Emerging Technologies

Market Assessment of Water & Wastewater Treatment Load Management Strategies in California

DR17.07

Prepared by:
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SOUTHERN CALIFORNIA EDISON

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EXECUTIVE SUMMARY

BACKGROUND

For decades, Southern California Edison (SCE) has been a leader in advancing energy management strategies in the water sector through energy efficiency programs and demand side management emerging technology studies. Recently, SCE has published a series of reports evaluating the technical potential for some of SCE's largest water customers to provide load flexibility to address overgeneration on the grid. In support of SCE's goals to accelerate the penetration of energy efficiency technologies and strategies, Southern California Edison Emerging Products and Alternative Energy Systems Consulting, Inc. performed a market assessment study of water and wastewater treatment load management in California.

PROJECT GOAL

California's network of more than 2100 wastewater treatment plants, municipal water agencies, special districts, public utilities, municipal water companies, and county districts offer the state a significant resource to solve regional and local grid needs through demand side management solutions. While the technical potential identified for demand response (DR) is high, historical participation in traditional resource adequacy programs has been limited by barriers including disincentives in tariff structures, program design, technical resources, the industry's risk aversion to violating regulatory and permit compliance, and a lack of tools to evaluate risks, cost and benefits, among others. The goal of this study is to provide process-based decision support tools to DR program managers, utility customer technical service providers, and water utility managers to participate in DR programs more aggressively as grid resources.

PROJECT DESCRIPTION

This study builds on SCE's recent research and analyses on the subject that looks beyond the largest agencies and common strategies to assess technical DR opportunities, strategies, and program offerings that can be useful to a broader set of agency sizes and treatment plant configurations. Accompanying this report is the DR Matrix, a technical decision support tool that describes twenty-five discrete DR measures that are evaluated in terms of potential, risk, technical difficulty.

PROJECT FINDINGS

California grid needs are driving new programs and opportunities that reward load flexibility strategies while California water agencies increasingly need to design flexible systems that allow them to be responsive to fluctuating climate, loads, and regulatory drivers and requirements. Many technologies and design strategies benefit both energy savings and demand flexibility and enhance opportunities for integrated demand side management.

In addition to existing resource adequacy DR programs, local request for offers for resource adequacy, capacity, and distribution deferral offer new opportunities for agency revenue and value. Similarly, new California Independent System Operator (CAISO) initiatives like the Energy Storage and Distributed Energy Resources initiative offer water agencies and aggregators new opportunities to bid directly into the CAISO market.

Twenty-five demand response strategies were identified for various process systems in water and wastewater treatment facilities. Any of these strategies, individually, will be met with hesitancy by most water and wastewater operators and facility managers across the sector, due to the regulatory and compliance requirements of the industry. However, when identifying the critical risk factors, mitigation strategies, and potential process benefits of these measures, and how they can be implemented holistically to improve energy cost savings, the likelihood of program participation will go up. Across the water and wastewater sector, when ranked by highest potential load impact and lowest potential risk, cost, and level of difficulty, the top DR strategies (and relative score on a scale of 0-100) include:

- Increase reservoir operation capacity (81)
- Automatic transfer to onsite power generators (77)
- Rescheduling filter backwash cycle (70)
- Delay dewatering pressate or centrate recycling (70)
- Reduce frequency or turn off primary sludge pumps and primary effluent pumping (69) (65)
- Reschedule biosolids thickening and dewatering (66)
- Lengthen time between backwash filter air scouring or disable backwash filter air scouring (64)
- Turn off channel agitation blowers and reduce odor scrubber output to minimum permit level requirements (63)
- Reduce speed or turn off fixed growth reactor blowers within air quality permit limits (63)

	Potential Risk Factors									Overall Rating			
Demand Response Opportunity	Health & Safety	Environmental Compliance	Process Upset	Equipment Failure	Labor Costs	Cost/Rates to Customers	Public Relations	Revenue Streams	Spare Parts Inventory	DR Potential	Impact on System Process	Risk Assessment*	Total Impact Potential
Increase Resevoir Operating Capacity	Low	Med	Low	Low	Low	Low	Low	Low	Low	77	22	95	**81**
Increase Wet-Well Level Operations	High	High	Med	Med	Med	Low	Med	Low	Low	33	59	58	**50**
Bypass Influent Flows to Strategic Treatment Plants	Med	High	Med	Med	High	Low	Med	Med	Low	38	100	58	**56**
Trucked-in Waste Controls	High	Med	Med	Low	Med	Low	Med	Med	Low	58	52	63	**60**
Equalization (EQ) Basin flow modification	Med	High	Med	Med	High	Low	Med	Med	Low	58	74	58	**60**
Reduce Frequency/Turn Off Primary Sludge Pumps	Low	Low	Med	Low	Med	Low	Low	Low	Low	37	44	93	**69**
Primary Effluent Storage	Med	Med	High	Low	Low	Low	Med	Low	Low	48	74	73	**65**
Reduced Secondary Aeration Rate, DO and Mixed Liquor Recycle (MLR) Pumping	Low	Low	Med	Med	Low	Low	Low	Low	Low	29	19	90	**62**
Secondary Treatment Over-Oxygenation	Med	Med	Med	Low	Low	Low	Low	Low	Low	29	44	83	**61**
Low Energy Pulsed Large Bubble Mixing and Micronized Oxygen Infusion	Med	Med	Med	Low	Low	Low	Low	Low	Low	29	44	83	**61**
Temporary Reduction of Dissolve Oxygen (DO) Level	Med	High	High	Med	Low	Low	Low	Low	Low	58	30	68	**60**
Turn Off MLR Pumps + High-Pressure WAS Pumps + Reduce RAS Pumps	Med	High	High	Low	Med	Low	Low	Low	Low	33	52	70	**56**
Turn Off Foam Air Spray to Reduce Utility Water Pressure and Feed Pumps	Med	Med	High	Med	Med	Low	Med	Low	Low	50	48	65	**58**
Turn Off Channel Agitation Blowers and Reduce Odor Scrubber Output to Minimum Permit Levels	Low	Med	Med	Low	Low	Low	Low	Low	Low	23	52	90	**63**
Bypass Fixed Growth Reactors (Trickling Filters)	Low	Med	High	Med	Med	Low	Low	Low	Low	15	33	78	**52**
Reduce Speed/Turn-Off Fixed Growth Reactor Blowers Within Air Quality Permit Limits	Med	Med	Low	Low	Low	Low	Low	Low	Low	35	19	88	**63**
Reschedule Biosolids Thickening and Dewatering (centrifuges, screw presses, etc.)	Low	Low	Med	Med	Med	Low	Low	Low	Low	38	41	88	**66**
Delay Dewatering Pressate or Centrate Recycling	Low	Low	Med	Low	Med	Low	Low	Med	Low	48	48	88	**70**
Disable aerobic digester aeration mixers	High	High	Med	Low	Low	Low	High	Low	Low	48	52	60	**55**
Lengthen Time Between Backwash Filter Air Scouring	Med	Med	Med	Low	Low	Low	Low	Low	Low	50	11	83	**64**
Disable Backwash Filter Air Scouring	Med	Med	High	Med	Low	Low	Low	Low	Low	71	11	73	**65**
Reduce/Turn Off Tertiary Filters	Med	Med	Low	Low	Low	Low	High	High	Low	25	26	68	**49**
Reschedule Filter Backwash Cycle	Low	Low	Low	Low	Low	Low	Low	Low	Low	40	11	100	**70**
Delay Recycle Water Production	Low	Med	Med	Low	Med	Med	High	High	Low	58	37	65	**60**
Automatic Transfer to Running Onsite Power Generators During Peak Demand Periods	Low	Med	Low	Med	Med	Low	Low	Low	Med	56	100	85	**77**

FIGURE 1. EXCERPT FROM DR MATRIX- RANKING IS ON A 1-100 SCALE WITH HIGH VALUES AS RECOMMENDED MEASURES

DISCUSSION AND RECOMMENDATIONS

Rapid California grid changes are leading to an overhaul of the type and characteristics of demand side resources that are needed, with load flexibility at a premium. To target and engage the DR potential in California's 2100 water agencies, a more targeted and nuanced approach is required to identify and implement risk-appropriate strategies. Customer rates and tariff structures need to be better aligned to eliminate dis-incentives including time of use pricing and standby demand charges. Visibility into the energy impacts, costs and benefits of DR control strategies should be improved to support engagement and risk-weighted decision making.

Co-benefits of DR strategies should be investigated and articulated including energy efficiency benefits, cost savings, process control, improved asset management, reliability, and operational flexibility. Integrated demand side management remains critical to cost effectively identify and implement coordinated site strategies that support California's energy efficiency, demand management and power resiliency goals. Available funding sources should be better leveraged. Participation barriers related to co-generation should be further explored, including leveraging energy and biogas storage or other strategies. Regional strategies between water distribution, retail agencies and customers should be explored further to coordinate and aggregate load control that benefits the entire system. Combining grid analysis tools like SCE's Distributed Resources Plan External Portal, in combination with more targeted tools like the DR Matrix, can be used to target highest potential customers for load management initiatives. The material developed and the findings identified through this study can be shared with the water and wastewater sector to encourage and accelerate program participation.

ABBREVIATIONS AND ACRONYMS

AFY	Acre-Feet per Year
AS	Activated Sludge
AES	Advanced Energy Storage
AMI	Advanced Metering Infrastructure
API	Agricultural and Pumping Interruptible Program
AESC	Alternative Energy Systems Consulting, Inc.
AWWA	American Water Works Association
BPP	Base Interruptible Program
BOD	Biochemical Oxygen Demand
CEC	California Energy Commission
CEC PIER	California Energy Commission’s Public Interest Research Program
CAISO	California Independent System Operator
CPUC	California Public Utilities Commission
CBP	Capacity Bidding Program
CF	Carbon Footprint
CEPS	Chemically Enhanced Primary Sedimentation
CNG	Compressed Natural Gas
CoFA	Consequence of Failure Analysis
CERTS	Consortium for Electric Reliability Technologies
CPP	Critical Peak Pricing
CFS	Cubic Feet per Second
CVWD	Cucamonga Valley Water District
DDSD	Delta Diablo Sanitation District
DR	Demand Response
DRAM	Demand Response Auction Mechanism
DRAS	Demand Response Automation Server
DRC	Demand Response Contract
DRP	Demand Response Provider
DRS	Demand Response System
DSM	Demand-Side Management
DER	Distributed Energy Resource
DG	Distributed Generation
DIDF	Distribution Investment Deferral Framework
DRPEP	Distribution Resources Plan External Portal

