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FINAL PROJECT REPORT

Biological Double-Efficiency Process for Advanced Biological Wastewater Treatment

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PREFACE

The California Energy Commission's (CEC) Energy Research and Development Division supports energy research and development programs to spur innovation in energy efficiency, renewable energy and advanced clean generation, energy-related environmental protection, energy transmission, and distribution and transportation.

In 2012, the Electric Program Investment Charge (EPIC) was established by the California Public Utilities Commission to fund public investments in research to create and advance new energy solutions, foster regional innovation, and bring ideas from the lab to the marketplace. The EPIC Program is funded by California utility customers under the auspices of the California Public Utilities Commission. The CEC and the state's three largest investor-owned utilities—Pacific Gas and Electric Company, San Diego Gas and Electric Company, and Southern California Edison Company—were selected to administer the EPIC funds and advance novel technologies, tools, and strategies that provide benefits to their electric ratepayers.

The CEC is committed to ensuring public participation in its research and development programs that promote greater reliability, lower costs, and increase safety for the California electric ratepayer and include:

- Providing societal benefits.
- Reducing greenhouse gas emission in the electricity sector at the lowest possible cost.
- Supporting California's loading order to meet energy needs first with energy efficiency and demand response, next with renewable energy (distributed generation and utility scale), and finally with clean, conventional electricity supply.
- Supporting low-emission vehicles and transportation.
- Providing economic development.
- Using ratepayer funds efficiently.

For more information about the Energy Research and Development Division, please visit the CEC's research website (www.energy.ca.gov/research/) or contact the Energy Research and Development Division at ERDD@energy.ca.gov.

ABSTRACT

The Issue

The activated sludge process is the most common secondary wastewater treatment method for nutrient removal. However, it is energy and space intensive due to the need for separate anoxic and aerobic tanks with secondary clarifiers. This infrastructure demands high capital investment, land, energy, and operation and maintenance costs. Aeration in the activated sludge process is the most energy-intensive and accounts for between 45 percent and 75 percent of the plant's electricity consumption. With California's drought intensifying water and energy conservation efforts. The current challenge is to meet the demand from population growth, increasingly strict regulations and aging infrastructure while potentially reducing the energy and water consumption from wastewater treatment plants.

Project Innovation + Advantages

The Biological Double Efficiency Process (BDP) is an important breakthrough that combines state of the art/easy to maintain aeration technology, airlift circulation/dilution technology, and an integrated all-in-one bioreactor technology. It utilizes simultaneous nitrification/denitrification principles, leading to significant savings: on average, 50 percent energy, 30 percent capital, 50 percent land footprint, between 30 percent and 50 percent operation and maintenance, and 15 percent water savings.

BDP's key innovation for energy savings includes the proprietary aeration technology, short-cut nitrification/denitrification, and the airlift recirculation system. BDP aeration technology reduces 50 percent of the air needed for the secondary treatment process and greatly improves oxygen transfer efficiency to between 48 percent and 52 percent compared to between 20 percent and 30 percent in conventional technologies. Short-cut nitrification/ denitrification was observed in the BDP process that provides substantial energy savings. In addition, the BDP airlift recirculation system reduces energy by using the same blower for aeration and recirculation. The BDP process has an excellent performance record which removes chemical oxygen demand (up to 95 percent), ammonia (99 percent), and total nitrogen (95 percent).

Keywords: Activated Sludge, Chemical Oxygen Demand, Total Nitrogen, Biological Double Efficiency Process, Nitrification, Denitrification, Wastewater, Aeration, Bioreactor

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Background

The most common secondary wastewater treatment process for nutrient removal is the activated sludge process. Most activated sludge processes are energy and land intensive since they require separated anoxic and aerobic tanks, with secondary clarifiers. The infrastructure requires high capital, land, and operation and maintenance costs. In addition, aeration in the activated sludge process is highly energy-intensive, accounting for between 45 percent and 75 percent of the plant's electricity consumption. The current challenges for wastewater treatment plants in California are to meet energy demand from population growth, increasingly stringent regulations, aging infrastructure, and high energy and operational costs.

The innovative process from BDP provides substantial energy savings for wastewater treatment plants from a proprietary aeration technology, short-cut nitrification and denitrification, and airlift recirculation system. The proprietary BDP aeration technology reduces 50 percent of the air needed for secondary treatment and improves oxygen transfer efficiency to between 48 percent and 52 percent, compared with between 20 percent and 30 percent in conventional technologies. The BDP process removes chemical oxygen demand (COD) (up to 95 percent, ammonia up to 99 percent, and total nitrogen up to 95 percent. BDP technology integrates several processes into one treatment basin. Where a conventional process requires that an activated sludge basin be followed by a secondary clarifier, the BDP process eliminates the need for a secondary clarifier. This saves both space and energy.

Across California, municipal wastewater treatment plants are estimated to consume between 2 percent and 4 percent of total electricity consumption in the state. Electricity alone can constitute 25 percent to 40 percent of a wastewater treatment plants' annual operating budget and make up a significant portion of a given municipality's total energy bill. These energy needs are expected to grow in the next decades, driven by population growth and increasingly higher water quality requirements as well as a water supply shortage in California.

In the last decade, California's population has grown by an average of 330,000 new residents per year, equivalent to the population of the city of Santa Ana. The BDP process requires less land while meeting this growing water and wastewater demand, while providing the advantages of reduced energy and land use, carbon footprint (CO_2 emissions), and waste sludge production, resulting in a cleaner and safer environment.

Project Purpose and Approach

The biological double-efficiency process created by BDP Technologies with the support of the California Energy Commission, advances the quest for sustainable wastewater management in California. This project integrates anaerobic and aerobic processes within a singular, highly efficient bioreactor system, which promises a significant reduction in energy and water usage, lower operational expense, and a smaller environmental footprint when compared with conventional treatment practices.

This demonstration project shows the practical scalability of BDP technology across diverse pilot sites. It also advances California's ambitious environmental and sustainability mandates by offering a tangible solution to the state's pressing water management challenges. The successful implementation of this technology creates the opportunity for its broader adoption, including wastewater treatment, water recycling, and reuse in municipal and industrial sectors, promoting sustainable water management in California and beyond.

This project supports California's ambitious energy conservation and sustainability laws. It provides a cost-effective option for municipalities grappling with rising energy costs. The energy savings potential of the BDP system advances California's environmental leadership and commitment to reducing carbon emissions and increasing resilience against climate change.

Moreover, this project directly addresses California's urgent need for water conservation. During severe droughts and water scarcity, the enhanced efficiency of the BDP process facilitates higher water recycling and reuse rates, strengthening the state's water security and sustainability. This initiative marks a significant technological leap in wastewater treatment, a vital step toward a sustainable and resilient future.

In summary, this demonstration project's objectives and goals reflect a comprehensive strategy to address the multifaceted challenges of wastewater treatment. Demonstrating the viability of BDP technology sets a precedent for sustainable, efficient, and cost-effective wastewater management practices, offering a blueprint for future advancements.

Key Results

The wastewater treatment and recycling industry in California has prioritized energy efficiency to reduce costs and improve environmental performance. Wastewater treatment plants are significant consumers of electricity, and efforts are underway to adopt more energy-efficient technologies. One promising approach is to enhance secondary biological treatment processes that dominate current wastewater treatment operations. By simplifying these processes and optimizing equipment, significant energy and water savings can be achieved.

Energy Savings

The BDP demonstration project in California showcased notable energy savings in various components of the secondary biological treatment process. Compared to conventional methods, the BDP system achieved a substantial reduction in energy consumption, particularly in aeration, which accounted for about 50 percent of total energy usage. In the city of Rialto, where the project is located, the person equivalent (PE) wastewater flow is 50 gallons per day and averages 3.86 people per household. The project capacity is 200,000 gallons per day, up to 500,000 gallons per day between dry and wet season, which is 4,000-10,000 PE, or 1,036-2,590 households. Saving 50 percent of the energy is equivalent to 2,000-5,000 PE or 578-1,295 households, potentially saving 138,700 kilowatt-hours (kWh) annually.

The unit power consumption of the demonstration project is 1.7 kWh per 1,000 gallons of wastewater treated. Conventional wastewater treatment processes are averaged at 3.6 kWh per 1,000 gallons of wastewater treated. This demonstration project therefore reduced energy consumption by 1.9 kWh per 1,000 gallons of treated wastewater. This translates into an annual reduction of 693 kWh per 1,000 gallons of treated wastewater, equivalent to a 1-million-gallon-per-day wastewater plant saving 693,000 kWh per year.

Water Savings and Land Footprint

The BDP system's design reduced the wastewater treatment footprint due to a shorter hydraulic retention time from an average of 28 hours for conventional biological processes, down to 18 hours for BDP technologies, an approximate 30 percent reduction; a 30 percent reduction in concrete usage further increased energy savings.

Improved effluent water quality also met the state's strict environmental standards (especially total nitrogen effluent) and increased recycled water production by at least 15 percent, which equates to 112,350 acre feet per year (AFY) of recycled water.

Greenhouse Gas Emissions

Implementation of BDP technologies can also significantly reduce greenhouse gas emissions. By retrofitting existing treatment basins and reducing waste sludge production, BDP systems can mitigate emissions from wastewater treatment plants. By retrofitting 35 percent of existing basins in California with BDP technology, the project estimates an annual CO_2 emission reduction equivalent of approximately 14,000 tons.

Capital

Implementing BDP technologies offers cost savings when compared with conventional upgrades. The BDP demonstration project in Rialto, California, showed a 19-percent reduction in capital improvement budgets and anticipated operational cost savings of between 24 percent and 33 percent, which also contribute significant annual savings.

In summary, the BDP demonstration project highlights the significant energy and water savings potential of innovative wastewater treatment technologies. By adopting BDP systems, California can substantially reduce energy consumption, greenhouse gas emissions, and operational costs while simultaneously improving water quality and supporting environmental sustainability.

Knowledge Transfer and Next Steps

The project undertook a comprehensive approach to knowledge and technology transfer to ensure the sustainable adoption and operational efficiency of the biological double-efficiency process across California's water-management infrastructure. Efforts included educational outreach, stakeholder engagement, and the dissemination of findings through diverse channels to maximize impact and public awareness.

Key Actions Taken

Educational Programs: Implemented formal and non-formal education programs in collaboration with academic institutions and industry stakeholders, focusing on the practical application and operational management of BDP technologies.

- **Stakeholder Engagement:** Conducted in-person meetings, on-site presentations, and technology introduction seminars with municipal, regional water management entities, and private sector participants. This facilitated direct dialogue and refined technology implementation strategies.
- **Dissemination of Findings:** Utilized publications, online platforms, seminars, and conferences to share project outcomes, demonstrating the environmental and operational benefits of BDP technologies.
- **Community Outreach:** BDP participated at the Southern California Chinese Association of Environmental Protection events numerous times. BDP became a sponsor of the association, and Eric Li was elected as a board member. During these events, the BDP promoted the Rialto project and its performance outcomes.

Recommendations and Takeaways

- **Expand Educational Outreach: Continue** and broaden educational initiatives at vocational and university levels to cultivate deeper understanding of the BDP technology among future professionals.
- **Strengthen R&D Collaborations:** Promote joint research efforts between academia and industry to address local challenges and advance technology adoption.
- **Enhance Digital Platforms for Knowledge Sharing:** Leverage digital tools for broader dissemination of knowledge, including online training modules and interactive forums.

Prospects for Broader Adoption and Policy Influence

The project underscores the importance of engaging a broad spectrum of stakeholders to promote innovative water treatment solutions. Successful deployment both across municipalities, along with interest from numerous other entities, highlights the demand for these technologies. Further contacts with state utilities, engineering consultants, and industries should also be made. Also, the potential to replace existing aeration systems with BDP aeration should be explored since the lifespan of BDP is two-to-three times longer and plant shutdowns are not required for either maintenance or diffuser replacement.

- Recommendations call for sustained educational outreach, enhanced digital knowledge dissemination, and active stakeholder engagement to ensure that the technologies' benefits are widely understood.
- Policymakers and regulatory bodies are encouraged to recognize and incorporate the knowledge and benefits of BDP technologies into relevant policies and regulations, promoting sustainable water management practices.

Future Research Directions

- Future actions should focus on expanding the scope of research and development collaborations to refine and enhance BDP technologies further.
- Investigate the long-term economic and environmental impacts of widespread adoption of BDP technologies to inform policy and planning.
- Explore innovative applications of BDP technologies beyond traditional water treatment settings to address emerging water management challenges.

This comprehensive approach ensures the project's findings and technological advancements are effectively shared, fostering an environment conducive to sustainable development and innovation in water management.

