation, and they were the first to purchase an EcoVolt solution in 2014.

The EcoVolt solution, which consists of two EcoVolt Reactors and 95 kW of microturbine capacity, enables Bear Republic to meet sewer discharge requirements, cut operating electricity costs, and eliminate over 4,000 metric tons of carbon dioxide emissions each year (Fig. 2).

On average, the system is exceeding performance expectations across all design parameters, including treatment rate,

contaminant removal, biogas generation, and methane fraction. It removes 80% of the BOD in Bear Republic's process water and produces an average methane fraction of 70%, significantly reducing the brewery's reliance on natural gas. It currently supports Bear Republic's annual production of 82,000 barrels per year, and it can easily expand to support their planned growth to an annual production of 150,000 barrels per year.

Case Study: An EcoVolt Solution for Lagunitas Brewing Company

Lagunitas Brewing Company faced steep economic and environmental costs for dealing with the spent process water at their Petaluma, California, facility. They were trucking more than 50,000 gal (10 trucks) per day of high-strength process water—approximately 40% of their total flow—to a municipal treatment plant over 50 miles away. Their low-strength process water was

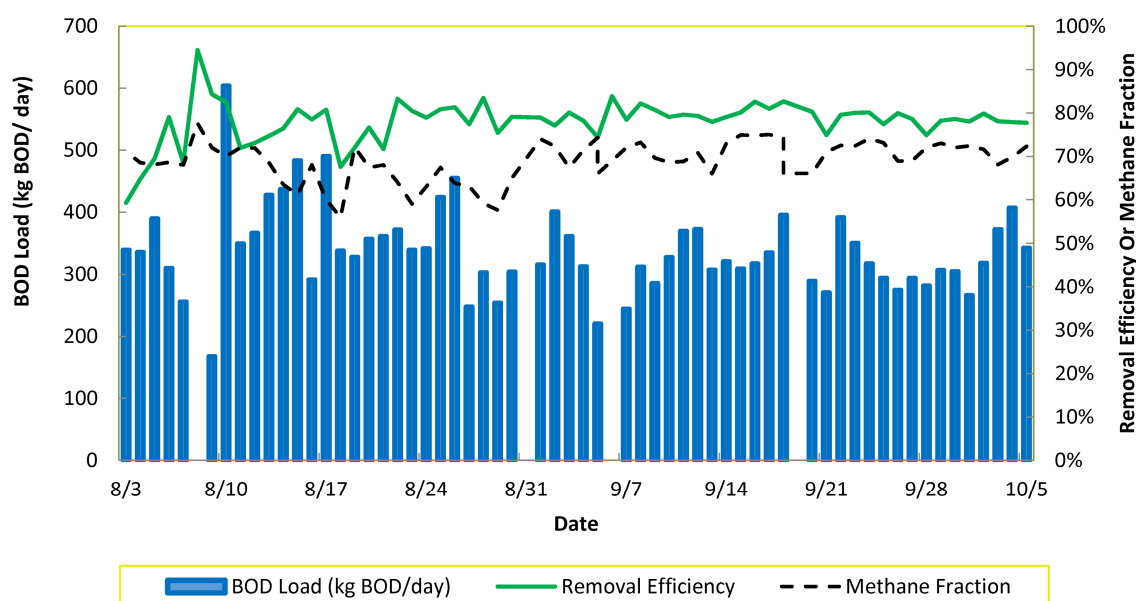


Figure 1. EcoVolt Reactor performance.

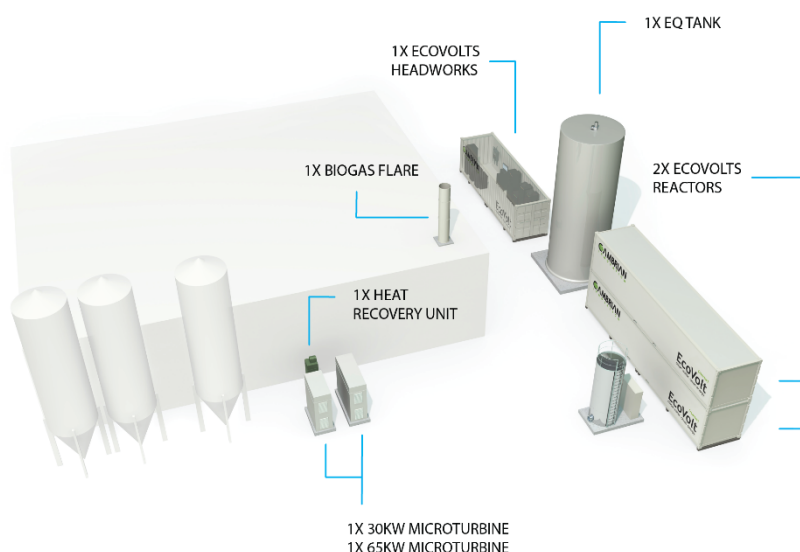


Figure 2. Layout of EcoVolt solution at Bear Republic Brewing Company.