EMWD	Eastern Municipal Water District
ECLWRF	Edward C. Little Water Recycling Facility
EPIC	Electric Program Investment Charge
EP	Emerging Products
EMCS	Energy Management Control System
EMS	Energy Management System
ESDER	Energy Storage and Distributed Energy Resources
EIR	Environmental Impact Report
EQ	Equalization
FSSD	Fairfield-Suisun Sewer District
FC	Fecal Coliform
FSL	Firm Service Level
GHG	Greenhouse Gas
HVAC	Heating, ventilation, and air conditioning
HP	Horsepower
IERCF	Inland Empire Regional Composting Facility
IEUA	Inland Empire Utilities Agency
IDER RFO	Integrated Distributed Energy Resources Request for Offers
IRP	Integrated Resource Plan
IOU	Investor Owned Utilities
JPA	Joint Powers Agreement
kW	Kilowatt
kWh	Kilowatt Hour
LACSD	Lake Arrowhead Community Services District
LBNL	Lawrence Berkeley National Laboratory
LSE	Load Serving Entity
MRI-S	Market Results Interface – Settlements
M&V	Measurement and Verification
MW	Megawatt
MBR	Membrane Bio-Reactor
MWD	Metropolitan Water District
MF	Microfiltration
MGD	Millions of Gallons per Day
NF	Nanomicrofiltration
NWA	Non-wires alternatives
PG&E	Pacific Gas and Electric Company
PWD	Palmdale Water District

PDP	Peak Day Pricing
PV	Photovoltaic
PRM	Planning Reserve Margin
PSPS	Power Safety System Shutoff
RCWD	Rancho California Water District
RWRPs	Regional Water Recycling Plants
RES-BCT	Renewable Energy Self-Generation Bill Credit Transfer
RFO	Request for Offer
RA Program	Resource Adequacy Program
RAS	Return Activated Sludge
RO	Reverse Osmosis
SMUD	Sacramento Municipal Utility District
SDG&E	San Diego Gas and Electric
SGIP	Self-Generation Incentive Program
SCE	Southern California Edison
SWP	State Water Project
SCADA	Supervisory Control and Data Acquisition
TATI	Technical Assistance and Technical Incentives
TAF	Thousand Acre-Feet
TOU	Time-of-Use
TC	Total Coliform
T&D	Transmission and Distribution
UF	Ultrafiltration
UV	Ultra-Violet
UCR	University of California Riverside
WAS	Waste Activated Sludge
WWT	Wastewater Treatment
WWTP	Wastewater Treatment Plant
WSWB	Willow Springs Water Bank
ZNE	Zero Net Energy

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INTRODUCTION

Since the early 2000's California has implemented resource adequacy programs to prevent power shortages, extreme price spikes and rolling blackouts. Following the electricity crisis of 2000-2001, the California Legislature enacted Section 380 of the Public Utilities Code requiring the California investor owned utilities (IOUs) to cooperate with the California Independent System Operator (CAISO) to adopt a resource adequacy program (RA Program) that would ensure load serving entities (LSE's) "maintain physical generating capacity and electrical demand response adequate to meet its load requirements, including, but not limited to, peak demand and planning and operating reserves."

California's LSEs are required to own or contract with sufficient resources to meet their share of the CAISO system's peak demand, plus a Planning Reserve Margin ("PRM") of 15%. Resources are committed to offer capacity when called, but are dispatched economically, with the lowest cost resources being dispatched first. The RA Program also requires LSE's to procure a certain amount of local resources to address insufficient transmission capacity for local requirements (local resource adequacy), and to procure "flexible" resources that can ramp up or down on short notice to meet intermittent energy production on the grid. Demand Response (DR) and energy storage can provide RA directly to the CAISO, and recent updates to tariffs now allow distributed resources to be aggregated to participate in markets.

With California's rapid growth of distributed energy resources (DERs) and the resulting "Duck Curve", large sources of flexible resources are becoming more valuable in order to help balance California's aggressive climate action and decarbonization/electrification strategies with the need to safely manage the grid and ensure reliability. At the same time, new climate related pressures in California resulting from wildfires and utility Power Safety System Shutoff (PSPS) events are driving a greater need for regional power resiliency in the form of sources of backup power to support customers and communities.

California's network of water treatment and wastewater treatment facilities offer a largely untapped source to support California's existing and emerging resource adequacy needs, as well as local capacity and resiliency needs. With high energy demand and plentiful waste combined with opportunities to improve operational control, water and wastewater treatment plants have long been targeted for demand response program participation but have generally not met the theoretical potential due to a variety of barriers including technical, organizational, regulatory, tariff structures and perceived risks. Of particular concern to agencies is the requirement to meet permit and performance expectations, preventing most agencies from considering anything but a narrow set of zero risk strategies and has limited the potential.

SCE has long been a leader in exploring opportunities to do more with the water sector. Since 2015, SCE has collaborated with certain large water customers in their territory to perform in-depth analysis of potential for both conventional and non-conventional preferred energy resources – energy efficiency, demand response and storage – including in water, wastewater and biosolids systems and facilities that can benefit both the agency and support electric reliability. Their effort is designed to measure grid impacts, and implement preferred resources, in order to reduce peak needs, meet local capacity requirements, and reduce energy, cost and carbon. It is also designed to develop strategies, tools and templates to support tech transfer to other agencies.

This study builds on this recent body of SCE work, while taking a broader approach to market understanding and prioritization in order to inform policy, programs, rates and implementation strategies. It considers a wider range of plant capacity and design characteristics and offers an inventory of demand response and load management strategies that can be deployed at the customer, plant, and sub-system specific levels.

ASSESSMENT OBJECTIVES

The objectives of this study are to:

- Provide an approachable and easy-to-use resource for interested water sector stakeholders including utility account representatives, program managers, water agencies and demand side management implementers to identify, scope, value, fund and implement load management strategies that meet site requirements, improve operational performance and support regional grid needs.
- Leverage literature review, direct market research and team experience and process expertise to compile a comprehensive compendium of water and wastewater treatment load management and demand response technologies, strategies and approaches.
- Characterize market requirements for implementation of various DR strategies based on system configurations, local/regional constraints, end-user needs, and forecasted future shifts in agency needs and treatment conditions.
- Compile strategies into a excel-based demand response decision matrix tool (DR Matrix) organized by DR Opportunity, Process Impacts and Potential Risks and Failures, Complexity and Difficulty of Implementation, DR type (shape/shift/shed/shimmy), DR Duration Potential, Water Sector, Affected System Process, Potential Risk Factors, DR program applicability and overall summary ratings and rankings.
- Assess key factors impacting historical and future strategy adoption including key agency decision drivers, market trends, grid needs, current and emerging load management programs, and opportunities for integration of behind the meter distributed energy resources.
- Explore gaps between technical or theoretical demand response potential in California's water sector to inform findings and recommendations.

REPORT STRUCTURE

The overall report follows a standard Emerging Technologies report structure including Introduction, Background, Findings, and Discussion sections.

- The Introduction provides an overview of study needs and background, study objectives, study structure, and study approach and methodology.
- The Background section, in order to provide context for the strategies, findings and recommendations in the report, provides an overview on a variety of topics including: California grid needs; an overview of load management strategies including a definition of Shed, Shift, Shimmy strategies; a review of demand response and emerging load management programs and tariffs; and a discussion of emerging water and wastewater infrastructure needs and trends impacting decision making including aging infrastructure, municipal funding challenges, climate impacts on plant design, increasingly strict environmental permits and energy and climate goals and regulations, shifts in the industry workforce, and emerging operational requirements such as data management and enhanced control.

- The Findings section presents both a compendium of demand management strategies and a look at historical implementation relative to the theoretical potential. It begins by providing a high-level overview of the typical water and wastewater treatment plant processes, systems and subsystems before providing a compendium of load management strategies by process. Each load management strategy is also organized into an accompanying excel matrix that defines system and subsystem, DR strategy, estimated duration, DR program fit, risk of implementation and other key decision factors. The matrix is intended to be a sortable stakeholder decision support tool to identify preliminary load management strategy opportunities based on specific plant characteristics and design constraints and guide further site-based detailed technical investigation where warranted. The Findings section also presents findings on the implementation of DR in plants, including a discussion of our qualitative findings on key barriers challenges and opportunities identified through a review and summary of case studies and interviews. Theses case studies and interviews are summarized in the Appendix A.
- The Discussion section concludes the report by summarizing observations and recommendations for improving the adoption of advanced load management strategies at water and wastewater treatment plants. This includes ways to improve DSM strategy integration, programs and incentives, industry education and organizational alignment, and data management and control.

APPROACH/ASSESSMENT METHODOLOGY

The goals of this study are to build on SCE's recent research and analyses on the subject by developing a Market Assessment of Water and Wastewater Treatment Load Management in California that looks beyond the largest agencies and common strategies to assess technical demand response opportunities, strategies, and program offerings that can be useful to a broader set of agency sizes and treatment plant configurations. The report, and accompanying DR Matrix tool, is designed to be an approachable and easy-to-use resource for stakeholders to identify, scope, value, finance and implement load management strategies that meet site requirements, improve operational performance and support regional grid needs. There are at least three different audiences that are considered in the research and analysis of this study:

- Electric utility stakeholders who may not have intimate familiarity with water and wastewater treatment facilities and operations.
- Water and wastewater stakeholders who may have limited knowledge of demand response and grid resiliency issues/opportunities.
- Energy champions of water and wastewater treatment facilities who want to take aggressive energy actions at their organizations but need decision support tools to participate in grid response activities.

The study approach included:

- Summarizing background information including California grid needs and drivers; water sector needs and drivers including regulatory and environmental decision drivers; existing and emerging demand response programs and initiatives; and tariffs.
- Literature review, direct market research, and levering expert process expertise to compile an overview of energy using systems in water and comprehensive compendium of DR strategies by system.
- Characterizing market requirements for implementation of strategies based on system configurations and user needs.
- Compiling strategies into a decision support tool that ranks strategies on implementation difficulty, risk, and benefit, and determines DR potential in shed, shift, shape and shimmy.
- Assessing factors impacting historical and future strategy adoption informed by case studies and new customer interviews.
- Exploring gaps between technical or theoretical demand response potential in California's water sector to inform findings and recommendations.

WATER AND WASTEWATER TREATMENT DR DATA COLLECTION AND SCOPE REFINEMENT

As a starting point to this study, AESC coordinated with SCE to identify and collect relevant data gathering activities to collect reports, case studies and program data to inform the study. The intent of this coordination was to ensure that this study was building on the breadth and depth of knowledge that SCE has produced in this sector to provide meaningful and relevant recommendations for program improvement and customer engagement.

PROGRAM AND LITERATURE REVIEW

Once the information was gathered and organized, AESC reviewed and summarized years of research and information to develop the background summary, and state of the industry for inclusion in this report. AESC reviewed literature, reports, studies, videos, and case studies provided by SCE and available on the internet to inform our research. Our team attended targeted conferences that discussed emerging regulatory pressures and drivers impacting agency decision making. AESC next reviewed SCE's demand response program designs and structures, SCE utility tariff structures, and emerging load management market mechanisms from the utilities and CAISO. Finally, AESC evaluated local and regional constraints using the SCE Demand Response Plan External Portal (DR PEP) website.