CHAPTER 1: Introduction

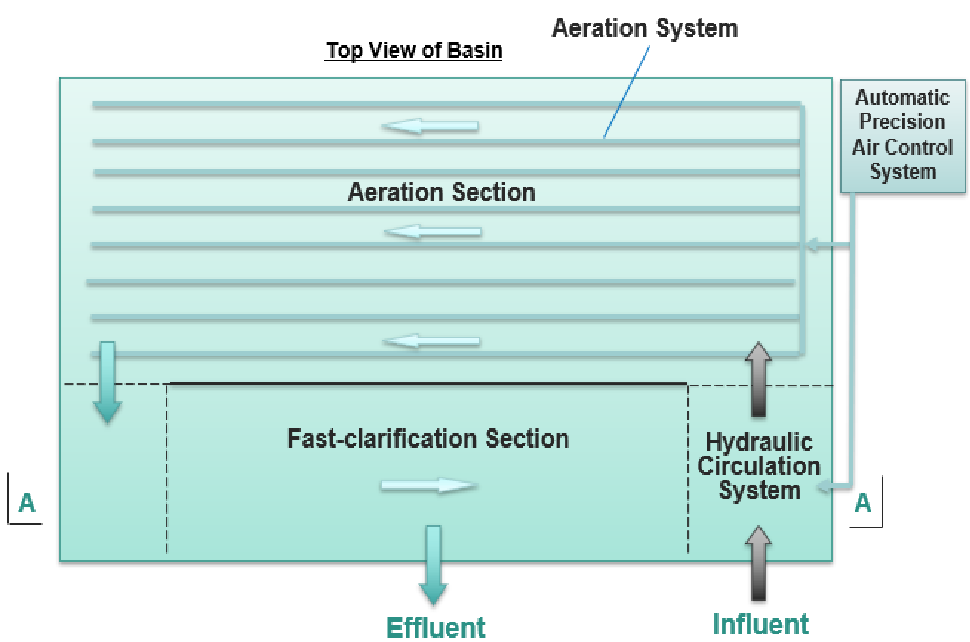
This research project introduces and demonstrates the benefits of a biological double-efficiency process (BDP) technology in wastewater treatment plants (WWTPs) across California. This technology presents a comprehensive solution to the challenges faced by WWTPs including energy consumption, reliability, regulatory compliance, and infrastructure aging. By showcasing the advantages of BDP technology, this project addresses the increasing demands for water and energy conservation in the state while adhering to strict regulations and improving overall efficiency.

Activated sludge processes are commonly used for nutrient removal in conventional WWTPs. They are energy and land intensive, with aeration as its most energy-consuming component. California's persistent drought conditions have heightened the urgency for water and energy conservation, creating significant market demand for innovative wastewater treatment technologies. This technology also illustrates that incorporating proprietary aeration technology, short-cut nitrification/denitrification, and airlift recirculation systems, can together reduce energy consumption and increase efficiency.

The BDP technology has already been applied globally in over 65 WWTPs.

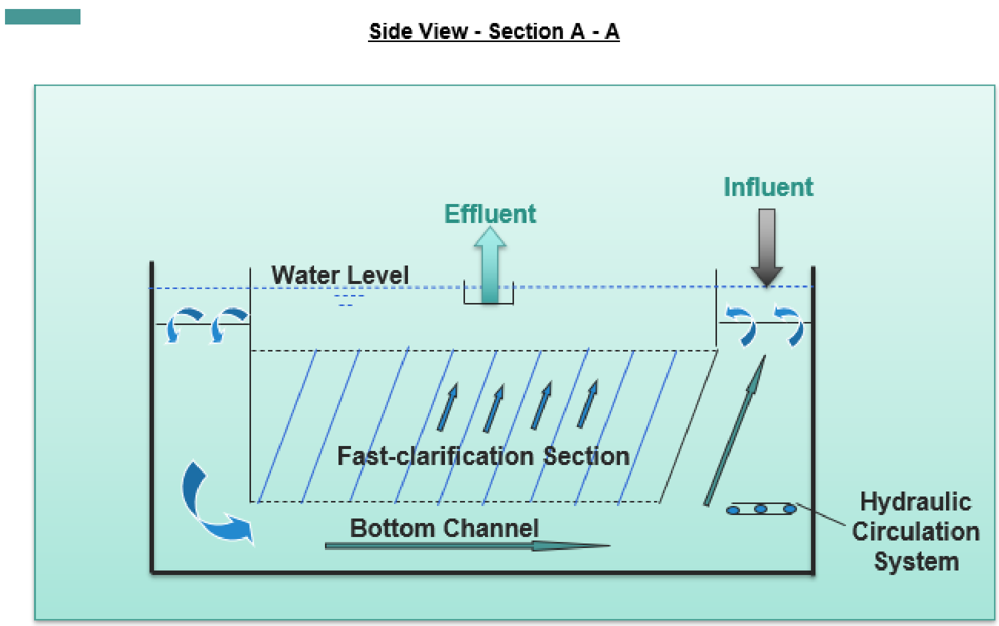
The following Figures 1 and 2 illustrate the concept of the *all-in-one basin* technology.

Figure 1: Integrated All-in-One Basin Structure



Source: BDP Full Introduction Presentation

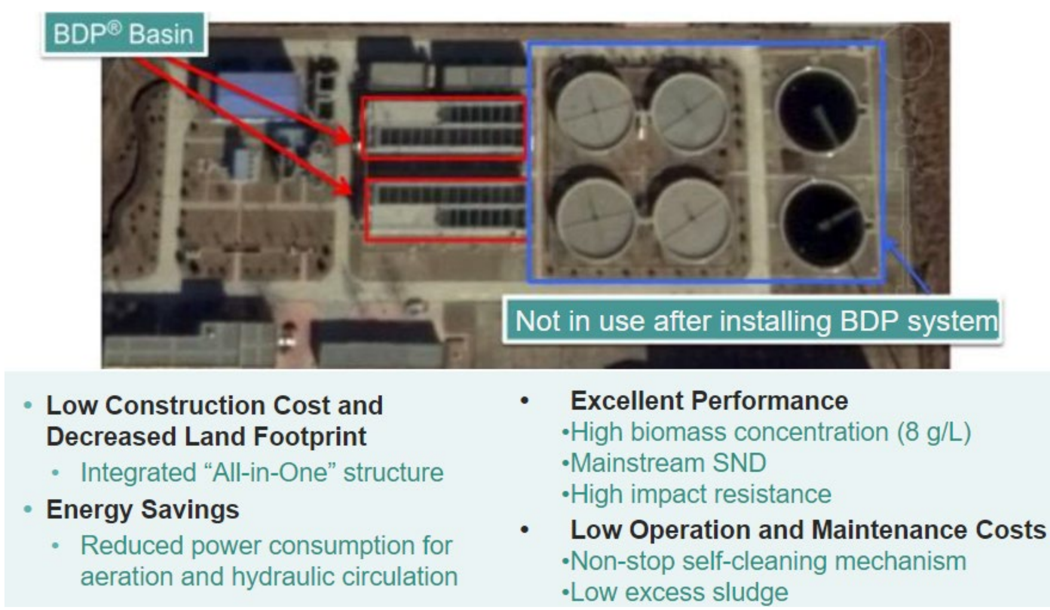
Figure 2: Clarification and Airlift Cross Section



Source: BDP Full Introduction Presentation

As an example of the effectiveness of BDP technology, **Figure 3** illustrates the prominent advantages of a BDP plant before and after a conventional plant upgrade.

Figure 3: Top View Comparison of BDP And Traditional Basin and Benefits of BDP Basin



Source: BDP Full Introduction Presentation

The project's overarching goals were:

1. **Lower Costs:** The project will demonstrate how BDP technology can significantly reduce aeration power requirements, electric blower usage, and overall operation and

maintenance (O&M) costs for WWTPs, lowering capital and embedded costs. This reduction in costs will not only benefit the WWTPs but also contribute to cost savings for the municipalities and industries utilizing these facilities.

2. **Greater Reliability:** BDP technology's stability and low energy consumption provide greater reliability for the electric grid and minimize downtime for cleaning or maintenance. This increased reliability ensures consistent wastewater treatment operations, reducing the risk of service interruptions and environmental hazards.
3. **Increased Safety:** The high nutrient removal capabilities of BDP technology ensure compliance with strict regulatory standards and safe discharges into water bodies. By effectively removing pollutants, BDP technology safeguards water resources and ecosystems, promoting public health and environmental sustainability.
4. **Economic Development:** The project illustrates how deploying BDP technology can contribute to California's economic development by enhancing water and wastewater capacity while reducing energy and water consumption. By investing in innovative wastewater treatment solutions like BDP, California can create jobs, attract investments, and foster economic growth in the water sector.
5. **Environmental Benefits:** Environmental advantages of the BDP technology include reduced energy and land use, a smaller carbon footprint, less waste sludge, and improved water quality. By promoting sustainable practices and reducing environmental impacts, BDP technology supports California's commitment to mitigating climate change and preserving natural resources.
6. **Public Health:** BDP technology's ability to meet regulatory standards while reducing carbon footprints and odors will promote public health. By ensuring the effective treatment of wastewater, BDP technology helps protect communities from waterborne diseases and contamination, improving overall public health outcomes.
7. **Consumer Appeal:** The expected cost savings for ratepayers due to reduced energy, capital, and O&M costs of WWTPs, as well as the potential for further development on reclaimed land, will appeal to consumers. By lowering utility costs and enhancing the quality of life, BDP technology offers tangible benefits to both consumers and communities.
8. **Energy Security:** The project will demonstrate how BDP technology reduces energy requirements, contributing to greater energy security for California. By optimizing energy usage and reducing dependence on external energy sources, BDP technology strengthens California's resilience to energy shocks and disruptions.

The primary audience for this project includes public and private sector stakeholders involved in wastewater treatment, water reclamation, and water reuse. Specific organizations targeted include the California State Water Resource Control Board, California Water Environment Association, WateReuse California, academic institutions such as the University of California, Irvine, and the University of California, Los Angeles, and research centers like the U.S. Clean Tech Center and the Institute of Marine Sciences at the University of California, Santa Cruz.

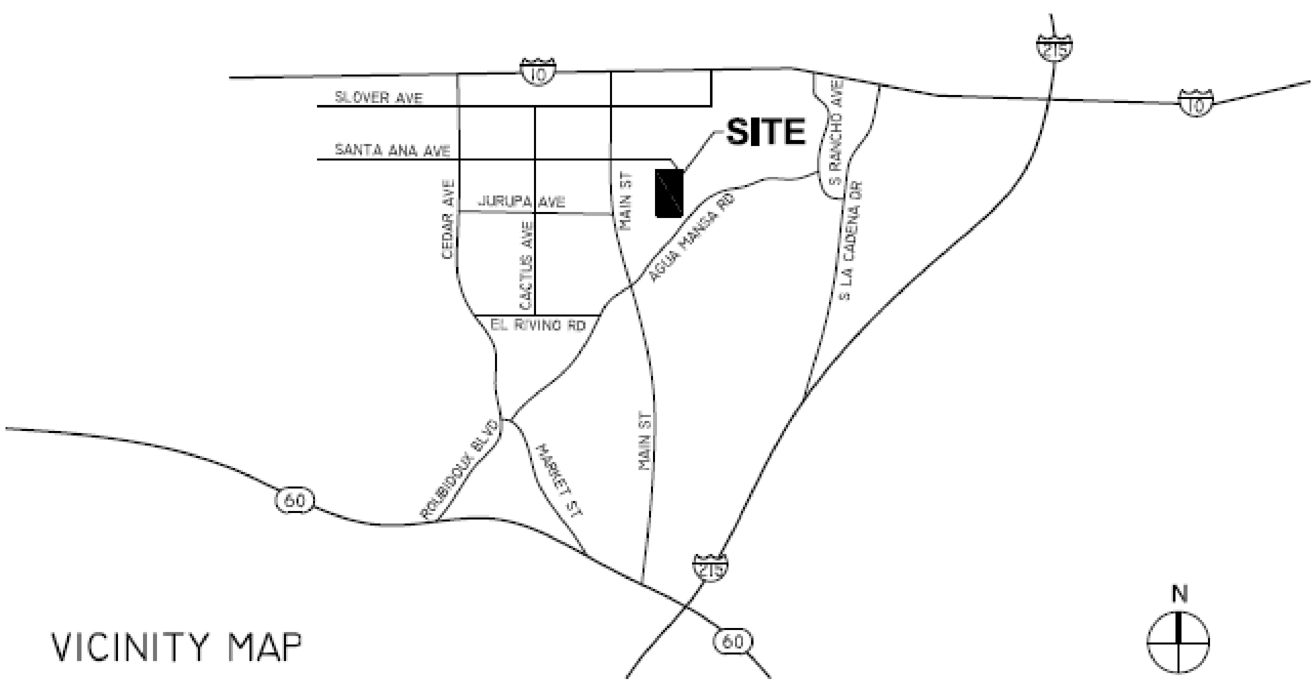
Potential clients for BDP technology include municipalities, industrial facilities (for example, oil and gas, petrochemical, agricultural), and other industries requiring wastewater treatment (for example wineries, breweries, food processing). Notable projects like Morgan Hill and Apple Valley serve as examples of successful implementations, while ongoing pursuits in Crockett, Silicon Valley Clean Water, and San Jose Sanitation District represent future opportunities.