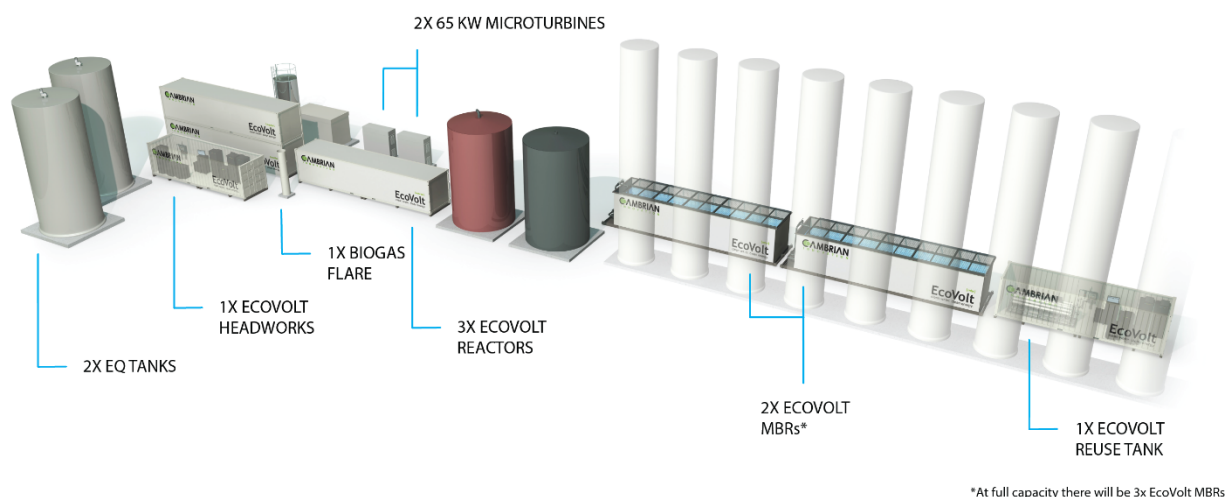


Figure 3. Layout of EcoVolt solution at Lagunitas Brewing Company.

being discharged to Petaluma for treatment, in compliance with environmental regulatory standards.

When it came to process water management, Lagunitas had three priorities: 1) find a cost-effective, compact process water treatment solution that could grow with the brewery; 2) eliminate trucking of process water to save money while slashing their carbon footprint; and 3) reuse water to hedge against capacity fees and increased water scarcity, and to ensure sustainable growth. These priorities led them to Cambrian's EcoVolt solution.

Lagunitas's EcoVolt solution (Fig. 3) consists of three EcoVolt Reactors, three EcoVolt MBRs (membrane bioreactors, which efficiently remove over 99% of contaminants, enabling reuse), and a reverse osmosis system. The self-powered installation treats over 120,000 gal of spent process water per day and produces over 80,000 gal of clean, recycled water per day. Overall, it cuts the brewery's water footprint by 40% while generating 130 kW of electrical power and 40,000 therms of heat per year.

Because of the project's success, Lagunitas recently selected Cambrian's EcoVolt technology for their new brewery in Azusa, California, signing a 20-year Water-Energy Purchase Agreement™ (WEPA) for process water treatment as a service. This agreement is the first of its kind in the industrial wastewater treatment industry.

Conclusion

Today's forward-thinking industries, including the brewing industry, are actively seeking progressive solutions for process water treatment and water reuse. The right solution can offer both improved process economics and increased water security, an important strategic benefit in the face of climate change concerns.

BES-enhanced anaerobic treatment solutions transform process water into a source of revenue, producing high-quality

biogas for renewable electricity and heat, and clean, recycled water. Cambrian's EcoVolt solutions embody the convergence of high-tech control systems, efficient and inexpensive data management, complex systems automation, and ready-to-install fabrication. Designed specifically for scaling, these systems allow industrial businesses incremental expansion of treatment capacity to better match their actual growth.

In late 2015, Cambrian also introduced a financing model for its EcoVolt solutions. The WEPA makes EcoVolt solutions accessible to breweries of all sizes by offering onsite wastewater treatment as a service. Under the WEPA, Cambrian owns and operates its EcoVolt solutions for customers, who are simply charged by gallons of wastewater treated and by kWh of clean energy and gallons of clean water returned to the facility. This allows breweries to focus on their core competency—making beer—while realizing immediate savings around wastewater and energy.

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