REVIEW OF W/WWT DR IMPLEMENTATION IN CALIFORNIA

Next, AESC performed outreach to California utilities (PG&E, SCE and SDG&E), demand response program managers and analysts at PG&E and SCE, and utility account representatives to attempt to obtain quantitative data on demand response implementation and load impacts in the sector. Because this data was not readily available due to confidentiality and other factors, AESC instead reviewed recent SCE case studies and interviewed additional agencies to inform historical constraints and recommendations to increase future participation and impacts from the sector.

DEVELOP FINAL REPORT AND PRESENT FINDINGS TO SCE

Ultimately, this study compiles a compendium of load management strategies by process and system based on literature review as well as input from water and wastewater treatment process experts on our team. AESC has organized load management strategies into an excel-based decision support tool, called the DR Matrix. Further. The study identifies key barriers and opportunities as well as individual DR opportunities for market adaptation and to increase market potential in California.

Next, the study identifies potential grid impact of flexible DR integration, including how flexible DR can benefit the grid, mitigate curtailments, and allow treatment facilities to act as a grid asset. This report documents key opportunities, program gaps and recommendations to improve market adoption of those viable strategies. We recommend customer targets for outreach and implementation, and potential effective strategies for improving participation, as well as identify potential future state scenarios.

BACKGROUND

Flexible load management in California's water and wastewater treatment segment can enable a water agency to reduce demand costs, participate in traditional demand response (DR) programs and supply grid flexibility benefits in support of emerging capacity and distribution market offerings.

An overview of key California electricity grid needs and drivers, and a high-level overview of load management programs, initiatives and project funding and incentives to address them is provided below.

California's electricity grid is facing significant stressors because of aging grid infrastructure, solar overgeneration, and new challenges posed by climate change, drought, and fires. At the same time the state is replacing legacy dispatchable generation assets with clean but intermittent solar and wind assets, there is also growth in behind the meter distributed energy resources, fueled in part by the need for power resiliency in the face of public safety power shutoff (PSPS) events and climate related disruptions.

Solar overgeneration on the grid is causing problems including voltage instability and costs, including the need for California to pay other states to take excess generation. To alleviate these issues, in addition to adding energy storage to the grid, California policymakers and utilities are increasingly looking to more cost-effective demand side solutions (demand response, energy efficiency, new tariffs) to meet localized capacity, transmission and distribution (T&D) needs.

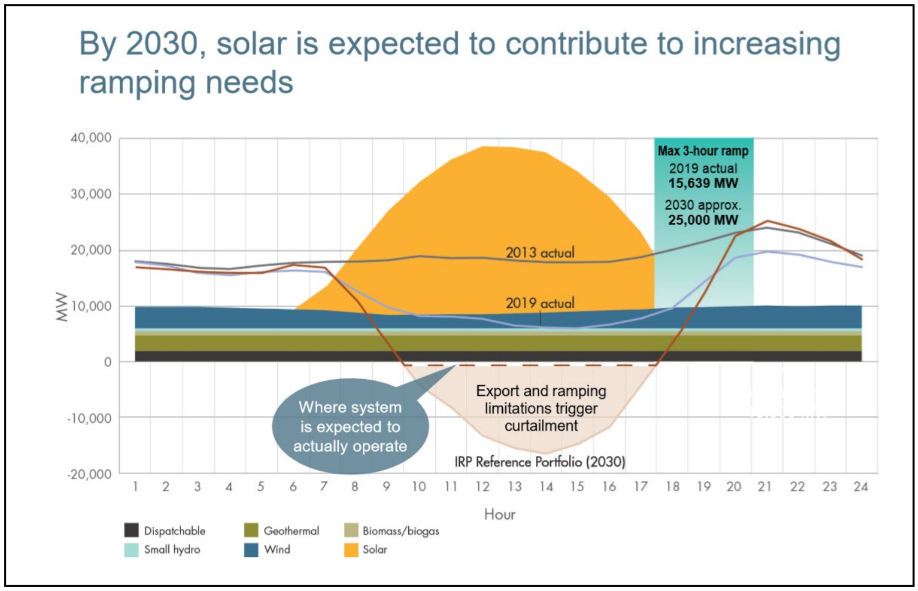
California's network of more than 2100 wastewater treatment plants, municipal water agencies, special districts, public utilities, municipal water companies, and county districts offer the state a significant resource to solve regional and local grid needs through demand side management solutions. While the technical potential identified for demand response (DR) is high, historical participation in traditional resource adequacy programs has been limited by barriers including disincentives in tariff structures, program design, technical resources, the industry's risk aversion to violating regulatory and permit compliance, and a lack of tools to evaluate risks, cost and benefits, among others.

Lawrence Berkeley National Lab's "2025 Demand Response Potential Study" evaluated the trajectory of California's demand shapes and concludes that "traditional demand response – that which reduces hot summer peak demand – may be of limited value in the future…" (2017). Future load management initiatives should focus on aligning customer usage patterns to complement abundant day-time solar generation, and should consider more targeted, locational demand response strategies.

CALIFORNIA GRID NEEDS AND DRIVERS

By 2030 the state is targeting to meet 50% of retail electricity sales with renewable energy, to reduce greenhouse gas (GHG) emissions to 40% below 1990 levels, and to have 5 million electric vehicles on the roads. By 2045 California plans to be operating on 100% clean, carbon free energy.
At the same time, as the state faces drought, fire and PSPS, the CPUC is expanding incentives to support economic equity and grid resiliency through new equity resiliency incentives under the Self Generation Incentive Program (SGIP).

The state's rapid growth of non-dispatchable and intermittent solar and wind generation is leading to unprecedented challenges for California's electricity system. Solar overgeneration, when real-time electric supply exceeds demand, is causing voltage instability. While voltage instability can be alleviated by electric storage, there are currently shortcomings in the ability for storage technologies to store large quantities of excess wholesale power, such as that generated by utility scale photovoltaics (PV). As a result, California has taken to both curtailing power from utility solar contracts and regularly paying other states to take excess generation. Solar is also shifting the new peak period to 4 p.m. – 9 p.m. and is affecting the design of customer tariffs and time of use periods.



As is described below, traditional demand response approaches are evolving to meet the fast-changing load profiles and grid needs of the state.

Demand Response Approaches

Demand response (DR) programs have been and are still used to balance the energy markets and support local capacity resources and have provided California ratepayers with various economic and environmental benefits including avoiding building new power plants, avoiding the purchase of high-priced energy, providing greater reliability to the grid and reducing higher carbon generation assets.

In California, load serving entities (LSEs) like the California IOUs, public utilities and community choice aggregators procure supply in advance to meet forecasted demand, and leverage demand response to ensure local reliability and a 15% reserve margin.

While traditional DR programs were designed to shed load on hot summer days through load shed, the function demand response has been quickly evolving to meet California's fast changing grid needs. LBNL's "2025 California Demand Response Potential Study" created a new taxonomy to describe four categories of demand response "service types" based on future grid needs:

- **Shape -** also known as 'load modifying demand response', reshapes the underlying load profile through relatively long-run price response or on behavioral campaigns, with advance notice of months to days.

- **Shift -** is a DR strategy that involves moving the energy consumption from times of high demand to times of day when there is a surplus of energy generation, generally in order to smooth out net load ramps associated with daily patterns of solar and wind energy generation.

- **Shed -** is load that can occasionally be reduced to provide peak capacity and support the system in emergency or contingency events, with dispatch advance notice at a statewide or local level.

- **Shimmy -** refers to dynamically adjusting demand on the system to alleviate short-run ramps and disturbances at timescales ranging from seconds up to an hour.

Figure 2 below shows the relative timescales of strategies from years to seconds.

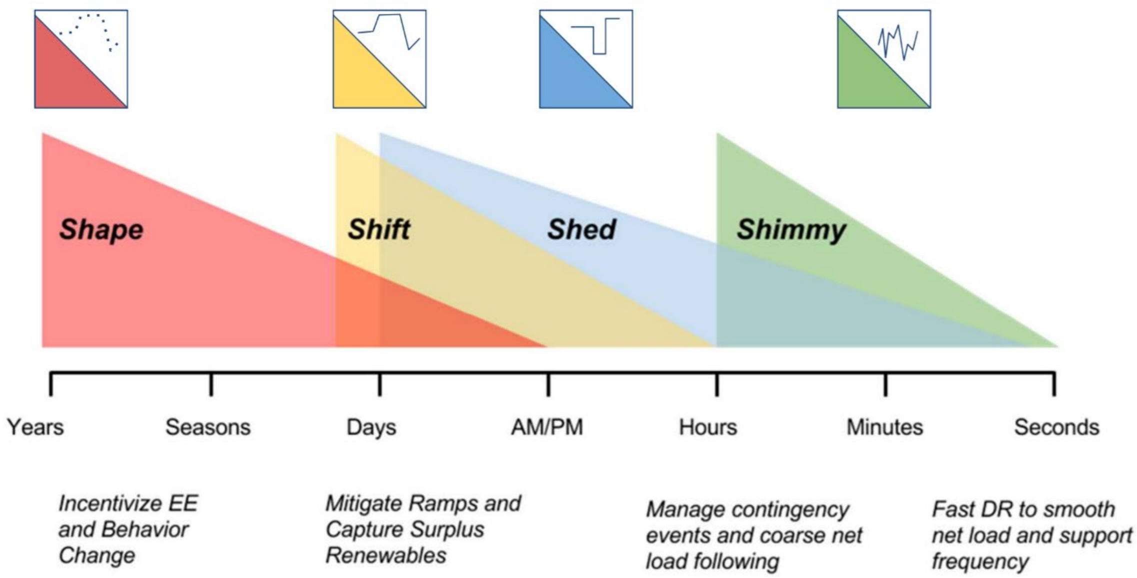


FIGURE 2. DR SERVICE TYPES PRESENTED OVER TIMESCALE FOR GRID SERVICE DISPATCH FREQUENCY AND/OR RESPONSE

Increasingly, California and the state's Independent System Operator (CAISO) are advancing policies and strategies to support Shift and Shape load to alleviate the impacts of overgeneration and other emerging trends.

Each demand response strategy identified in the Findings section of this report is classified within the accompanying DR Matrix tool as having potential for shape, shift, shed or shimmy.

CAISO INITIATIVES

The California Independent System Operator (CAISO) utilizes the nearly 26,000 circuit miles of high-voltage transmission lines to manage the flow of electricity across 80% of California. They are responsible for grid reliability, infrastructure planning and market operations. They serve to coordinate competing and diverse energy resources into the grid where it is distributed to consumers, while simultaneously operating a competitive wholesale power market designed to promote a broad range of resources at lower prices. This is done through a nearly real-time forecast of electrical demand and dispatching of the lowest cost generator to meet the demand, while ensuring enough transmission capacity for delivery.