Research conducted by the Institute of Marine Environmental Technologies and the French National Academy of Science Institute of Environment and Agriculture have demonstrated BDP technology's efficiency in real-world conditions. BDP's aeration system maintains high oxygen transfer efficiency, surpassing conventional methods even in complex wastewater treatment environments. Utilizing off-gas testing methodology, BDP technology achieves excellent results, ensuring continuous operation without downtimes for cleaning or maintenance.

Overall, this project promotes BDP technology as a sustainable solution for California's wastewater treatment needs. By addressing key challenges faced by WWTPs and emphasizing the benefits of BDP technology, the project could both accelerate its adoption and contribute to California's water and energy conservation efforts. Through targeted demonstrations and partnerships with industry and regulatory bodies, BDP technology can play a pivotal role in advancing wastewater treatment practices and fostering environmental sustainability across the state.

The following Figures 4-7 demonstrate the location, layout, and details of the project location and the basin itself. Taking the influent from the p5 primary clarifier of the Rialto Wastewater Treatment Plant, the BDP basin can treat 200,000 to 500,000 gallons per day between dry and wet season. The effluent is discharged back to p2 aeration/clarifier.

Figure 4: Location of the Project Site Between Santa Ana Avenue and Agua Mansa Road in Rialto, California



Source: CEC Rialto Civil Eng Drawings

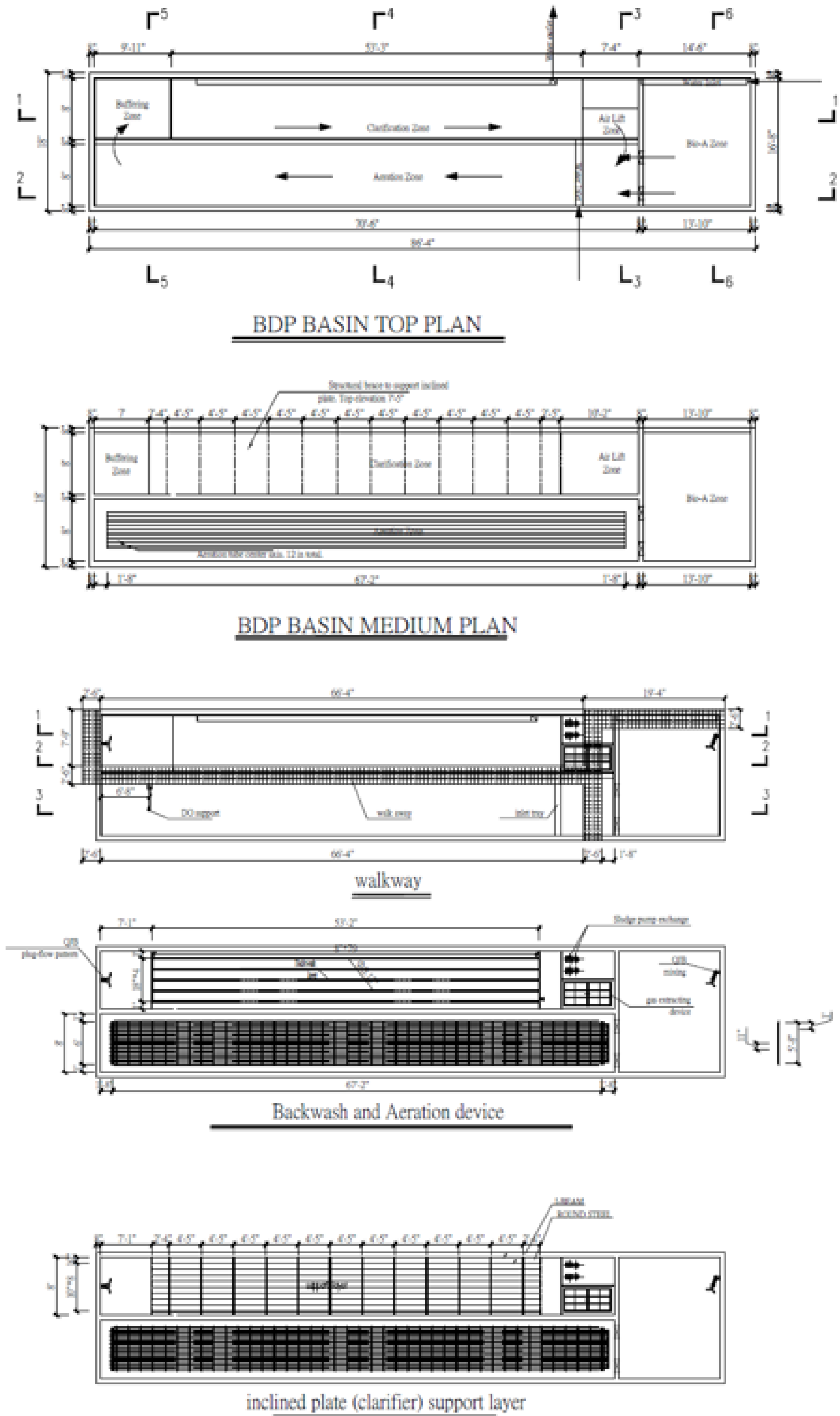
Figure 5: Detailed Aerial Site Map of the BDP Project on the Site of Rialto Wastewater Treatment Plant

Source: CEC Rialto Civil Eng Drawings

Figure 6: Close-up Site Map of the BDP Project

Source: CEC Rialto Civil Eng Drawings

Figure 7: Section Views of the BDP Demonstration Project Basin



Source: Rialto CEC Process Design Drawings

CHAPTER 2: Project Approach

The biological double-efficiency process created by BDP Technologies with support from the California Energy Commission, is a milestone in advancing sustainable wastewater management. By introducing a novel approach that integrates anaerobic and aerobic processes into a single, efficient bioreactor, this initiative reduces energy and water consumption, lowers operational costs, and minimizes environmental impacts when compared with traditional treatment methods. This project demonstrates the practical and scalable benefits of BDP technology across various pilot sites. It also aligns with California's strict environmental and sustainability goals by offering a viable solution to the state's pressing water management challenges. *The project's successful execution and the resulting insights set the stage for broader adoption of BDP technology. The implications extend beyond wastewater treatment to include water recycling and reuse across public and private sectors, improving sustainable water management in California and beyond.*

Introduction

The biological double-efficiency process (BDP) represents an advance in sustainable water management solutions within California. Traditional wastewater treatment methodologies, burdened by high energy consumption, high operational costs, and notable environmental footprints, are increasingly unsustainable given strict environmental and regulatory demands. With these challenges, the BDP technology can improve treatment efficiencies, reduce energy and water consumption, and mitigate environmental impacts commonly associated with conventional wastewater treatment facilities.

The state's wastewater treatment facilities are increasingly challenged by surging demand, higher regulatory directives, and the need for sustainable water management. This is exacerbated by the high energy requirements of wastewater treatment, a significant contributor to the state's overall energy consumption. It is estimated that municipal wastewater treatment plants account for between 2 percent and 4 percent of California's total electricity use, a substantial portion of which is dedicated to the aeration processes of conventional biological treatment methods.

This research project provides a solution for those challenges. By combining anaerobic and aerobic stages within a single reactor, the BDP technology significantly reduces the energy consumed by wastewater treatment operations. This alignment with California's aggressive energy conservation and sustainability objectives offers a cost-effective alternative for municipalities wrestling with escalating energy expenses. The energy savings potential of the BDP system is especially significant for California, a state known for its environmental leadership and committed to reducing carbon emissions and bolstering resilience against climate change. The project's contribution to reducing energy consumption in wastewater treatment directly supports these goals, providing a scalable and sustainable blueprint.

This demonstration project directly addresses California's acute need for water conservation. Amidst severe droughts and water scarcity, the improved efficiency of the BDP process enables higher recycling and reuse rates, bolstering the state's water security and sustainability. This project marks a technological improvement in wastewater treatment and represents a step toward California's sustainable and resilient future.

This project also It embodies a move toward fulfilling California's environmental and energy aspirations. By reducing energy consumption in one of the state's most energy-intensive public service domains, the project lowers municipal operational expenses and encourages broader energy conservation, emission reductions, and sustainable water management goals.

Project Partners and Stakeholders: A Collaborative Ecosystem

This demonstration project, supported by the California Energy Commission (CEC), is built upon a network of collaborative partnerships and stakeholder engagements that include academic institutions, local wastewater treatment facilities throughout California, and technical advisors. This collaborative ecosystem was designed to meld scientific research with real-world applications, adopting a holistic strategy to navigate the state's water management challenges.

The Rialto Wastewater Treatment Plant (Rialto Water Services) fills a crucial role in the city's infrastructure by treating millions of gallons of wastewater daily. Established in 1953, this facility occupies a significant area and utilizes advanced treatment processes that meet environmental standards. Rialto Water Services provides water and wastewater services to more than 100,000 people in the state's Inland Empire; its systems are operated in partnership with Veolia North America. The facility's commitment to innovation and sustainability makes it a key asset in supporting Rialto's growth and environmental goals.

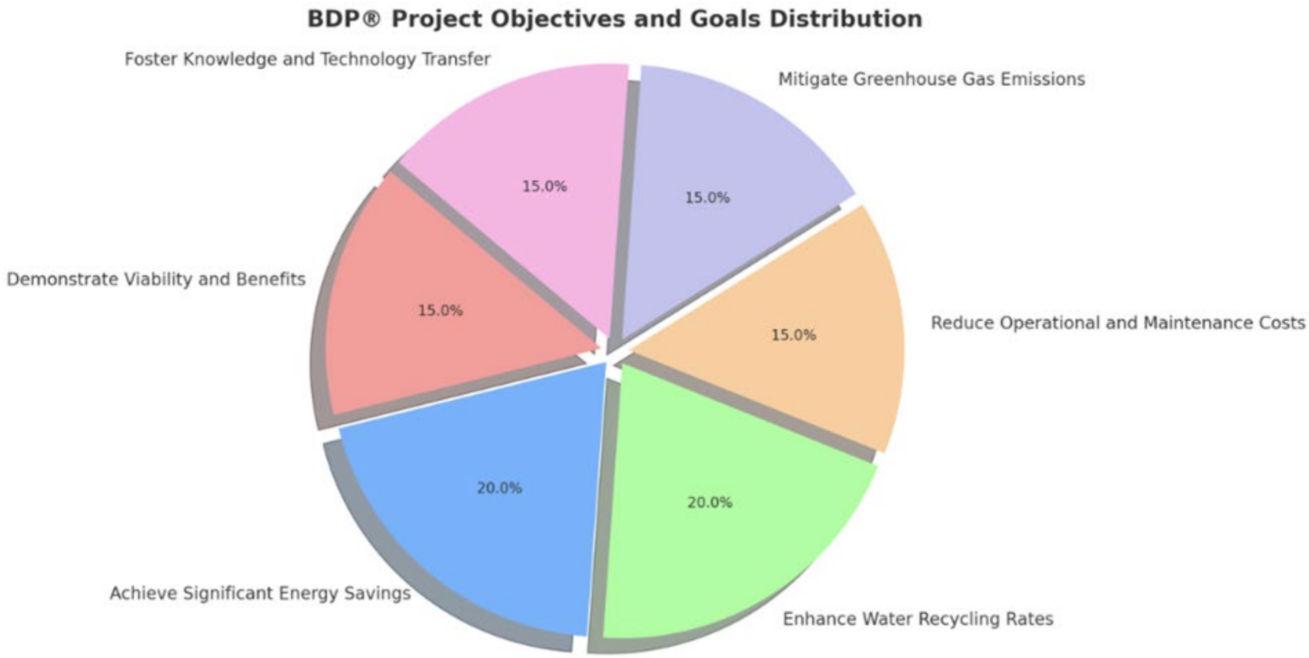
The City of Rialto is in San Bernardino County, with a population of 103,526 (U.S. Census, 2019). The city of Rialto provided both support for and space within this facility for this demonstration project. This showcases the city's innovative water management solutions and emphasizes the project's potential for broader applicability both within the state and beyond.

Veolia North America manages water treatment operations along the West Coast and played a pivotal role in this collaborative project. Through a public-private partnership (PPP) with the city of Rialto, Veolia was instrumental in operating the Rialto Wastewater Treatment Plant under a 30-year agreement. Its partnership with the CEC Rialto BDP demonstration project provided support throughout the development phases of the project.

Objectives and Goals

This project, supported by the California Energy Commission (CEC), was conceived with a multifaceted approach to improve wastewater treatment. The primary impetus of this initiative was to demonstrate the effectiveness and sustainability of the BDP technology in a tangible, operational environment, and to address broader environmental and economic challenges facing California. Drawing upon insights from the project's comprehensive framework and collaborative efforts, the objectives and goals were grouped into several key areas. **Figure 8** illustrates the distribution of the project's objectives and goals.

Figure 8: BDP Objective Distribution Pie Chart



Source: BDP

1. Demonstrate the Viability and Benefits of Biological Double-Efficiency Process Technologies

At its core, the project demonstrated BDP technology's practical advantages in a real-world setting, emphasizing its potential as a transformative solution in the wastewater treatment sector. This involved rigorous testing and analysis to validate the technology's performance, efficiency, and adaptability within existing wastewater management infrastructures.

2. Achieve Significant Energy Savings

A critical aim was to substantiate the energy efficiency of the BDP technology compared to conventional wastewater treatment methods. By optimizing the biological treatment process, the project aspired to significantly reduce energy consumption, aligning with California's aggressive energy conservation and sustainability laws. The BDP demonstration project highlighted the potential for reducing energy use by up to 50 percent during the secondary treatment stages, bolstering the technology's role in fostering a more energy-efficient wastewater management ecosystem.

3. Enhance Water Recycling Rates

Another pivotal goal was to improve water recycling capabilities, thereby bolstering California's water conservation strategies amidst ongoing water scarcity. Through advanced nutrient removal and treatment efficiency, the BDP technology produced higher quality effluent suitable for reuse applications, from agricultural irrigation to industrial processes, contributing to a circular water economy.

4. Reduce Operational and Maintenance Costs

By simplifying the treatment process and integrating multiple stages into a single, more efficient system, the project lowered the operational and maintenance costs associated with wastewater treatment. This cost reduction is vital for the long-term sustainability of water management practices, offering a financially attractive alternative for municipalities and industries facing budgetary constraints.

5. Mitigate Greenhouse Gas Emissions:

An integral aspect of the project's environmental objectives was to demonstrate how the BDP technology could lead to a reduction in greenhouse gas (GHG) emissions. By lowering energy requirements and optimizing the treatment process, the technology contributes to a decrease in carbon footprint associated with wastewater management, aligning with broader goals to combat climate change and reduce environmental impact.

6. Foster Knowledge and Technology Transfer

Beyond the immediate technical and environmental benefits, the project emphasized the importance of knowledge dissemination and technology transfer. Through educational initiatives, training programs, and collaborative research, the project built capacity among water professionals and stakeholders, ensuring the widespread adoption and long-term success of innovative water treatment solutions.

This demonstration project's objectives and goals offer a comprehensive approach to addressing the multifaceted challenges of wastewater treatment. By demonstrating the viability of the BDP technology, the project sets precedent for sustainable, efficient, and cost-effective wastewater management practices, offering a blueprint for future advancements.

Approach and Methodology

1. Technology Development and Optimization

Initial efforts to refine the BDP technology emphasized a breakthrough in aeration efficiency, pivotal for California's wastewater treatment paradigm shift. Considering California's significant energy expenditure on wastewater management—2-4 percent of the state's total electricity consumption—the project's focus on reducing aeration energy by 50 percent presented a substantial opportunity to curb energy use across the sector. This optimization is especially crucial in a state grappling with water scarcity challenges, stringent environmental regulations, and the urgent need for sustainable water management solutions.

2. Demonstration in California Settings

Implementing the BDP system in selected facilities underscored the technology's adaptability to California's diverse environmental and operational conditions. The state's wastewater treatment plants, vital to managing its water needs, face pressing needs for energy efficiency and regulatory compliance. The demonstration project in Rialto tested the BDP system's resilience and efficiency in real-world scenarios and highlighted the potential for statewide adoption. The outcomes offered a compelling narrative of reduced energy consumption, enhanced nutrient removal, and operational reliability—a narrative that supports the state's goals for environmental sustainability and economic efficiency.

3. Comprehensive Performance Evaluation with Statewide Implications

The analysis of a demonstration project within California provided crucial data on the BDP technology's impact on energy savings, water conservation, and operational cost reductions. These findings are significant against California's energy and water landscape. With an annual treatment flow rate of 2955 million gallons per day across the state, the demonstrated energy savings potential of the BDP technology—averaging a 50 percent reduction in energy use—could translate into a statewide reduction of approximately 2,047 GWh annually. This reduction addresses California's immediate energy consumption concerns and contributes to the state's long-term environmental and sustainability goals by annually saving $501 million in energy bills.

The project's success in California is testament to the feasibility and benefits of scaling BDP technology across the state's wastewater treatment infrastructure. It aligns with California's broader environmental objectives and the significant ratepayer benefits anticipated from widespread adoption. The technology's impact extends beyond energy and water savings, encompassing reduced greenhouse gas emissions, enhanced water recycling rates, and decreased waste sludge production. These contributions are critical for a state committed to pioneering sustainable practices in water management and energy consumption.

In summary, the project's strategic approach—from the initial technology development phase through to the demonstration and comprehensive performance evaluation—has not only showcased the BDP technology's effectiveness in a Californian context but also highlighted its potential to improve wastewater treatment practices statewide. By addressing the dual challenges of energy efficiency and environmental sustainability, this project paves the way for a future where California can meet its water treatment needs more sustainably, aligning with the state's ambitious environmental and energy mandates.

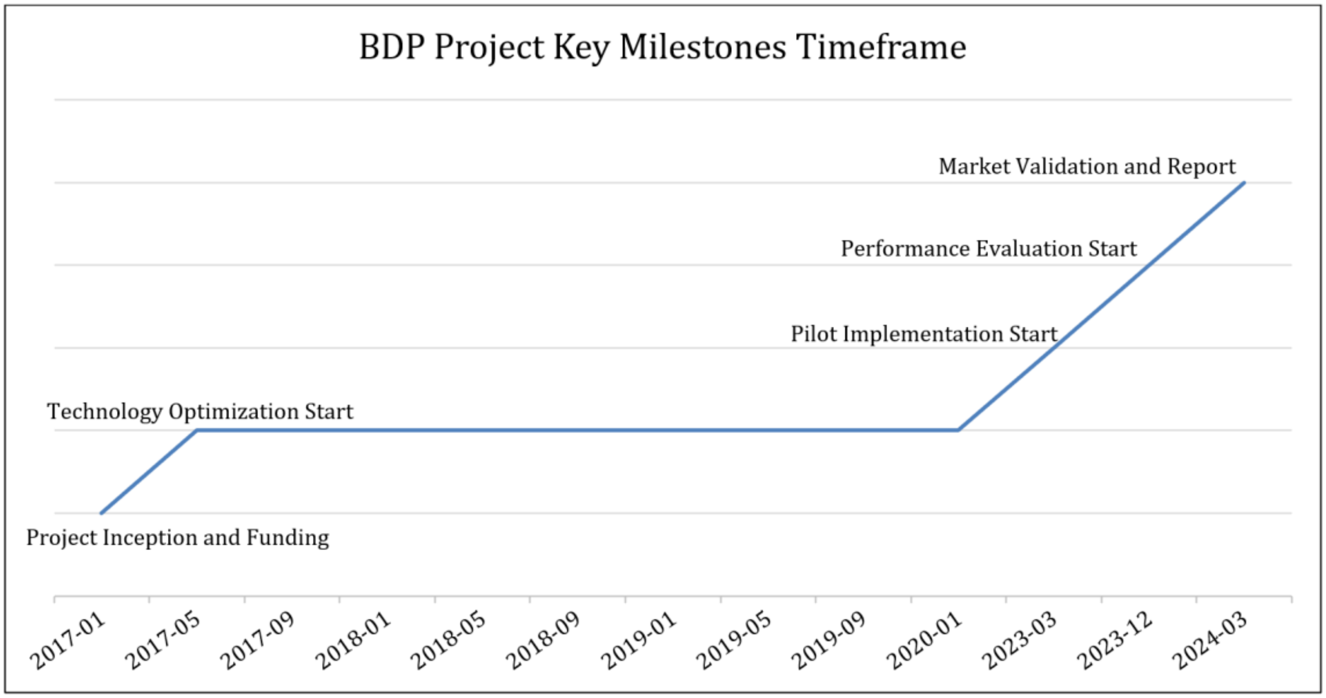
Key Milestones

Figure 9 displays the major project milestones which are described in greater detail in the following sections.

Project Inception and Funding

The project began in November 2016, when BDP Technologies entered into a grant agreement with the California Energy Commission (CEC). This secured the necessary funding and formalized the commitment to explore and validate the BDP technology's potential to improve wastewater treatment in California. With an allocated budget of $1,565,400 in reimbursable funds and an additional $330,904 in match share, the project goal was to explore sustainable wastewater management practices.

Figure 9: Biological Double-Efficiency Process as an Advanced Biological Wastewater Treatment Method to Achieve Substantial Energy and Water Saving Initial Project Millstones Timeframe



Source: BDP

Technology Optimization

During the initial phase, the project team focused on refining the BDP technology, significantly enhancing the system's energy and oxygen transfer efficiency. This period was characterized by research and development efforts to reduce air requirements by 50 percent while achieving superior treatment effectiveness compared to conventional methods. The goal was optimization and surpassing the existing standards for nutrient removal, thus setting a new benchmark for wastewater treatment efficiency and sustainability.

Project Implementation

By the midpoint of the project timeline, several project installations had been completed at several wastewater treatment facilities across California: Apple Valley, Morgan Hill, Menifee, and Santa Cruz. These installations served as practical demonstrations of the BDP technology's adaptability, scalability, and efficacy in real-world settings. Notable among these was the Rialto demonstration project, which highlighted the ability of the technology to achieve substantial energy savings and enhance nutrient removal rates, validating the BDP process as a viable and effective solution for modern wastewater treatment challenges.

Performance Evaluation and Market Validation

An evaluation of the pilot projects yielded empirical data that illustrated the BDP technology's substantial contributions to energy savings, water conservation, and operational cost efficiencies. This phase involved further collaborative research with academic and scientific institutions to validate the technology’s performance and environmental benefits. The findings from this stage were compiled into a detailed report, showcasing the technology’s success in reducing energy consumption by nearly 50 percent, as well as significant water savings and GHG emissions reductions. This report highlights the potential for a statewide reduction of approximately 2,047 GWh annually in energy consumption, with an associated energy bill savings of around $501 million.

Market Opportunities and Future Directions

The project’s conclusions demonstrated the effectiveness of BDP technology and identified significant market opportunities within California. By showcasing the technology’s flexibility for application across various sectors—including governmental, commercial, and industrial wastewater treatment, the project laid the groundwork for future scalability and adoption. The successful demonstration of the technology’s benefits has opened avenues for further exploration and deployment of BDP systems, positioning it as a pivotal contributor to the advancement of sustainable water management practices.

In summary, the project has navigated a path of significant milestones from its inception and secured critical funding for technological advancements, pilot implementations, and comprehensive performance evaluations. Each stage has contributed to building a robust case for the BDP technology’s role in advancing wastewater treatment efficiency, sustainability, and environmental stewardship, marking a new era in water management solutions.

Conclusion and Future Directions

This research project represents a significant step forward in sustainable wastewater management. The project illustrates a prospective new method of energy and resource efficiency both in California and globally. The BDP technology has achieved significant reductions in energy consumption and water usage, operational cost savings, and significant environmental benefits. The BDP technology is an innovative approach to overcoming the challenges faced by California’s wastewater treatment infrastructure. It meets the current demands of efficiency and sustainability and aligns with the stringent regulatory requirements governing the state’s water and wastewater sectors.

The success of the demonstration project is evident from the rigorous demonstrations and comprehensive performance evaluations, which highlight the technology’s efficacy and adaptability. The demonstration projects in California, mainly the Rialto site, have not only validated the BDP technology’s promises of energy savings and operational efficiency but have also illuminated its broader implications for environmental stewardship.

Looking ahead, the demonstration project lays the groundwork for the deployment of BDP technology as the technology demonstrates the benefits of water recycling and reuse. It presents compelling opportunities for integration across various sectors including agricultural, industrial, commercial, and urban water management. This versatility illustrates the potential for BDP technology to play a crucial role in California's strategy for sustainable water resource management, addressing critical challenges such as water scarcity, energy demand, and environmental conservation.

Moreover, the project's outcomes offer insights for policymakers, utility operators, and stakeholders across the wastewater treatment and water management ecosystems. It highlights the benefits of investing in innovative technologies. As California continues to face the dual pressures of population growth and climate change, adopting BDP technology represents a step toward securing a sustainable, resilient water future.