Recent activities at the CAISO demonstrate the shift from traditional DR approaches to new flexible load management strategies that are required to meet California's fast evolving grid needs.

CAISO RULEMAKING ON LOAD MANAGEMENT - In November 2019, the California Independent System Operator (CAISO) initiated a rulemaking on load management to increase demand flexibility via rates, storage, automation, and "other cost-effective measures". The Order Instituting Rulemaking (OIR) identified areas of structural change to the resource adequacy program that the Commission may consider including:

- Examination of the broader RA structure to address energy attributes or hourly capacity requirements, given the increasing penetration of use limited resources, greater reliance on preferred resources, rolling off of a significant amount of long-term tolling contracts held by utilities, and material increases in energy and capacity prices experienced in California over the past year.
- Energy efficiency measures that reduce demand during peak periods, and utility targets and goals for demand flexibility. Goals include structuring a tariff with electricity prices that "change frequently enough to help offset the variability in a 100% renewable grid, support the tools that enable automated response to prices and/or system conditions".

DEMAND RESPONSE FOR SPINNING RESERVES PILOT **-** There has long been interest in whether demand side resources could be leveraged for spinning reserves. The CAISO is responsible for procuring "spinning reserves" as a first strategy for maintaining reliability following a major contingency, such as the unplanned loss of a large generation facility or critical transmission line. Traditionally on the supply side, spinning reserves are competitively bid by the CAISO on day ahead and hour ahead markets and are required to meet its obligation within 10 minutes of being called.

Advantages to using demand side resources for spinning reserves include that they can offer: 1) near-instantaneous response (compared to the 10 minutes allowed for full response from generators); and 2) responses that can be targeted geographically anywhere electricity is consumed within a utility's service territory.

SCE, in a joint project with the Consortium for Electric Reliability Technologies (CERTS), funded by the California Energy Commission's Public Interest Research Program (CEC PIER), is launching a demand response spinning reserves demonstration in which they will call on participating customers to curtail their energy use at pre-scheduled times during summer weekday afternoons for periods of five to 20 minutes each between 2 p.m. and 6 p.m.

ENERGY STORAGE AND DISTRIBUTED ENERGY RESOURCES PHASE 3: (ESDER3) **-** The focus of the Energy Storage and Distributed Energy Resources (ESDER) initiative is to ease the ability of ISO connected and distribution-connected resources to participate in the competitive market, including residential rooftop solar, plug-in electric vehicles and demand response strategies. CAISO recognizes the increasing importance of these resources in the future resource mix, providing lower carbon emissions and operational benefits like grid stability. Under ESDER, entities beyond

LSEs (e.g., IOUs, municipal utilities, or community choice aggregators), can participate directly in the CAISO market.

To date, four phases have been implemented or are in the process of implementation, with Phase 4 currently in progress. Phase 1 began in 2016, which enhanced the ability of grid-connected storage and distribution-connected resources to participate in the ISO market. Improvements included the ability for submitting the state of charge as a daily bid parameter in the day-ahead market, as well as an option to not provide state of charge limits or not have the ISO co-optimize non-generator resources based on state of charge.

In 2018, the initiative provided three new types of demand response performance evaluation methods, clarified Station Power treatment for storage resources, and incorporated additional gas indices into the net benefits test calculation to reflect all real-time participation regions.

The Phase 2 policy allowed for baselines to be performed and submitted by scheduling coordinators, resulting in all remaining demand response system (DRS) functionalities to be integrated into MRI-S (Market Results Interface – Settlements) and decommissioning of the DRS. Phase 3 in 2019 further went on to provide new dispatchable bidding options for demand response resources and remove the single LSEs' requirement for demand response aggregations as well as the application of the default load adjustment. This provided the ability for scheduling coordinators of demand response resources to submit Customer Load Baseline data to the Settlement Quality Meter Data Systems, required for monitoring and audit purposes, in compliance with the CAISO Tariff requirements.

Currently, Phase 4 is exploring refinements to the distributed energy resource (DER) and storage participation models, as well as lowering integration barriers for demand response resources. In all, the ESDER initiative is capturing the value of ISO connected resources, such as demand response, and their ability to support grid reliability.

NON-WIRES ALTERNATIVES / PREFERRED RESOURCES PILOTS / DISTRIBUTION DEFERRAL

Other emerging opportunities for application of large customer demand response strategies are in investor owned utility (IOU) non-wires alternatives (NWA), preferred resource pilots, and distribution deferral funding mechanisms, described below:

NON-WIRES ALTERNATIVES (NWA) **-** is an electric grid investment that uses non-traditional T&D solutions, such as distributed generation, energy storage, energy efficiency, demand response, and grid software and controls. These resources intend to defer or replace the need for specific equipment upgrades, such as T&D lines or transformers, by reducing load at a substation or circuit level. Pacific Gas and Electric (PG&E) developed the first implementation of NWA in California in 1991 as a targeted demand-side management measure. Renewed interest in NWAs is underway due to the widespread deployment of distributed energy resources (DER), efforts to reform the traditional utility business model, respond to forecasted load growth and for integration of DERs to the grid.

SCE's Virtual Power Plant is an example of the industry's movement toward leveraging customer-sited energy storage systems to provide demand response. This effort included more than 100 customer-sited electric storage systems that were dispatched during DR events. The Virtual Power Plant also integrated automated artificial intelligence software, in an effort to make the initiative "fatigueless" on the end-users. Aggregation and oversubscription of DR resources cuts the risk of resource unavailability that may occur if an NWA relies on a single, large DR asset. Coupled with other initiatives, NWAs offer a unique alternative to distribution system investment, as well as alleviating grid stress when used in the capacity of demand response.

LOCAL CAPACITY REQUIREMENTS (LCR) – as traditional generation assets and peaker plants are decommissioned, IOUs are releasing competitive solicitations like LCR in which clean alternatives and "non wires alternatives" like energy efficiency, demand response and energy storage have been invited to compete with traditional generation. In recent LCR procurements, traditional resources such as gas fired generation have competed directly with combined heat and power (CHP), demand response, energy efficiency, energy storage, renewables, resource adequacy and distributed generation.

DISTRIBUTION INVESTMENT DEFERRAL – under the Distribution Investment Deferral Framework (DIDF), IOUs are required evaluate non-wires alternatives as an option to defer or avoid regional distribution system investments such as substation upgrades and transformer replacements.

In 2017 SCE released the "Integrated Distributed Energy Resources Request for Offers (IDER RFO) to procure DERs in order to defer capital. In January of 2020, SCE released a DIDF RFO to potentially defer distribution projects in Palm Springs, Santa Clarita, Pechanga, Moreno Valley, and Elizabeth Lake. Eligible product types included the following resources connected to SCE's distribution system or at customer locations: "Demand Response, Renewable Distributed Generation (DG) both in front of and behind the meter; Energy Storage, Renewable DG paired with Energy Storage, Permanent Load Shift and Energy Efficiency". SCE solicited a minimum of 100 kW for the demand response product. Furthermore, SCE encouraged projects and aggregation of customers in areas with a high likelihood of being impacted by PSPS events.

GRID RESILIENCY

California's electricity infrastructure is vulnerable to both short and long-term disruption from fire, PSPS events, natural disasters like storms, floods and earthquakes, as well as cyber-terrorism. The increased frequency and intensity of power outages due to these disruptions in recent years has highlighted the urgency

of enhancing distribution grid resilience. Even the risk of a fire – such as from high winds and dry conditions sparking a fire from T&D systems can cause grid disruption, through CA IOU PSPS events.

In such circumstances, DR in the water/wastewater industry can be a turning point in preventing complete blackouts and ensuring grid resilience. This can in a way act as "virtual power plants," freeing up energy demand and providing the same service as a power plant. The benefits of using DR in water/wastewater sector for grid resilience include: relieving stress on the electric grid during peak hours and extreme weather events, avoiding costly transmission infrastructure upgrades, freeing up electricity during power plant or transmission outages and helping the grid adapt to fluctuations in wind and solar energy generation.

SGIP Incentives

The CPUC's Self-Generation Incentive Program (SGIP) provides financial incentives for the installation of distributed generation (DG) and advanced energy storage (AES) technologies at customer homes and businesses. SGIP is funded by California's electricity ratepayers and managed by Program Administrators (PAs) representing California's major IOUs. The California Public Utilities Commission (CPUC) provides oversight and guidance on the SGIP. SGIP provides rebates for qualifying distributed energy systems installed on the customer's side of the utility meter, including wind turbines, waste heat to power technologies, pressure reduction turbines, internal combustion engines, microturbines, gas turbines, fuel cells and AES systems. Currently, incentives are offered from the following utilities and can be used to buy down the cost of systems that can be used to support load management strategies:

- Pacific Gas & Electric: for PG&E electric customers and PG&E gas customers of public electric utilities in Northern California such as SMUD and Alameda
- Southern California Edison
- Southern California Gas Company: for SoCalGas customers that take electric service from a non-SCE entity in Southern California.
- Center for Sustainability Energy: for SDG&E customers

California Demand Response and Load Management Programs

Demand Response programs offer incentives for reducing electricity use when the demand for electricity is high. During these periods, DR "events" occur, where participants are either asked or remotely signaled to reduce energy usage. In return, participants receive bill credits, a reduced rate, or other forms of compensation. Additionally, participants may also be eligible to receive extra incentives for the integration of DR-enabling technology installed at their facilities.

The following DR programs are applicable to the water and wastewater industry, based on historical participation data.

Auto-DR

Auto-DR is an "enabling technology" incentive program. Auto-DR enables communication with the energy management control system (EMCS) that responds to a DR event or signal via the OpenADR 2.0 National Communications Standard. Depending on the DR Program, the enrolled customer is notified of an event either one day before or on the day of the DR event. Customers seeking Auto-DR customized incentives are required to provide at least 30 kW reduction, which is verified in the two-hour measurement and verification (M&V) test. When there is a DR event, participants have three choices:

1. They can do nothing and participate.
2. They can choose to override their pre-programmed strategy and opt-out of the event.
3. They can change their load reduction strategy for that specific event.

Auto-DR's design is made up of two major elements built upon OpenADR (aka: an open-interface standards model).

1. First, the Demand Response Automation Server (DRAS) sends event notification signals to participating DR customers.
2. Second, a customer's dedicated client device maintains constant communication with the DRAS and links to the facility's pre-programmed load reduction strategies. This happens independently of control network protocols, such as BACnet and Modbus. Honeywell (formerly Akuacom) provides the communications infrastructure (DRAS) and connectivity support for SCE's Auto-DR participants. If for any reason the automated load reduction signal fails to reach a customer's client device, customers are still responsible for load reduction obligations.

Agricultural and Pumping Interruptible Program (API)

API is a DR program in which a control device is installed either near the meter or pumping equipment to control the total load served. When the grid is experiencing critical demand, the CAISO notifies the Utility that energy use needs to be reduced. They then transmit a signal to the device that will automatically turn off electricity until critical demand—or the occasional test—has ended.