The project's success encourages broadening the scope of BDP technology applications. Further exploring strategic partnerships for technology scaling and pursuing further innovations to enhance efficiency are important. Continuous research and development efforts will be useful in adapting the technology to meet emerging challenges and leveraging advancements in related fields. Moreover, fostering policy frameworks and incentive programs supporting technology adoption can accelerate the transition to more sustainable wastewater treatment solutions statewide.

In conclusion, the demonstration project achieved its objectives and serves as a foundational blueprint for future projects in sustainable water management. The lessons learned and successes from this project will influence the development of next-generation wastewater treatment technologies, driving toward a future where water sustainability and environmental protection are paramount.

CHAPTER 3: Results

System Operation and Testing Stage: Energy and Water Savings Through BDP Technologies

In the state of California, energy efficiency has become a higher priority within the wastewater treatment and recycling industry, with public and private facility operators and state and local governments increasing efforts to reduce energy use, related costs, and improve environmental performance. According to the Public Policy Institute of California and USEPA, municipal wastewater treatment plants are estimated to consume between 2 percent and 4 percent of total electricity consumption in the state of California. Electricity alone can constitute 25 percent to 40 percent of a wastewater treatment plants' annual operating budget and make up a significant portion of a given municipality's total energy bill. These energy needs are expected to grow in the next decades, driven by population growth and increasingly higher water quality requirements as well as a water supply shortage in California.

In the state of California, wastewater treatment plants and treatment facilities are taking steps to reduce energy usage by upgrading older infrastructure with high-efficiency pumps, motors, and aeration systems as recommended by organizations such as the California Energy Commission.

One of the most efficient ways to reduce high energy consumption for operating wastewater treatment plants is to improve secondary biological treatment processes, making them simpler to operate with fewer pumping and piping installations and fewer steps in processing wastewater, as well as breeding a more energy efficient micro-biological environment through changing biological processes.

Secondary biological treatment processes dominate an estimated 80 percent of the operation of wastewater treatment plants. Significant energy consumption will not only reduce energy usage in the state, but will also reduce financial burdens on water ratepayers, in turn reducing financial pressures on local governments and businesses. In addition, reducing electricity usage also reduces greenhouse gas emissions.

Energy Savings – Electricity

The BDP demonstration project at Rialto showcased significant energy savings in the secondary biological process, including equipment and components that are electricity-dependent processes in operation, including:

- Influent wastewater pumps.
- Mixer in equalization section.
- Blowers.
- Precision air control automation system.
- Power control cabinet, power transformer.
- BDP carpet aeration systems.
- Self-cleaning system for aeration diffusers.
- Mixer in deaeration section.
- Self-cleaning system for fast clarification section.

- Control DO probe and control system.
- Hydraulic circulation system.
- Waste sludge pump.
- Effluent pumps.

As shown in Table 1 and Figure 10 below, with a total installed nominal power of 16.2 kilowatts (kW) and an average operational consumption of 14.2 kWh, the project achieved an average daily consumption of 340 kWh. This is a notable reduction when compared to conventional biological wastewater treatment processes, which range between 388 kWh to 1,450 kWh per day, averaging at 720 kWh for secondary treatment alone.

The aeration component, crucial for the process, accounted for about 50 percent of the total energy consumption at 7.2 kWh. This initial data analysis indicates an annual energy usage reduction of nearly 50 percent, equating to a savings of 138,700 kWh when compared to conventional systems. Additionally, BDP's design optimization led to a reduced wastewater treatment footprint. By designing a system with a hydraulic retention time (HRT) of 18.2 hours — significantly lower than the conventional 24-28 hours — the project achieved a minimum of a 30 percent reduction in concrete usage. This reduction translates to energy savings of 7,478 kWh for concrete production alone, which contributes to the broader environmental and operational benefits of BDP technologies.

The unit power consumption of the Rialto demonstration project is 1.7 kWh per 1,000 gallons of wastewater treated. In comparison with conventional wastewater treatment processes, which average 3.6 kWh per 1,000 gallons of treated wastewater. This demonstration of reduction of energy usage therefore showed a 1.9 kWh per 1,000 gallons of wastewater treated. This will bring an annual reduction of energy usage of 693 kWh per 1,000 gallons of treated wastewater. This is equivalent to a 1 million gallon per day wastewater plant saving 693,000 kWh per year.

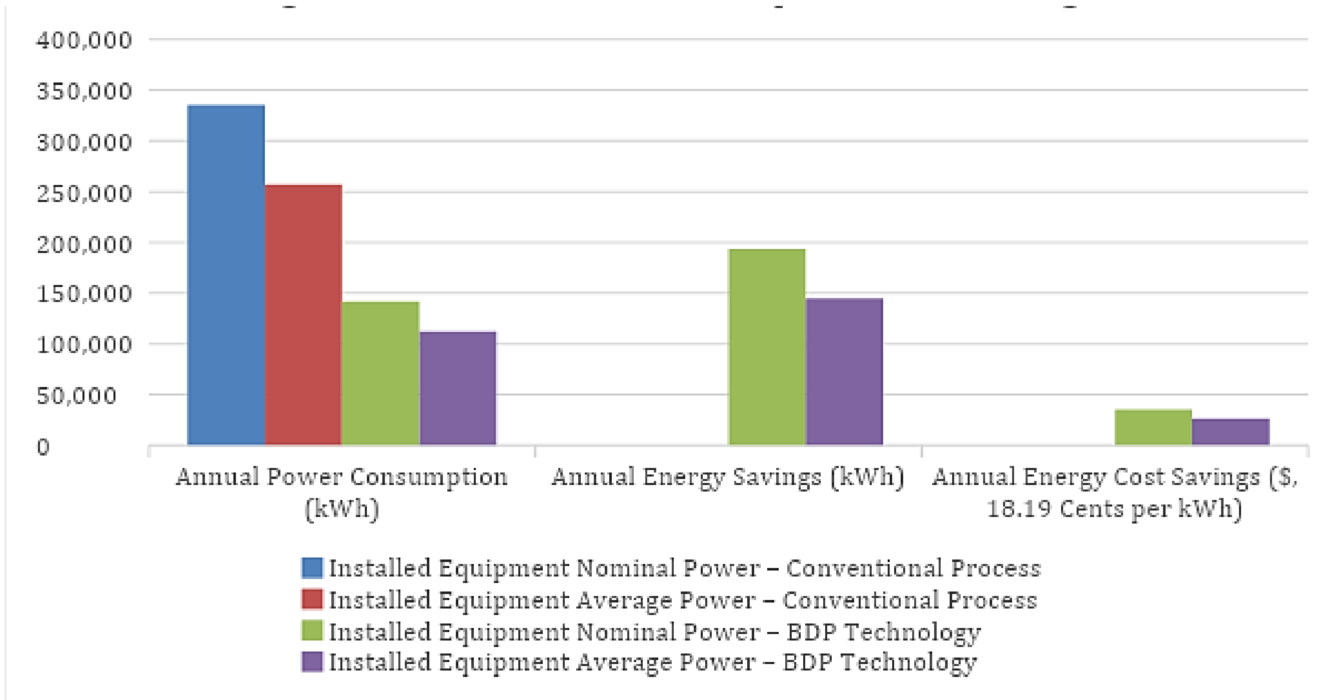
In 2022 in California, a total of 3.31-million-acre feet per calendar year was treated. That equals a 2,955 million gallon per day treatment flow rate. With the per million-gallon day energy savings of 693,000 kWh, this would result in a 2,047 GWh reduction annually in the state. The average electricity rate in California considering commercial, industrial, and residential is 18.19 cents per kWh. The potential overall energy bill reduction by applying BDP technologies would therefore be $372 million annually.

Table 1: Energy Savings

	Installed Equipment Nominal Power – Conventional Process	Installed Equipment Average Power – Conventional Process	Installed Equipment Nominal Power – BDP Technology	Installed Equipment Average Power – BDP Technology
Total Equipment Power (kW)	38.3	29.3	16.2	12.8
Daily Power Consumption (kWh)	919	705	388.8	308.02
Annual Power Consumption (kWh)	335,435	257,325	141,912	112,427.3
Annual Energy Savings (kWh)	-	-	193,523	144,897.7
Annual Energy Cost Savings ($18.19 Cents per kWh)	-	-	$35,201.83	$26,356.89

Source: BDP

Figure 10: Energy Savings Comparison Chart



Source: BDP

Energy Savings – Water

Initial testing of the BDP treatment system's effluent water quality showed improved total nitrogen (TN), Biochemical Oxygen Demand (BOD), and Total Suspended Solids TSS levels compared to conventional biological processes, as shown in Table 2. These improvements not only comply with California's stringent environmental standards but also enhance the production rate of recycled water by potentially 15 percent, due to the better elimination of pollutants. This equates to an additional 112,350 AFY of recycled water according to the total AFY of 732,000 in 2021, directly contributing to water savings and addressing water scarcity challenges in California.

The current permits of the California Water Resource Control Board for wastewater treatment plants treating wastewater flowrates greater than 100,000 gallons per day on the Central Coast, would require effluent as follows:

- Biochemical Oxygen Demand, 5-Day (BOD) 30-45mg/L.
- Total Suspended Solids, 30-45 mg/L.
- Ammonia (as N) 0-65 mg/L.
- Nitrite and Nitrate (as N) 0-65 mg/L.
- Total Nitrogen 5-35 mg/L.

Table 2: BDP Effluent

Item	Units	Effluent of BDP
COD	mg/L	25
BOD5	mg/L	10
TSS	mg/L	20
TKN	mg/L	2-6
NH_4+	mg/L	1

Source: BDP

Through another case study of BDP upgrading and retrofitting an existing 2.6 million gallon per day wastewater treatment plant, BDP redesigned the multiple stages of the wastewater treatment process: Anaerobic-Aerobic-Oxic (AAO) process – Biological Aerated Filter (BAF) process – Secondary Clarifiers. The main purpose of the upgrading was to improve the BOD effluent and the ammonia effluent. With the complete redesign of the wastewater treatment plant, the BAF and Secondary Clarifier were eliminated, saving more than 50 percent of the site's footprint.

The results of the upgraded operation are solely within the previous AAO process basins, which were converted to BDP basins. The conversion was straight forward by adding a center separating wall with two openings on each end. By operating only two of four blowers, overall energy consumption was reduced by 35 percent.

In addition, before upgrading, BOD in the effluent was 35 mg/L; after upgrading the wastewater treatment plant, the BOD reduced to 5 mg/L, while the ammonia nitrogen reduced from 13 mg/L down to 1mg/L. The overall performance, shown in Table 3, of the upgrade project surpassed the new permitted parameters.

Table 3: Design Parameters

Item	Units	Influent System	Effluent of BDP
COD	mg/L	≤500	≤50
BOD_5	mg/L	≤198	≤20
TSS	mg/L	≤96	≤20
TN	mg/L	≤48	≤10
TP	mg/L	≤4.5	≤1

Source: BDP

Greenhouse Gas Emissions Reduction

According to UC Davis, California used a staggering 77 million tons of concrete (emitting roughly 21 million tons of CO2 in the process), in 2022, which computes to 0.27 tons of CO2 emission equivalent for one ton of concrete.

The application of BDP technologies in wastewater treatment facilities can lead to significant reductions in GHG emissions. By retrofitting existing treatment basins with BDP's more efficient processes, the project estimates an annual CO_2 emission reduction equivalent of approximately 14,000 tons. This is based on the anticipated upgrade of 35 percent of California's wastewater treatment plants for improved nutrient removal efficiency over the next decade.

According to the United States Environmental Protection Agency (U.S. EPA), greenhouse gas is generated through anerobic wastewater treatment systems, which counted for 1.9 million MT of CO_2 equivalent in 2017. The BDP technologies process eliminates the anerobic stage by engineering the application of simultaneous nitrification and denitrification, with relatively low dissolved oxygen concentration at 0.3mg/L, delivering sufficient oxygen to the mixed liquor without surplus. This ensures minimizing potential releases of greenhouse gas.

The reduction of waste sludge has a significant impact on GHG emissions as well. According to the USEPA, it is estimated that a total of 1.8 percent of total greenhouse gas emission in the United States is produced from wastewater treatment plants, of which between 25 percent and 30 percent are related to waste sludge production and waste sludge digestion and combustion. A 25 percent reduction by applying BDP technology will reduce at least between 5 percent and 10 percent of overall GHG emissions from the source; this will result in a total reduction of 0.19 million MT of CO_2 equivalent GHG emissions.

Capital Improvement and Operational Benefits

Implementing BDP technologies reduces the capital investment required for upgrading nutrient removal capabilities and offers operational and maintenance benefits. The project in Rialto demonstrated a 19 percent reduction in capital improvement budgets, compared with conventional Biological Nutrient Removal (BNR)upgrades. Additionally, the expected reduction in Operation and Maintenance (O&M) costs by between 24 percent and 33 percent translates to significant annual savings, underscoring the economic viability of BDP technologies for wastewater treatment facilities.

Investing in conventional BNR to improve nutrient removal costs about $7.38 M per Million Gallons per Day (MGD) treatment capacity. By applying BDP technologies to upgrade the treatment facility to a BNR (in other words, to retrofit the existing biological treatment trains), is generally possible without expanding the treatment facility. In reference to the project budget of the BDP demonstration project in Rialto, without the cost of building the concrete structures, pipelines, power supply, and other investments (other than equipment investment and installation), it is estimated at around $ 1.2 M at today’s cost in 2024 for a 0.20 MGD wastewater treatment plant’s upgrade to a BNR facility. This is equivalent to around $6 M per MGD for capital investment. This is a 19 percent reduction of the capital improvement budget. This reduced cost estimation could be reflected in all the capital improvement projects in California for energy usage and for nutrients removal in water reuse projects.

Operation and Maintenance Benefits of Increased Treatment Capacity

BDP technology can be used to increase the treatment capacity of an existing treatment facility without expanding the treatment basins and adding additional electrical equipment. This at the same time reduces the existing equipment's operation, such as reducing the number of blowers in operation by 50 percent, less pipeline between conventional process stages, less process monitoring, elimination of secondary clarifiers, its sludge scrapers, submersible sludge pumps, and return activated sludge pumping stations. It is estimated that an average 15 percent reduction in O&M cost would result from delivering better effluent water quality for recycled water.

The average O&M cost for conventional treatment processes is $2.00 per 1,000 gallons. Between 25 percent and 40 percent of it is energy cost, with estimated energy savings of 50 percent, a 12 percent to 20 percent reduction in anticipated operating costs. Between 1 percent to 2 percent maintenance cost reduction and 2 percent chemicals cost reduction are expected. Waste sludge treatment costs in conventional processes are between 40 percent and 45 percent of the total cost; around a 9 percent cost reduction is expected by applying BDP technologies.

In conclusion, a total of between 24 percent and 33 percent in O&M savings is expected, for a grand total of $43,800 in O&M annual cost savings for the BDP demonstration project when compared to conventional treatment processes.

Based on the findings and operation of the Rialto demonstration project, because each section of the process is modular, one example is the aeration system: its aeration intakes, the balance holders, and membrane aerators. They are all standardized sizes; scaling up requires simply adding more numbers in these standardized components. Another example is the hydraulic circulation system, which is also standardized; to scale up, simply adjust the number of units. The number of identical basins also serves as a template to scale-up by simply adding more parallel treatment basins.

Key Results - System Operation and Performance Report

Energy Saving – Electricity

The BDP wastewater treatment system demonstrates substantial energy savings through its innovative design, which integrates several key components such as influent equalization, hydraulic circulation, aeration, de-aeration, and fast clarification sections. This system begins with pumping influent wastewater from the primary clarifier, effectively removing solids before entering the bio-aeration stages.

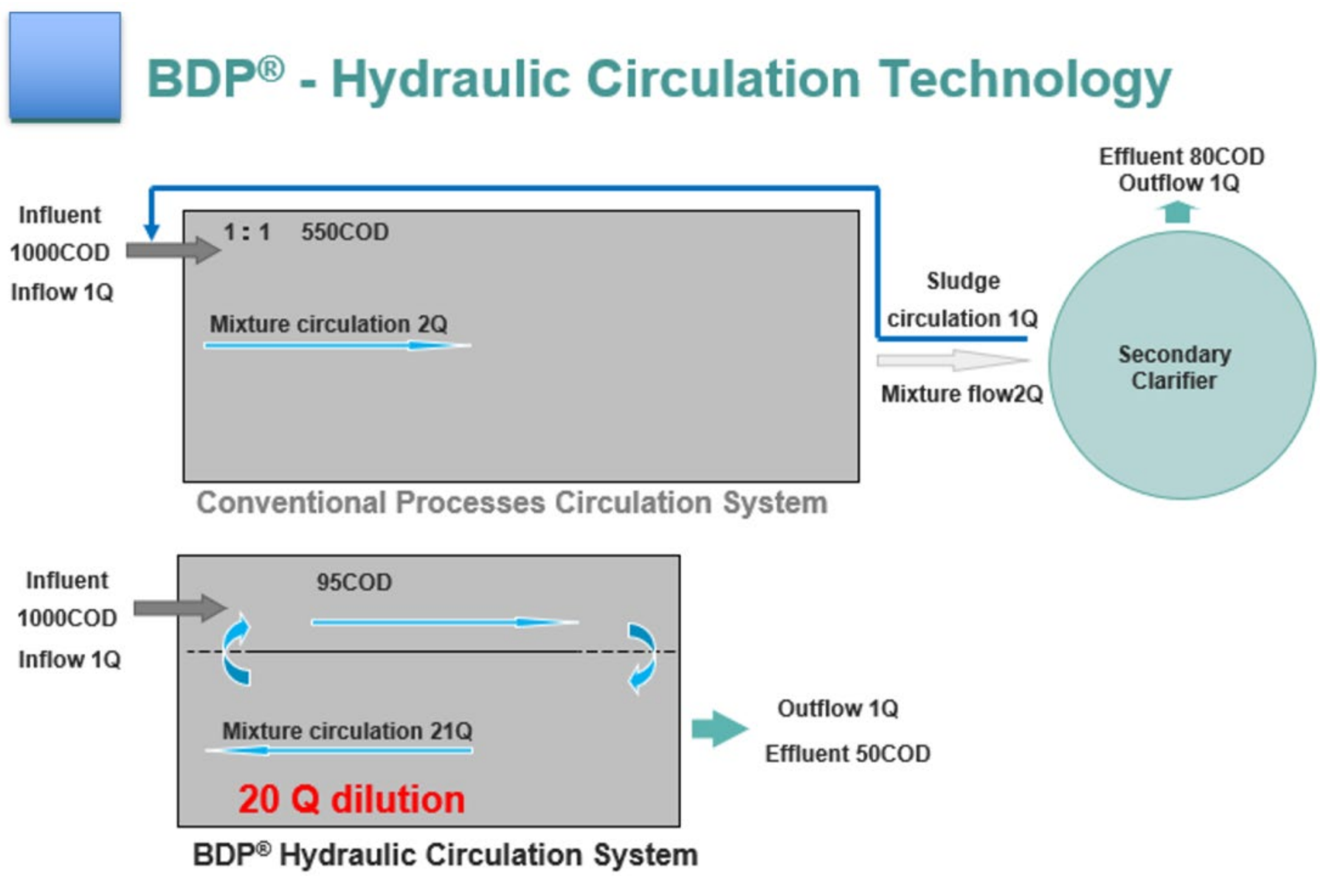
The system's hydraulic circulation is particularly efficient, employing an airlift system with a high dilution ratio, significantly reducing the energy required for liquid movement. The BDP air control automation system finely tunes the airflow rate, which contributes to the system's high energy efficiency.

A standout feature is the BDP aeration system, which operates at a significantly lower air flowrate than conventional aerators, leading to a 50 percent reduction in energy usage for aeration alone. This efficiency is further enhanced by the aeration diffusers' self-cleaning mechanism, maintaining optimal oxygen transfer efficiency (OTE) significantly higher than conventional systems. Overall, the operation of these sections independently and collectively results in an energy saving of approximately 50 percent or more, compared to traditional secondary biological treatment processes.

The hydraulic circulation section accounts for an estimated 5 percent to 10 percent overall energy savings compared to conventional secondary clarifiers' return activated sludge pumping stations.

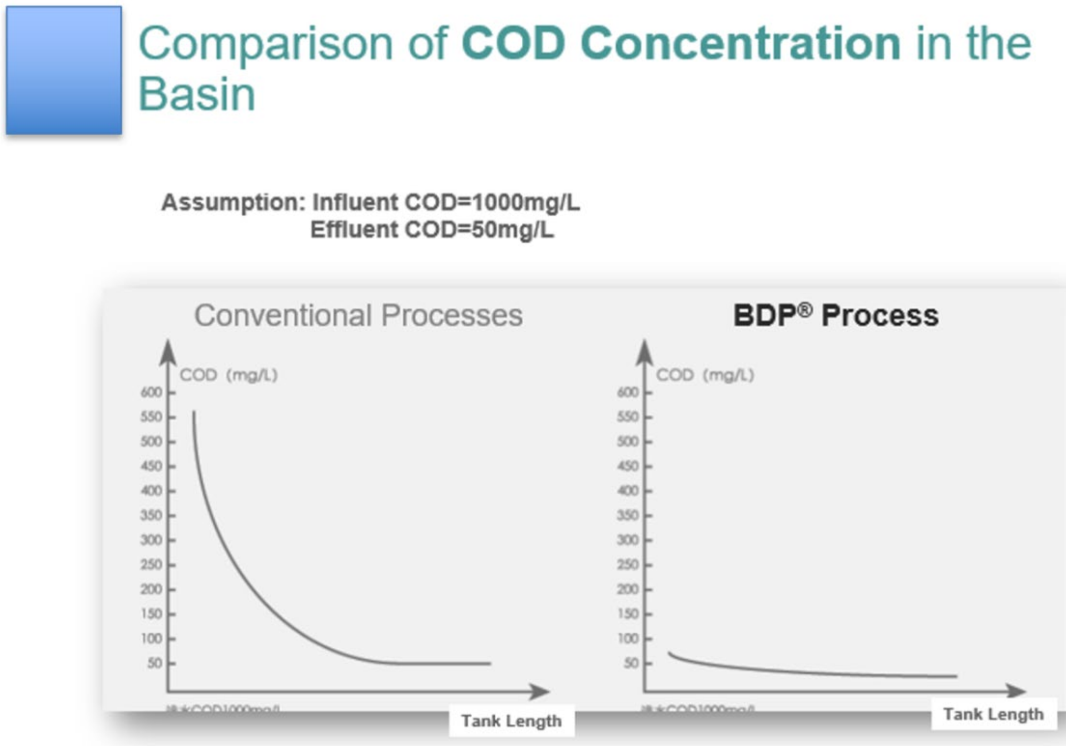
In a conventional biological wastewater treatment system, transitioning from a 1:1 return activated sludge (RAS) recycling ratio to a 20:1 ratio requires a significant increase in the pumping flow rate at the sludge pumping station. This adjustment achieves a higher dilution ratio, thereby balancing the influent wastewater's organic load to a more consistent concentration before it enters subsequent treatment stages. As shown in Figure 11 and Figure 12.

Figure 11: Hydraulic Circulation Technology



Source: BDP Full Introduction Presentation

Figure 12: COD Concentration Comparison in the Basin

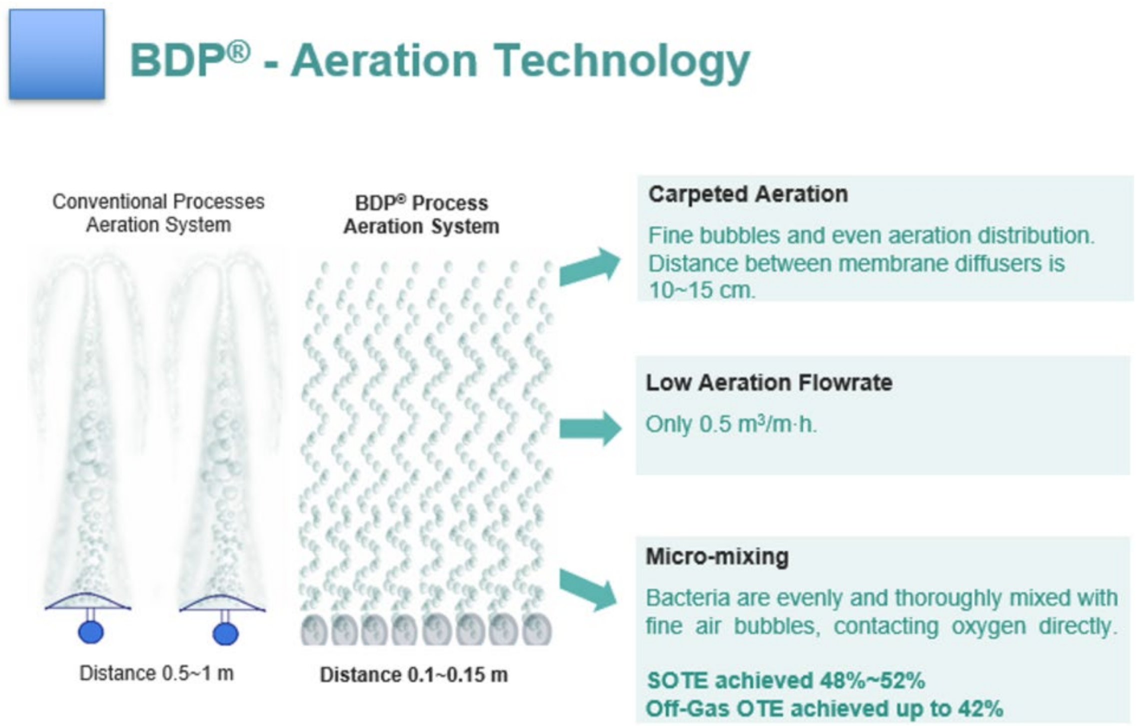


Source: BDP Full Introduction Presentation

By using only air from the same source of aeration in the BDP process, without any electrical and mechanical equipment, the average 10 percent airflow rate distribution to the airlift system will save substantial electricity, compared to conventional RAS pumping.