To be eligible for enrollment in this program, the participant must be equipped with an SCE SmartConnect™ or other qualifying interval data meter, be billed under an Agricultural and Pumping rate schedule, and have a measure demand of at least 37 kW or a connected load of at least 50 HP. DR evens are limited to the following criteria:

- One event per day, maximum of 6 hours
- Maximum 4 days per calendar week
- 25 events maximum per calendar year
- 40 hours maximum per calendar month
- 150 hours maximum per calendar year

Participants in this DR program are incentivized at $19.62 $/kW per meter per month during the Summer Average On-Peak period and $10.87 $/kW per meter per month during the Winter Average Mid-Peak period. This program may not be available in certain areas of SCE's service territory where communication signaling equipment has not been installed or signal strength is inadequate to activate or deactivate interruption. SCE provides and installs automatic disconnection equipment at no charge to participants and has sole access to equipment as they own, operate, and maintain all disconnection equipment.

Critical Peak Pricing (CPP)

CPP is an optional rate that offers a discount on summer electricity rates in exchange for higher prices during twelve CPP event days per year, usually occurring on the hottest summer days. By reducing electricity use during CPP events, participants can lower electric costs during the summer season when bills are typically the highest. Most business customers receiving bundled service (delivery and generation of electricity) from SCE are eligible for CPP.

Twelve CPP events are called every year between 4 p.m. and 9 p.m. and can be called year-round on non-holiday weekdays. The events are usually called when electricity demand peaks due to extreme or unusual temperature conditions. Other triggers can include higher energy prices, electrical emergency alerts issued by the California Independent System Operator (CAISO), or an SCE system emergency that affects local grid operations. On these days, the costs of energy will increase during On-Peak demand times between 4 p.m. and 9 p.m. CPP event notifications are sent to participants a day-ahead of the event so proper planning can be made. An overview of the CPP structure is provided in Figure 3 below.

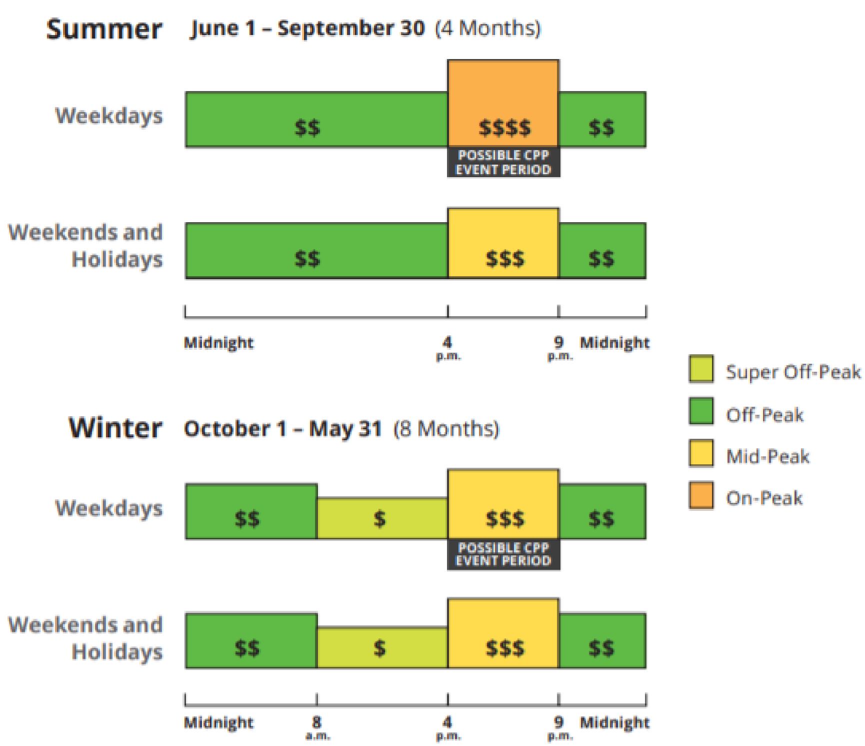


Figure 3. Overview of the CPP structure for Summer and Winter seasons.

Base Interruptible Program (BIP)

BIP is a manual, predetermined load reduction program available to general service customers as well as aggregators that requires a facility to reduce the onsite load within a 30-minute time period for the duration of the DR event. Participants must have a monthly maximum demand or aggregated monthly maximum demand reaching or exceeding 200 kW and service under the provisions of a Time-of-Use (TOU) or Real Time Pricing (RTP) rate schedule. A commitment to curtail at least 15% of the maximum demand, which cannot be less than 100 kW, per period of interruption must be made at enrollment.

For this program, the site chooses how much energy they need to stay up and running, and the Utility provides advance notice according to their preference. When a TOU-BIP event is initiated, designated contacts are notified via email, phone, and/or text (SMS) that a period of interruption will begin. Events are limited to 1 per day, 10 per calendar month, up to 6 hours each for a maximum of 180 hours a calendar year. Participants are presented with two options under the BIP program:

- Participation Option A: 15-Minute Participation Option requires a Customer or Aggregated Group to reduce its demand imposed on the electric system to its Firm Service Level within 15 minutes of a Notice of Interruption from SCE.
- Participation Option B: 30-Minute Participation Option requires a Customer or Aggregated Group to reduce its demand imposed on the electric system to its Firm Service Level within 30 minutes of a Notice of Interruption from SCE.

The bill credits are based on the kW demand difference between the customer's monthly average kW demand recorded during each TOU period (on-peak and mid-peak during the Summer Season, and mid-peak during the Winter Season), and the customer's Firm Service Level (FSL). The kW demand difference, as described above, are multiplied by the applicable bill credit amounts differentiated by the selected Participation Option (A or B), by voltage levels, by season, and by TOU period. The bill credit(s) for each applicable TOU period is then summed to arrive at the total credit for the month. Participants that commit to this program are subject to excess energy charges for failing to reduce energy during events.

Demand Response Auction Mechanism (DRAM) Pilot

The DRAM pilot is a DR capacity auction open to third-party demand response providers (DRP). The purpose is to provide Utilities with DR resource adequacy through a standard, non-negotiable purchase contract. When third parties enter into DRAM contracts, they must provide the Utility with DR capacity supply plans and register their DR resources into the CAISO wholesale energy market.

Participants must have a SmartConnect™ or interval meter installed at their project site and have an existing utility service account with at least 12-months of billing and usage history. Intermittent loads (i.e., pumping or agricultural irrigation) need 24-months of billing and usage history. Additionally, participants must already be enrolled in a qualifying DR program or be eligible to enroll in a qualifying DR program. Auto-DR Customized Program customers must have a minimum of 30 kW, per service account, of eligible available load to qualify for technology Incentives.

A credit of $200 per kW of verified load reduction or 75% of actual eligible qualifying equipment and installation costs are provided for participation in this program. Additionally, all DR events that occur between May through October from noon to 8 p.m. will count towards the participation bonus incentive calculation. An overview of the program incentive structure is provided in the figure below.

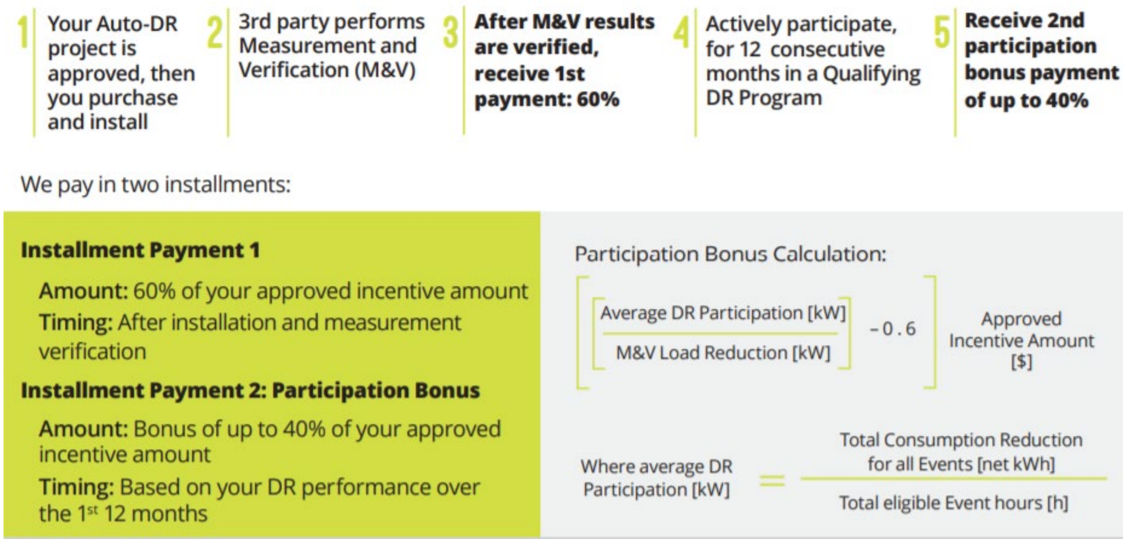


FIGURE 4. OVERVIEW OF THE DRAM PILOT PROGRAM INCENTIVE STRUCTURE

Capacity Bidding Program

The Capacity Bidding Program (CBP) provides participants an incentive for reducing energy when energy prices are high, demand reaches critical levels, or supply is limited. The CBP is a year-round, event-based program, allowing the Utility to call an event any weekday (excluding holidays) between 1 p.m. and 7 p.m. to temporarily reduce energy usage. Events are called in response to weather- or system-related energy shortages, high energy prices, or may be called up to three times a year for testing purposes. Each month, participants choose how much they can commit to reduce, and receive incentive payments for meeting the bid. Even if no CBP event is called, participants still earn incentives.

Participants must be enrolled in Bundled Service, Direct Access or Community Choice Aggregation, or is an aggregator of these customers. Additionally, they must have internet access and an SCE-approved communicating interval metering system that records usage in 15-minute intervals. Events can be scheduled on a day-ahead or on a day-of basis and can last from one to six hours. Event participants will not be required to reduce load for more than one event per day and not for more than 30 hours per month.

Energy Payments are only earned when events occur and are based on actual energy-use reduction. Generally, capacity payments are based on the load reduction amount nominated for the month and vary depending on the month's capacity price and whether a day-ahead or day-of notification is required. The closer the average actual energy load reduction during event hours is to the bid/nomination amount, the higher the Capacity Payment. If no event is called in a given month, participants receive the full Capacity Payment. Participants that fail to meet the bid commitment during an event may be subject to penalties, so it is recommended setting bidding reduction levels that are attainable.

Demand Response Providers (DRP) and Aggregators

A DRP/aggregator is a commercial entity that provides demand response services such as assisting retail customers with strategies or technology to reduce their electric consumption and then making the electric load reductions as a 'bid' in wholesale energy markets. Some entities focus entirely on working with customers to reduce their electric consumption and paying incentives for their reductions. Such entities are often referred to as "aggregators" and will have commercial arrangements with other entities that specialize in interfacing with the wholesale market. DRPs are the wholesale-facing entities. Some entities will handle both retail and wholesale transactions. The bidding of retail customers' load reductions in wholesale markets is often referred to as "Direct Participation". Much like standard DR programs, electric retail customers will be called upon by the DRP to reduce their electric demand on certain days within certain hour(s), and in exchange for that reduction, the participant will receive a financial incentive.

A list of approved California aggregators is provided in Table 1 below.

Table 1. List of approved California Demand Response Providers and Aggregators

Advanced Microgrid Solutions	IPKeys Power Partners
AutoGrid	Leap
Chai Energy	NRG Curtailment Solutions
CPower	OhmConnect
EDF	Polaris Energy Services
eMotorWerks	Redwood Energy Storage
Enel X	Siemens Industry
EnerGTech Experts	Stem
EnergyHub	Swell
Enersponse Energy	THG Energy Solutions
Engie	Trane
GridPoint	Viridity Energy Solutions
Innovari	Voltus

Time of Use Tariffs

Tariffs are rate plans that utilities offer to customers. Along with the pricing plan, there may be certain rules for each tariff a utility offers, such as the times or seasons when prices will vary, eligibility for a tariff, when/how a customer can join or leave the tariff, what type of meter must be installed and more.

Many California water and wastewater facilities are on time-of-use rate (TOU) rate tariffs. TOU is a rate plan in which rates vary according to the time of day, season, and day type (weekday or weekend/holiday). Higher rates are charged during the peak demand hours and lower rates during off-peak (low) demand hours. Rates are also typically higher in summer months than in winter months. This rate structure provides price signals to energy users to shift energy use from peak hours to off-peak hours. Figure 5 below shows the pricing for an illustrative TOU rate plan.

TOU pricing encourages the most efficient use of the system and can reduce the overall costs for both the utility and customers. Prices are predetermined for each time period and do not adjust according to day-to-day changes on the wholesale electricity market. Currently, all commercial, industrial and agricultural customers in California are required to be on a TOU plan.

FIGURE 5. TIME-OF-USE PRICING STRUCTURE FOR SUMMER AND WINTER SEASONS.

EMERGING WATER AND WASTEWATER INFRASTRUCTURE NEEDS AND TRENDS

Below are key water sector trends that impact decision making and investment.

AGING INFRASTRUCTURE, ENERGY COSTS AND CAPITAL

Water and wastewater facilities account for nearly 40% of a municipality's energy consumption and in times of austerity can be an increasingly lucrative opportunity for energy cost saving investments. Water and wastewater treatment (W/WWT) facilities can be designed and operated to maximize energy revenue generation, minimize energy costs, and even as community resiliency centers, providing emergency back-up power, Compressed Natural Gas (CNG) fueling stations and a drought proof water supply through recycled water production.

Most W/WWT facilities in California are 20-50 years old. Some are 100 years, or older, and only a few are less than 20 years old. That said, the rate of aging of some key assets, especially buried infrastructure, has accelerated in the recent decade. The service and energy demand on many systems has increased due to changing urban water usage, as well as changes in overall climate and climate cycles. Concurrently, environmental, regulatory, and social constraints have increased the technical burden on systems, driving the need to modify the infrastructure and increase demand expectations on service reliability. Combined, the cost of service has increased radically and shows little sign of slowing.

The W/WWT community is focused on maintaining service to its constituents, meeting ever increasing regulatory constraints and maintaining economic and political survival. Most of the significant WWT infrastructure was built in the 1970's and 1980's using Clean Water Act grants, wherein their investment was 12.5 cents on the dollar. Now, those aged facilities are in need of significant upgrade, if not replacement. The design technologies of that age were much less energy efficient than what is required now. The relative cost of energy is three to five times what it was, and the demand for energy has been ever increasing due to new requirements. However, while the annual budget for energy in most organizations is in the top three costs, it traditionally has not been a top focus or priority.

The funding mechanisms that built the current systems are no longer sufficient or are unavailable. Availability of funds outside of local revenues is substantially constrained. Further, according to a recent study by the American Water Works Association, local government budget impacts from the recent emergence of COVID-19 are expected to constrain available budget by approximately 20% in upcoming years.

Therefore, most agencies are in need of alternative technologies to do more at less capital and lower operating cost. The problem is that in many cases they do not have convenient resources and pathways to identify and incorporate those technological improvements. The support infrastructure, such as major design firms, continue to promote what they know best – industry-standard, but often antiquated, energy-intensive technologies. Regulatory entities follow the same mantra – stay with what has worked in the past. Funding decisions follow the same path and resist investment in newer, alternative, low-energy systems. The inherent risk aversion of the sector further exacerbates the problem.

Energy cost profiles are changing, and will continue to change, for municipal and local water and wastewater treatment facilities. The effect of COVID-19 on communities is unknown at this point. It is possible that observed disturbance to patterns of water use, and wastewater discharge will shift permanently, or change dramatically for a long period of time. If workers commute less to urban areas, the water and wastewater use patterns will also necessarily change. If university and college students no longer reside in communities they once did, then the impact on both rural and urban communities may be significant. Further, as the economic recession grips the world, local government budgets will be stressed, in many cases to bankruptcy. For example, a recent study by the American Water Works Association reported that water sector capital expenditures in this sector are likely to decrease by as much as $5 billion (annualized) (AWWA 2020). The aggregate effect on the drinking water industry may be as much as $14 billion, representing an approximate 17% financial impact on the sector.

EMERGING ENVIRONMENTAL AND CLIMATE IMPACTS ON DESIGN AND OPERATION

While the mission-critical function of water and wastewater services cannot change, the tools used to maintain consistent levels of service must evolve to meet new systemic challenges and high expectations of energy and sustainability performance. Contemporary "one water" approaches are now encouraging water managers to emerge from traditional silos to cross disciplines and physical barriers. Today's environmental and regulatory constraints are having an impact on resource management and asset reliability and undoubtedly will impact infrastructure planning strategies. Communities continue to increase the use of reclaimed water while decreasing the use of potable water for industrial, irrigation and non-consumptive domestic uses. While environmentally beneficial, these strategies increase the embedded energy costs of operations, and if not properly considered in the carbon accounting, can leave well-intended projects a net cost to society.

Water and wastewater treatment plants need to constantly be retrofitted to be able to meet treatment requirements, while at the same time efficiently treat water, utilizing minimum energy. However, most importantly, these systems are required to remain reliable. Failures in reliability can result in permit violations as well as major environmental catastrophes. The two major factors affecting asset reliability is quality performance and time performance.

Quality performance is the most important characteristic of asset reliability. Most of the water and wastewater treatment plants designed and built in the 20th and early 21st century, pose a risk of deteriorating performance and ultimately failing. Continuous monitoring and assessment ensure quality performance of the equipment, which promotes better treatment of water consuming minimal energy. Along with quality of the equipment, another factor affecting asset reliability is the lifespan of the equipment. Efficiency of the asset registry when balanced with their lifespan gives the best performance not just financially, but also with respect to energy efficiency. While reliability and simplicity were the primary drivers for how water and wastewater treatment systems were designed originally, now resiliency and efficiency are changing the nature of operational upgrades, retrofits and future design considerations.

A new paradigm for how and where we use recycled water requires efficient and reliable wastewater treatment process that can maintain required effluent standards. One of the challenges faced by the industry is the need to dramatically improve the economy of recycled water production while other resource constraints, including uncertainty and climatic variability, increase the cost of treatment. Robust infrastructure coupled with better resource management and sustainable asset reliability can change the outlook of conventional treatment and at the same time exponentially increase energy savings, provide operational flexibility, and support grid flexibility.

Climate change has affected the hydrologic cycles and water availability in California over the past two decades. Consequently, aggressive water conservation in Southern California communities has been changing not only water usage, but also the nature of sewage collection and treatment. Reduced flow from household and commercial water fixtures provides less volume and velocity in sewers and increases detention time for the same if not increasing mass of wastes. Coupled with elevated temperature in many areas, the physical collection and conveyance systems become biological reactors instead of simple physical conveyance systems. This not only increases odor and corrosion in collection system and pumping stations, but also creates septic conditions which stimulate undesirable biology to produce more dissolved sulfide, ammonia and odorous, soluble BOD. This changes the loading characteristics to the treatment plants and subsequent energy usage for treatment processes.

The impact of this condition is measurable and significant. Throughout California and the Southwest, treatment plants have suffered major upsets; violation of stringent discharge requirements and have incurred significant increased cost for energy and chemicals. Increased loading and pass-through to energy intensive processes is increasing wear and tear on equipment and infrastructure, reducing performance and maintenance reliability. The change in ammonia and organic loading creates the most challenging impact on design capacity of many facilities and has had the effect of both reducing rated capacity and increasing the demand and cost of energy and chemicals, while decreasing gas production and energy recovery from anaerobic digesters. Changing water chemistry has often required higher dosage of treatment chemicals and created challenges in water reuse markets and applications.

The change in chemistry of raw sewage because of elevated temperature and decreased flow rate has increased the process energy demand in many facilities by well over 20% in the past five years. This trend is not likely to abate and may worsen in coming years. This is due to legislated changes in water use efficiency, which will further reduce flow to the sewers as enforced by local building departments and worsen the biological conditions therein unless mitigated by alternative strategies and technologies. This will not only drive changes in general operating strategies but will motivate alternative design and technologies to more energy-affordable schemes.

Decentralized Water Infrastructure vs. Water Sector Consolidation

When modern water and wastewater systems were originally imagined and designed, the conventional logic was that larger, centralized systems would offer higher efficiency per unit of water produced and treated. Similar to the transition in the energy sector to a distributed generation paradigm, the water sector is re-imagining how to move water throughout communities with the lowest total impact in terms of GHG emissions, Carbon Footprint (CF) and the release of other pollutants in to the environment. Water sector decentralization provides both opportunities and challenges for grid responsive DR participation, generally. As the number of facilities operated by any one customer grows, very often accompanied by additional design capacity, each of those facilities may hold varying degrees of DR potential. Additionally, system-wide flexibility inherent in decentralized systems, presents opportunities to optimize energy performance on the electric grid, at the circuit level, when appropriate price signals and control strategies can be implemented.

Furthermore, many water and wastewater agencies throughout the Southwest are exploring the community benefits of consolidation, wherein a single entity absorbs and takes over the operation of a neighboring, often smaller agency. With this consolidation often comes an improvement in technological capabilities and in some cases resource availability. In a similar trend, water and wastewater customers are forming joint power authorities (JPAs) whereby multiple entities build/own treatment facilities to serve their collective service areas. This presents more of a management and governance challenge to DR participation than a technical challenge, as JPA's are usually burdened by slightly more cumbersome decision-making processes, leading to lower uptake in DR programs.