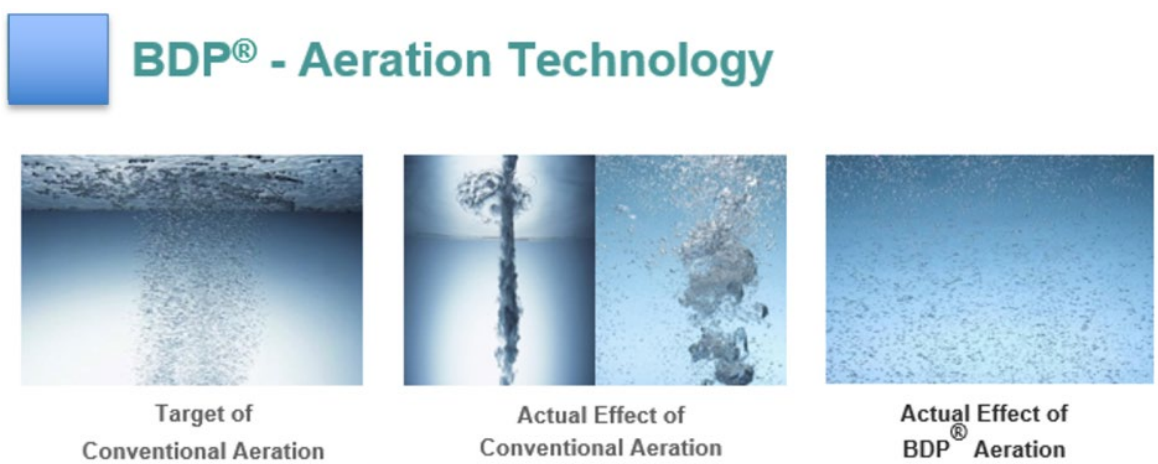
The aeration section operational savings account for about an 80 percent reduction in energy usage reduction compared with conventional secondary wastewater treatment processes. The uniformity of fine air bubbling of BDP aeration diffusors, even distribution of air bubbles, and accurate levels by BDP balance holders, ensure maximum efficiency. The up-flow velocity of air bubbles in a conventional aeration system is about 3 feet per second, while the BDP aeration system delivers a much slower up-flow velocity due to its finer and uniform diameter of air bubbles without merging into larger air bubbles when travelling to the water surface of the basin. See Figure 13 and Figure 14, as follows.

Figure 13: Aeration Technology



Source: BDP Full Introduction Presentation

Figure 14: Aeration Technology

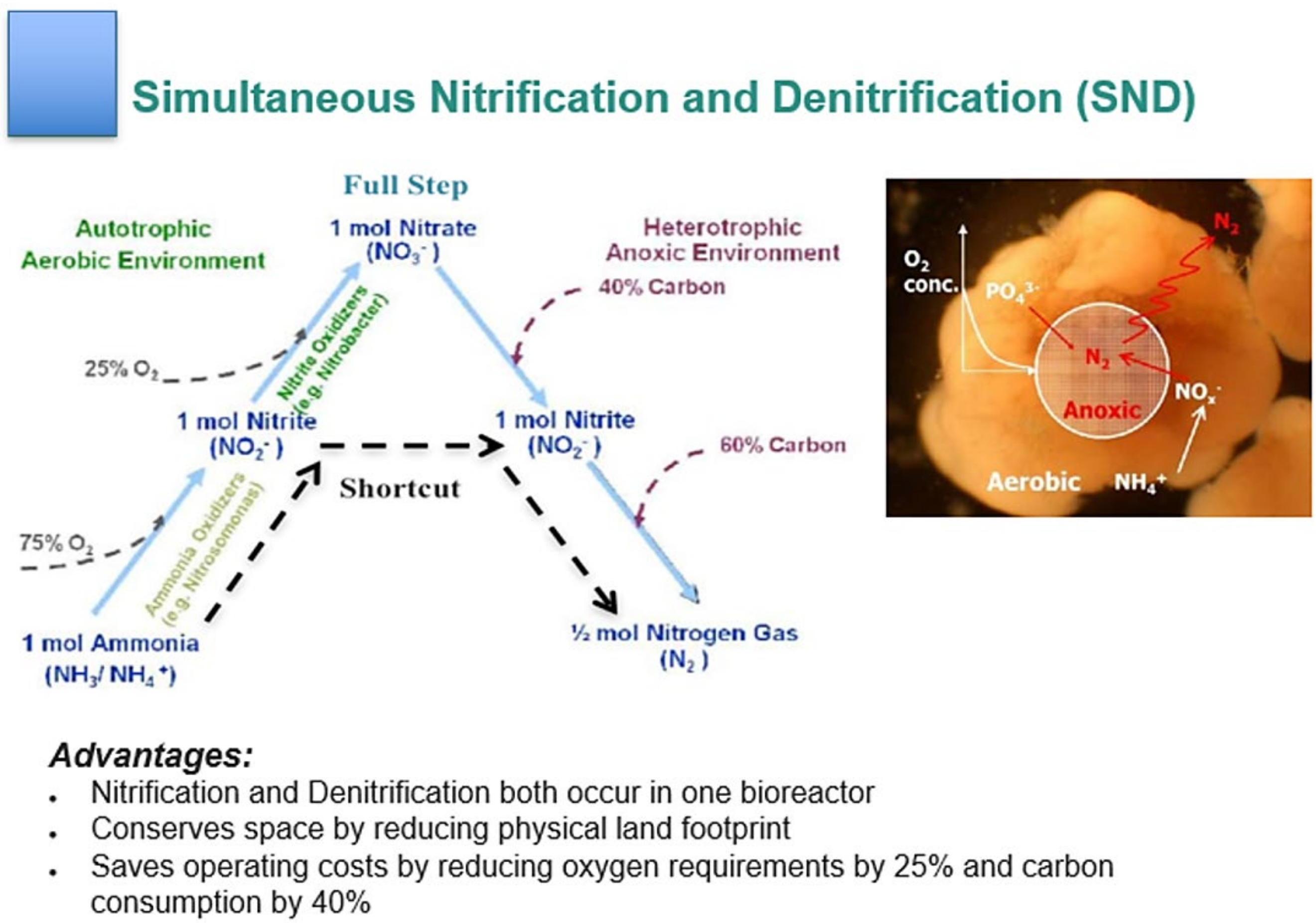


	Conventional Aeration	BDP® Aeration
Up-flow Velocity	1.0 m/s	**0.4 m/s**
Aerated Flowrate	3.5-5.0 m³/m·h	**0.5-0.7 m³/m·h**
Off-Gas OTE	15%~20%	**32%~42%**
Fine Bubble Micro-mixing with Bacteria		

Source: BDP Full Introduction Presentation

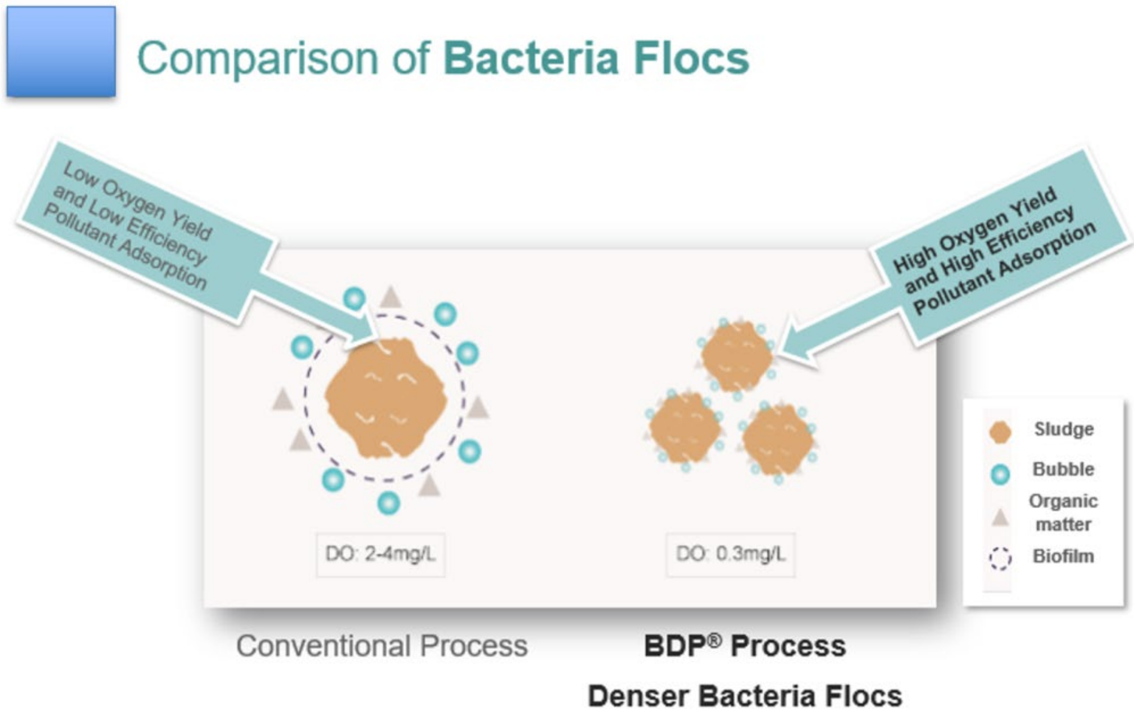
Low dissolved oxygen operations account for between 10 percent and 15 percent of total energy consumption savings. The simultaneous nitrification and denitrification operation condition dominates the biological environment in the BDP basin, with low dissolved oxygen concentration. The biological condition is optimized by the original seeding activated sludge, which converts, over a two-to-three week period, from larger sludge flocs into denser and smaller flocs with thinner bio-film outside of the flocs (refer to Figures 15 and 16 below). The thinner biofilm allows dissolved oxygen to reach the bacteria in the center of the flocs at much higher penetration velocity/efficiency, reducing the need for an electricity-driven air supply.

Figure 15: Simultaneous Nitrification and Denitrification



Source: BDP Full Introduction Presentation

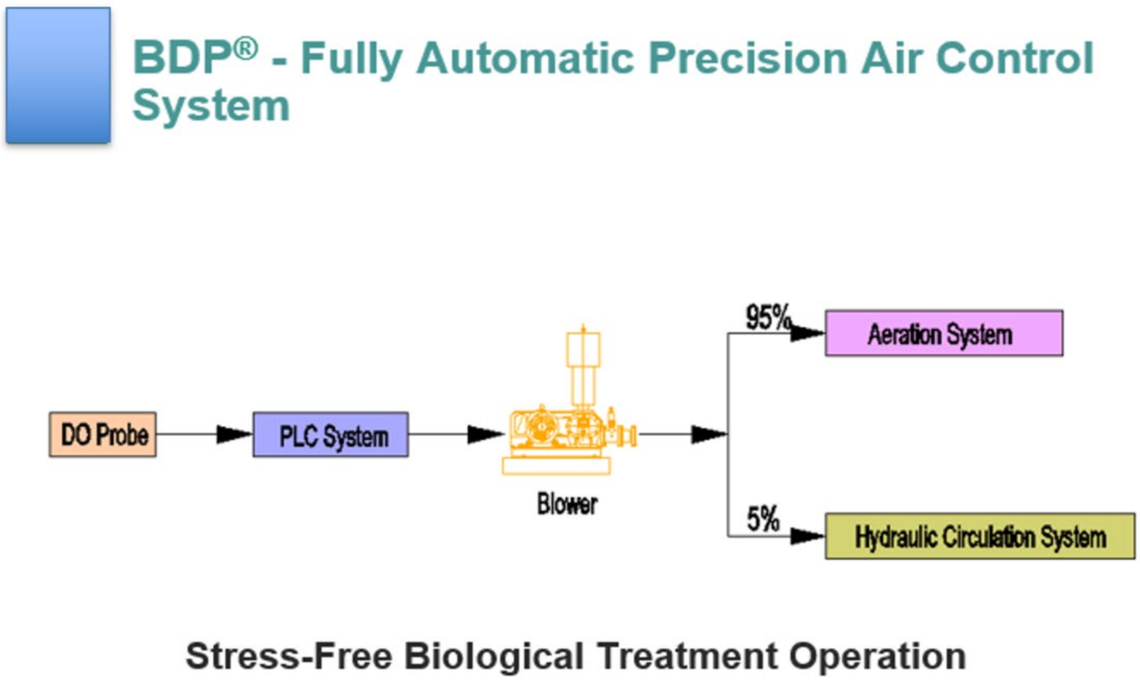
Figure 16: Comparison of Bacteria Flocs



Source: BDP Full Introduction Presentation

The BDP fully automatic precision air control system, as shown in Figure 17, is estimated to reduce electricity consumption (compared with conventional RAS pumping stations) by about 0.7 kWh for the 200,000 gallons per day demonstration project. An estimated 5.6 kWh consumption was saved through operating the BDP aeration system by setting the dissolved oxygen level parameters at between 0.2 mg/L and 0.7 mg/L. This ensures sufficient oxygen supply while leaving very little residual oxygen in the mixed liquor. In terms of the biological reaction of the simultaneous nitrification and denitrification operating conditions that require lower energy-driven oxygen and mixing power supplies, a 0.75 kWh energy reduction is estimated.