STRICTER PERMIT / LEGISLATIVE / REGULATORY REQUIREMENTS

Environmental pressure on stricter wastewater discharge limits will continue for the foreseeable future. The prime areas of focus will be on stricter control of nutrients, such as nitrogen and phosphorus, and emerging constituents of concern (such as chlorinated by-products and pharmaceuticals). Conventional treatment processes will be increasingly energy intensive.

Legislative changes do not always conform to scientific logic, but nonetheless imposed increasing performance demands upon existing infrastructure. Legislated water conservation will drive the unit cost for wastewater treatment higher due to increased concentration of contaminants. All these processes are energy intensive, typically consuming over 80% of the total energy consumed by the facility.

Coupled with increased regulatory constraints, the energy economy of wastewater treatment and reuse facilities will continue to escalate unless replaced with more energy-efficient alternative strategies, processes, controls, and designs.

ENHANCED CONTROLS

Water and wastewater facilities utilize a variety of sensors and monitoring equipment to aid in understanding the day to day operations, as well as reporting for regulatory requirements. Many sites are equipped with supervisory control and data acquisition (SCADA) systems, in both a localized and cloud-based environment. Enhancements in SCADA systems have enabled sites to monitor and maintain precise records of various process, chemical and electrical parameters, often in real-time. Feedback sensors have also improved greatly over time, providing more accurate data points and the ability to monitor discreet organic parameters that would previously require delayed laboratory testing. The combination of these two items allow for operators to make real-time process decisions, thus improving the consistency and efficiency of the treatment process, as well as reducing labor costs and burden.

More advanced facilities employ an advanced metering infrastructure (AMI), which is an integrated network of sensors, smart meters and software that allow operators to monitor and control various metrics such as chemical, gas and electric usage. With the integration of AMI, operators are now empowered to supplement their process decision making actions, with derived factors such as energy usage. An example of the implementation of such a system was piloted at the Moulten Nigel Water District. This involved the deployment of analytical tools and dashboards, integrated with hydraulic modeling software to form the Energy Demand Management System (EDMS). This software allows the operators to:

- Forecast and recommend optimized future operations
- Forecast future energy demand profiles and energy costs
- Facilitate on-site demand response participation
- Explore new operations based on the future energy rate structures or demand response participation

WORKFORCE SHIFTS AND TRENDS

Along with the infrastructure put in place since the early 1970s, the workforce is aging and retiring. The "Silver Tsunami" is imposing an intellectual drain on organizations, who by in large have not prepared adequately for the knowledge loss that is being realized. At the same time, interest in the water/wastewater career market has been waning and is not attracting educated, knowledgeable replacements. This situation is causing a dilemma in municipalities, resulting in loss of intellectual capital, and incurring increasing risk of process failures, loss of energy efficiency and increasing cost of operation.

This is driving a two-pronged attempt at a corrective action approach: increasing artificial control intelligence via automation and machine learning, and investment in learning institutions to increase the job bank. Both will be inherently slow responses to a current critical condition. This increases the need for an alternative pathway to address the gaps that are increasing energy demand. Additional resources are needed to bring advanced strategies, knowledge and experience to the aide of municipalities to quickly and effectively reduce energy losses related to lack of insight and awareness of appropriate alternatives to monitoring, control and replacement of energy intensive technologies, design and strategies.

ENERGY AND CLIMATE GOALS AND REGULATIONS: WATER-ENERGY-CLIMATE NEXUS

ENERGY AND GHG

The transition from energy intensive water and wastewater treatment (W/WWT) to a zero-net energy (ZNE) water supply is currently underway in California and around the world. Communities are focused on reducing the energy intensity of the water supply to meet future resiliency needs and climate goals. Much scholarship on the water-energy nexus comes from California and the study of its water supply. The complex interconnected nature of these resources, highlighted in practice in California, necessitates a continuous revision of our definition of sustainability.

AB 32 (2006) required California to reduce GHG emissions to 1990 levels by 2020 — a reduction of approximately 15% below emissions expected under a "business as usual" scenario. A decade later, SB 32 (2016) required 40% below 1990 levels by 2030. Water and wastewater will be an important sector for the state in its pursuit of these aggressive goals. Mitigation (and avoidance) actions occur in three broad areas: (1) onsite energy generation; (2) reduction of embedded energy and GHG emissions; and (3) design and construction decisions. Ultimately, more efficient reclamation provides new water supplies for agriculture, industry and even potable uses, particularly in places where climate change will increase drought and water stress.

A common trend in municipal WWTPs to reduce the energy intensity of wastewater treatment and wastewater reuse, is to increase co-digestion of sewage sludges with additional biomass to enhance biogas production in the digestion process. The choice of co-substrates and feeding strategy is fundamental because mobilized nutrients are recirculated in the digestion process. The addition of carbon to support anaerobic digestion reduces the direct emissions of the plants can also increase. Therefore, the trade-off between the increase in the direct CF and decrease in the indirect CF is critical for accurate analysis of the total carbon emissions. This analysis can support decision-making and give a rationale to implement a sustainable strategy meeting both energy neutrality and CF minimization targets.

Water Conservation

Title 22 of California's Building Code provides detailed guidelines and regulations for how treated and recycled water is produced, distributed, and how or where it can be used. Title 22 lists 40 specific uses allowed with disinfected tertiary recycled water (such as irrigating parks), 24 specific uses allowed with disinfected secondary recycled water (such as irrigating animal feed and other unprocessed crops) and seven specific uses allowed with undisinfected secondary recycled water (such industrial uses).

As part of its long-term planning, the state of California aims to:

- Increase the use of recycled water over 2002 levels by at least 1 million acre-feet per year by 2020, and by at least 2 million acre-feet a year by 2030.
- Increase the use of stormwater over 2007 levels by at least 500,000 acre-feet a year by 2020, and by at least 1 million acre-feet a year by 2030.

Water conservation policies and programs continue to drive down the consumption of freshwater throughout CA. As a result, wastewater treatment plants are receiving increasingly higher strength sewage and will continue to be called upon to produce more recycled water. As a result, the energy intensity of wastewater and water reuse will increase, unless design changes and new technologies are adopted by the industry to meet these changing conditions. Water conservation and water re-use are important components to community sustainability and climate change goals but must be approached with the understanding of the impact to energy and carbon emissions holistically.

FINDINGS AND RESULTS

OVERVIEW OF ENERGY USING SYSTEMS IN WWT

Energy usage within a wastewater treatment facility is highly variable and dependent on factors such as flowrate, the characteristics of the incoming raw wastewater and the treatment process employed. Various types of electric motor-driven equipment are involved in the operations and processes including pumps, blowers and mixers, as well as general facility lighting and HVAC. Nearly all the publicly owned wastewater treatment plants in the United States provide secondary or higher levels of treatment, and those with more stringent treatment limits generally require greater amounts of electric energy per volume of water treated. In conventional secondary treatment, most of the electricity is used for: (1) biological treatment by either the activated sludge process that requires energy for aeration blowers or trickling filters that require energy for influent pumping and effluent recirculation; (2) pumping systems for the transfer of wastewater, liquid sludge, biosolids, and process water; and (3) equipment for the processing, dewatering, and drying of residuals and biosolids.

Technology	Energy consumption[b]	
	$kWh/10^3$ gal	kWh/m^3
Conventional secondary treatment WWTP[c]	**0.38 to 0.67**	**0.10–0.18**
Wastewater influent pumping	0.12–0.17	0.032–0.045
Screens	0.001–0.002	0.0003–0.0005
Grit removal (aerated grit removal)	0.01–0.05	0.003–0.013
Trickling filters	0.23–0.35	0.061–0.093
Trickling filter-solids contact	0.35	0.093
Activated sludge for BOD removal	0.53–4.1	0.14
Activated sludge with nitrification/denitrification	0.87–0.88	0.23
Membrane bioreactor	1.9–3.8	0.5–1.0[d]
Return sludge pumping	0.03–0.05	0.008–0.013
Secondary settling	0.013–0.015	0.003–0.004
Dissolved air flotation	0.12–0.15	0.03–0.04
Tertiary filtration (depth filtration)	0.1–0.3	0.03–0.08
Tertiary filtration (surface filtration)		
Chlorination (sodium hypochlorite)	0.001–0.003	0.0003–0.0008
UV (ultraviolet) disinfection	0.05–0.2	0.01–0.05
Microfiltration/ultrafiltration	0.75–1.1	0.2–0.3
Reverse osmosis (without energy recovery)	1.9–2.5	0.5–0.65
Reverse osmosis (with energy recovery)	1.7–2.3	0.46–0.6
Electrodialysis (TDS range 800–1200 mg/L)	4.2–8.4	1.1–2.2
UV photolysis with O_3 or H_2O_2 (advanced oxidation)[e]	0.2–0.4	0.05–0.1
Sludge pumping	0.003	0.0008
Gravity thickening	0.001–0.006	0.0003–0.0016
Aerobic digestion	0.48–1.2	0.13–0.32
Mesophilic anaerobic digestion (primary plus waste activated sludge)[f]	0.35–0.6	0.093–0.16
Mesophilic anaerobic digestion with thermal hydrolysis pretreatment (primary plus waste activated sludge)[f]	0.58–0.6	0.015–0.02
Sludge dewatering (centrifuge)	0.02–0.05	0.005–0.013
Sludge dewatering (belt filter press)	0.002–0.005	0.0005–0.0013

TABLE 2. TYPICAL ENERGY CONSUMPTION OF VARIOUS TREATMENT PROCESSES IN WASTEWATER TREATMENT FACILITIES

A 2007 study conducted by the Water Research Foundation estimates the electrical energy required for wastewater treatment varies widely but is typically between 1,000 and 3,000 kWh/Mgal. Additionally, this study found that generally, energy use per volume tends to be lower at larger treatment plants. Table 2 presents the typical energy consumption of various treatment processes within a wastewater treatment facility (Metcalf and Eddy). For a typical activated sludge wastewater treatment facility, much of the energy usage is attributed to the secondary treatment aeration process that relies on characteristically large aeration blowers to introduce oxygen continuously. The energy consumption reaches its peak around midday and continues until the evening, since more wastewater is being produced and thus, more energy is needed for pumping and treating the water. An overview of the energy usage distribution in this type of facility is provided in Figure 6.