Figure 17: Fully Automatic Precision Air Control System



Source: BDP Full Introduction Presentation

Energy Savings – Water

The operation of the BDP system includes the strategic use of seeding sludge, which optimizes the sludge volume index (SVI) for greater treatment efficiency. The system's design allows for gradual improvement in SVI and a reduction in organic pollutants in the effluent. This leads to a potential increase in recycled water production rates by approximately 15 percent, alongside a reduction in chemical dosing requirements due to the lower concentration of organic matters in the treated water.

This streamlined process represents an increase in recycled water output and points to a decrease in operational costs associated with chemical usage, showcasing the BDP system's dual benefit of enhancing efficiency while reducing expenses.

The unique environment of BDP technologies' breeding process of well mixed and low dissolved oxygen concentration, with a high dilution ratio performed by high efficiency of the hydraulic circulation system, provides a homogeneous environment for the bacteria in the treatment basin while the dimensions of the bacteria flocs decrease, and their densities increase. The result of this microbiological progress evolved into the stability improvement of activated sludge, which resulted in a lower SVI of between 70 and 110.

A lower SVI is always appreciated due to a faster settling of the activated sludge. This will improve several operating conditions such as higher elimination ratio of COD, BOD and TSS, and more efficient absorbing and digestion of other organic matters such as nitrogen and phosphorus.

The BDP wastewater treatment system exemplifies a significant improvement in terms of energy and water savings in the wastewater treatment industry. By leveraging advanced technological components and optimization strategies, the system achieves good efficiency and contributes to environmental sustainability by reducing GHG emissions and increasing recycled water production.

Conclusion

The BDP demonstration project at Rialto, California, represents the advancements in wastewater treatment made over the past 15 years. It showcases BDP technology and the advanced secondary biological wastewater treatment technologies, comprehensive nitrification and denitrification processes, innovative aeration, fast clarification technologies, hydraulic circulation and precision air-control systems. The BDP technologies have been tested in California and successfully implemented in 65 full-scale projects worldwide, demonstrating their applicability and effectiveness.

Integrating these technologies presents an opportunity for enhancing California's energy and water management infrastructures. In 2022, the California Energy Commission reported that the state's total electricity supply reached 287,220 gigawatt-hours (GWh), a 3.4 percent increase from the previous year. Water management, including wastewater treatment, constitutes a sizable portion of the state's energy consumption, accounting for 19 percent and approximately 4 percent, respectively. This underscores the critical role of wastewater treatment facilities as substantial energy consumers and highlights the imperative to adopt more efficient solutions to mitigate carbon emissions.

Adopting BDP technologies across California's wastewater treatment plants could lead to an average energy usage reduction of 50 percent, potentially decreasing the state's electricity consumption by 5,744 GWh. This figure notably surpasses the 5,365 GWh of electricity generated from biomass in 2022, illustrating the potential of BDP technologies to contribute to clean energy generation efficiency.

The California Air Resources Board noted a concerning increase in GHG emissions, with a 4 percent increase to 384 million metric tons of carbon dioxide equivalent in 2021, a trend that persisted into 2022. Since approximately half of California's electricity supply is sourced from non-clean energy, incorporating BDP technologies in state wastewater treatment endeavors could substantially cut GHG emissions. By reducing emissions from non-clean energy sources by just 2 percent, BDP technologies could reduce 3.84 million metric tons of carbon dioxide equivalent in greenhouse gases, marking a significant step towards California's environmental sustainability mandates.

CHAPTER 4: Conclusion

The Biological Double-Efficiency Process (BDP) marks an advancement in wastewater management, showcasing energy and water conservation through innovative technology. The Rialto, California demonstration project highlights a decade of progress, aligning with the state's sustainability goals by reducing electricity use in water management. BDP streamlines wastewater treatment, offering energy savings, economic benefits, and enhanced water recycling. The demonstration project application BDP addresses California's environmental challenges, promising a sustainable future in water management and contributing to the reduction of greenhouse gas emissions. This initiative sets a precedent for sustainable and efficient wastewater treatment.

This innovative process is at the forefront of innovation in the field of wastewater management and advancements in energy and water conservation; BDP realized significant energy efficiency gains and became a proponent of environmental stewardship. Its success lies in reducing greenhouse gas emissions and increasing the quantity of water available for recycling.

The BDP demonstration project located in Rialto; California illustrates the technological advances within the wastewater treatment industry. It showcases the BDP technologies through the advanced biological treatment methods, optimized processes for nitrification and denitrification, state-of-the-art aeration techniques, fast clarification processes, and controlled hydraulic circulation and air management systems. Over 65 projects globally illustrate this.

California's commitment to environmental sustainability initiatives finds a strong ally in BDP technologies. With a sizable portion of the state's electricity attributed to water management systems, there is an evident demand for high-efficiency wastewater treatment solutions. BDP's capability to reduce energy usage by half, emerges as a step toward fulfilling California's environmental and sustainability goals.

The implementation of BDP technologies in wastewater management has led to advancements in operational efficiency, energy conservation, and beneficial impacts on both the environment and society through the demonstration project. Here is an overview of the principal outcomes:

Technological Efficiency

- **Energy Conservation:** BDP technology has significantly reduced energy consumption in wastewater treatment processes, achieving an average daily reduction to 340 kWh from the traditional range of 388 to 1450 kWh. This equates to a near 50 percent decrease in energy use, saving around 138,700 kWh annually when compared to standard practices.
- **Operational Improvements:** The project's design enhancements have reduced the hydraulic retention time (HRT) to 18.2 hours from the usual 24-28 hours, leading to at

least a 30 percent decrease in concrete use. This design efficiency also contributes to a 7,478-kWh saving in the energy required for concrete production.

Environmental Advantages

Reduction in Greenhouse Gas Emissions: By integrating BDP technologies, significant advances have been made in reducing greenhouse gas emissions, with an estimated annual reduction of 14,000 tons of CO2 in California. This progress is vital for combatting climate change.

Water Conservation

Enhancements in effluent water quality from the BDP system have potentially raised recycled water production by approximately 15 percent, yielding an extra 112,350 acre-feet per year (AFY). This increase is important for addressing the state's acute water scarcity.

Societal Benefits

- **Economic Gains:** Adopting BDP technologies not only lowers the capital and ongoing costs associated with wastewater treatment but also leads to considerable energy bill savings statewide, projected at $501 million. This reduction in expenses directly benefits ratepayers, local governments, and businesses by easing economic burdens.
- **Improvement in Water Quality and Supply:** The system's ability to better manage total nitrogen, BOD, and TSS levels ensures that the treated water meets high environmental standards, improving the quality and availability of recycled water for diverse applications.

Unveiling Implications and Enhanced Learnings

The demonstration of the BDP system in Rialto shows the ability to streamline the wastewater treatment process into an all-encompassing, highly efficient reactor, facilitating simultaneous nitrification and denitrification. This approach yields many advantages including diminished energy consumption, increased generation of recycled water, and substantial savings in both initial investment and ongoing operational and maintenance expenses.

Future collaborations, notably with the University of California, Irvine, will shed light on the need for off-gas testing for optimizing oxygen transfer efficiency (OTE). Such endeavors will extend the reach of BDP technologies beyond the traditional realms of wastewater treatment to include, for instance, the aeration of natural aquatic ecosystems, the reduction of odor and GHG emissions from waste sludge, and the effective removal of pollutants in water supplies.

Expanding Market Opportunities and In-Depth Evaluations

The BDP project has exposed market potential within the California landscape, providing extensive advantages for both public and private entities. These benefits include energy savings, reductions in greenhouse gas emissions, economic incentives via reduced energy expenditures, increased efficiency in water recycling, and a decrease in waste generation. Nevertheless, to harness the full potential of BDP technologies' capabilities, it is important to address enhancements such as scalability, cost-effectiveness, adaptability to influence variability, energy recuperation, and the achievement of wider environmental advantages. Overcoming barriers to market adoption through demonstration projects, strategic partnerships, and targeted educational endeavors is vital for implementing BDP technology to California's sustainable water management and energy conservation strategies.

In a state where municipal wastewater treatment plants are estimated to account for 2-4 percent of total electricity consumption—representing a significant part of a plant's yearly operating budget—BDP technologies illustrate both innovation and efficiency. With California processing approximately 3.31 million acre-feet of wastewater annually, translating to a daily flow rate of 2,955 million gallons, the adoption of BDP's energy-efficient measures could potentially result in a statewide annual energy reduction of about 2,047 GWh. This equates to an anticipated annual energy cost savings of approximately $501 million at California's average electricity rates.

Furthermore, with an increase in GHG emissions across California, the integration of BDP technologies into the state’s wastewater treatment infrastructure would significantly contribute to reversing this trend. This strategic integration aligns with California’s ambitious environmental sustainability mandates.

Concluding Insights

The BDP initiative not only illustrates the significant potential for energy and cost savings but also represents a sustainable model for water management. Through technological advances and enhanced operational efficiencies, BDP technologies provide viable solutions that address some of California's most critical environmental challenges. In the future, continuous advancements, adaptability, and the expanded application of these technologies are crucial in guiding California towards a future of sustainable and efficient water management practices. This journey, supported by comprehensive analyses, strategic collaborations, and breakthrough innovations, is poised to have a transformative impact on the state’s environmental and energy landscape, ushering in a cleaner, more sustainable future.

GLOSSARY AND LIST OF ACRONYMS

Term	Definition
AAO	Anaerobic Aerobic Oxic
AFY	Acre Feet per Year
BAF	Biological Aerated Filter
BNR	Biological Nutrient Removal
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
kW	kilowatt
kWh	Kilowatt-hour
MGD	Million Gallons per Day
NH_4+	Ammonium
O&M	Operation and Maintenance
PE	Person Equivalent
TN(TKN)	Total Nitrogen (Total Kjeldahl Nitrogen)
TSS	Total Suspended Solids

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Project Deliverables

- Final Engineering Design Report
    - P&ID
    - Process Design
    - Civil Design
    - Automation Control Panel Diagram
- Progress Report
- Milestone Questionnaires:
    - Kickoff Meeting Questionnaire
    - Midterm Benefit Questionnaire
    - Final Meeting Questionnaire
- System Operation Manual
- System Startup and Test Report
- System Operation and Performance Report
- Initial and Final Fact Sheets
- Technology/Knowledge Transfer Plan
- Technology/Knowledge Transfer Report
- Match Fund Status Letter
- Final Presentation Materials
- High-Quality Digital Photograph
- Final Report
- Final Engineering Design Report

ENERGY RESEARCH AND DEVELOPMENT DIVISION

APPENDIX A: Project Development Progress Photographs

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APPENDIX A: Project Development Progress Photographs

Figure A-1: Retrofitting Stage of Existing Treatment Train

After demolition stage of the partition walls and internal structures of the original basin and building the central wall.

Source: BDP CEC Monthly Report

Figure A-2: Construction of BDP Biological Drain

Constructing the raised walls of the BDP biological basin.

Source: BDP CEC Monthly Report

Figure A-3: Delivery of BDP Equipment

Source: BDP CEC Monthly Report

Figure A-4: Assembly and Insulation of BDP Equipment and Materials

Constructing the raised walls of the BDP biological basin.

Constructing the raised walls of the BDP biological basin.

Source: BDP CEC Monthly Report

Figure A-5: Commission and Start-up Stage

Installation, commissioning, and start-up of the BDP wastewater treatment system.

Source: BDP CEC Monthly Report

Figure A-6: Operating and Testing Stage

Operation of BDP Wastewater treatment system.

Source: BDP CEC Monthly Report