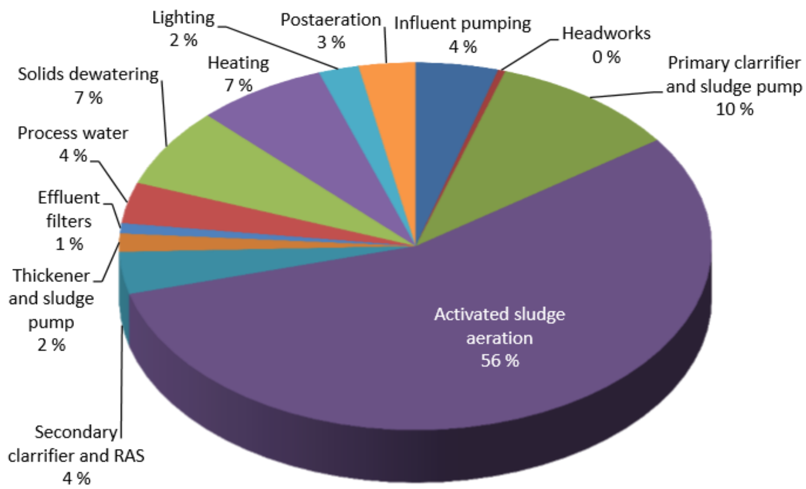


FIGURE 6. ENERGY BREAKDOWN OF WASTEWATER TREATMENT PLANT WITH ACTIVATED-SLUDGE TREATMENT

The energy intensity varies widely based on plant configuration and goals for effluent quality, such as reclamation, de-nitrification or other regulatory constraints. This is due to longer detention times and the need for more energy intensive equipment to facilitate these processes. Figure 7 below demonstrates an example of this for three plant configurations, illustrating the higher energy density of biological nutrient removal facilities.

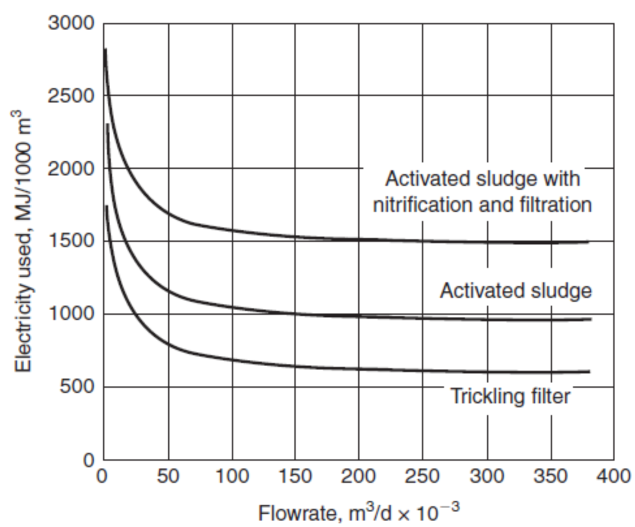


FIGURE 7. COMPARISON OF ELECTRICAL ENERGY IN DIFFERENT TREATMENT PROCESSES AS A FUNCTION OF FLOWRATE.

WASTEWATER TREATMENT AND DR POTENTIAL STUDIES

Below is a summary of key objectives and findings from previous studies that have evaluated potential for demand response and load flexibility for California's water sector.

LBNL 2006-2015 RESEARCH SUMMARY OF DEMAND RESPONSE POTENTIAL IN CALIFORNIA INDUSTRY, AGRICULTURE AND WATER SECTORS

LBNL's Demand Response Research Center evaluated the potential for DR and auto-DR in California's water sector based on demand response end use analysis and field studies. Wastewater treatment facilities were selected as one of the focus areas for the study due to the fact that: they are "energy-intensive facilities and have significant electricity demand during utility peak periods", many facilities had already implemented energy efficiency (EE) measures that could provide a base for participation in OpenADR programs and tariffs, and that certain technologies and control strategies used for EE have the potential to be used for Auto-DR as well.

- Key findings of this study included:
  - EE and load management technologies can enable successful participation in DR events.
  - Facility control systems are suitable for OpenADR when they are integrated into centralized control systems.
  - Over-oxygenation of wastewater prior to a DR event can reduce facility energy demand.
  - Utilizing wastewater storage capacity can reduce facility peak demand.
  - Shifting backwash filter pump use can reduce facility peak demand.
- Load Shed Opportunities identified included:
  - Turning non-essential equipment off and transitioning essential equipment to onsite power generators; Specifically, if biogas can be stored to shift load to off peak.
  - Turning off aerator blowers, pumps, and facility heating ventilation and air conditioning (HVAC) systems or using VFDs to operate equipment at a lower capacity.
  - Using SCATA systems to automatically transfer loads to onsite power generators (including running on biogas)
- Load Shift Opportunities identified included:
  - Over-oxygenating stored wastewater prior to a DR event to allow aerators to be turned off during the peak period.
  - Utilizing excess storage capacity to store untreated wastewater during DR events and process it during off-peak hours.
- Three field case studies were performed. Successful DR was demonstrated at two sites, showing pump reductions of 36% of peak load and solids separation centrifuges at reductions of 30% of peak load.
- LBNL recommended the following areas for future study. While they were specific to enhancing Auto-DR potential, we observe that many of the recommendations could also apply to advancing flexible load management.
  - Better understand existing controls capability in WWT facilities.
  - Understand the prevalence of cogeneration in WWT facilities and its relationship to DR potential, including utilizing schedulable self-generation and self-starting generation units.

- Scale and standardize the OpenADR protocol for control systems to apply to WWT facilities to reduce implementation cost and increase DR reliability and effectiveness.
- Improve understanding of how facility operators impact the effectiveness of DR strategies; Identify best operation practices and behaviors to enhance the impact of DR activities.
- Evaluate WWT plant flexibility to use their intermediate wastewater treatment stages as a non-thermal process/material storage medium for load shifting/shedding and grid response.
- Explore innovations in renewable energy for use at wastewater plants (e.g., photovoltaics and methane capture for fuel cell application)
- Survey literature for case studies and technology advances.
- Perform additional field studies to add to the body of knowledge.
- Develop a DR Quick Assessment Tool for WWT facilities to provide operators with the capability to assess facility performance within some range of performance criteria.

SCE's Demand Response Feasibility Study for the Sewage Treatment Industry

In 2008, SCE's Design and Engineering Services group analyzed the demand response potential for public sector sewage treatment plants (STPs) in their territory with capacity flow greater than 1 million gallons per day (MGD), for the peak summer period (3 p.m.- 5 p.m.). At the time of the study, there were 1,728 services accounts in the territory. Fifty-six agencies owned 80 STPs in SCE's territory with 1 MGD or greater capacity. Those STPs had a maximum load of 120 MW and used 407,000 mWh a year. The median major STP served a population of 500,000, had 6 MGD dry weather design flow, used 626 kW and consumed 2,671 mWh per year. This equated to a median consumption of 461 mWh/MGD and 112 kW/MGD. When classified by kW size category, a range was identified from 10 to 100-fold in the design flow rates, indicating a non-standard design and unit process approach for this industry. The study showed that the most likely scenario for an STP to participate in a DR program would be a facility greater than 500kW with tertiary treatment.

Six out of 80 agencies participated in DR programs, and another estimated 15% (11 agencies) would participate in an SCE DR program, resulting in a projected 6.1 MW reduction per DR event.

Based on an updated analysis of 2019 SCE demand response participation data, there are 139 STPs are currently enrolled in SCE DR programs.

Summary of DR Opportunities in WWT From Previous Studies

As a basis for this study, a compendium of municipal water and wastewater treatment DR strategies, technologies and practices were identified and assembled from SCE and other IOU integrated energy audits, programs and initiatives, other studies, reports and various other information resources. An overview of the data utilized is provided in the References.

Many of the DR strategies identified in previous studies were consistent and took the approach of addressing the traditional DR paradigm of shedding, shifting and shimmying loads. Many of the measures focused on equalization and storage of flows, as well as rescheduling of process function to facilitate the shifting of energy intensity to periods outside of the defined on-peak times. Others focused on reducing or curtailing energy usage on specific non-critical process equipment during specified periods, which often coincided with grid stress. Some strategies explored, such as switching to standby generators during DR events, were also explored although eventually deemed unfeasible. Overgeneration pilots and flexible DR studies provide insight into the unique challenges that an inverted model requires.

Building on the work previously completed, this effort identified key gaps in previous studies, including:

- Duration potential of proposed measures
- Impacts on the targeted system process conditions, as well as the cascading effects on subsequent processes
- Biological and chemical impacts of the strategies, both during and following reinstatement after a DR event
- Potential failure modes and equipment reliability issues
- Operational complexity, capital cost burdens, and difficulty of implementation
- Applicability under existing DR program structures

Compendium of Water and Wastewater Treatment DR Technologies and Strategies

A key objective of this study was to create an approachable and easy-to-use resource for interested water sector stakeholders to identify, scope, value, fund and implement load management strategies that meet site requirements, improve operational performance and support regional grid needs.

Based on literature review, direct market research and the research team's market experience and process expertise, the following 25 water and wastewater treatment load management and demand response technologies, strategies, and approaches were compiled.

Narrative Descriptions

Organized by process, each DR strategy is described narratively including:

- **Opportunity Description:** A brief description of the proposed opportunity synthesizing the overall intent, affected systems and benefits.

- **Process Impacts, Potential Risks & Failure Modes:** The implementation of DR opportunities has the potential to affect mission critical goals of regulatory, health & safety, as well as asset reliability. A brief narrative is provided for each to address these potential impacts and risks.

- **Complexity, Cost & Difficulty of Implementation**: The implementation of DR opportunities often can present a strain on operators, systems and capital expenditures. This portion of the matrix addresses these common and potential areas.

DR Matrix

The DR Matrix further expands on and classifies each of these opportunities to provide an identification and ranking system, used to determine a final total impact potential. The classifications and ranking logic used is as follows:

- **Sector and Systems:** The measures presented in this matrix address both the Potable Water and Wastewater sectors. Water treatment-specific measures receive a lower weighting factor due to the inherent lower energy intensity of water treatment compared to wastewater treatment.
  - Affected System Process: The system(s) affected by the DR opportunity are identified, often with multiple systems affected due to the cascading effects of implementation.
  - The systems covered include: Distribution System, Collection System, Headworks, Primary Treatment, Internal Pumping Systems, Secondary Treatment, Tertiary Treatment, Solids Handling and Digestion & Cogeneration. When a particular DR measure affects energy consumption in multiple sub-processes, it receives a higher overall “Impact on System Process” score.
- **DR Response Type:** Identification of the DR opportunity as it pertains to the potential to Shape, Shift, Shed, and Shimmy the electric load. Load shape strategies receive the greatest weighted ranking, as they provide the greatest flexibility in terms of customer potential and grid benefits. Shimmy strategies receive the lowest overall weighting since they are described as short duration activities.
- **Duration Potential:** The various opportunities provided each have unique characteristics with regards to sustainability without affecting the treatment process. A conservative approach was taken to identify the duration potential(s) for the following intervals: 15-Minute, 1 – 2 hours, 2 – 6 hours, 24 hours, Multi-Day and Seasonal. More weight is given to measures that can be implemented seasonally or for multiple days in sequence, since these necessarily could provide more consistent grid benefits.
- **Potential Risk Factors:** The implementation of DR opportunities can present an element of risk in various forms, specified in this matrix as: Health & Safety, Environmental Compliance, Process Upset, Equipment Failure, Labor Costs, Cost/Rates to Customers, Public Relations, Revenue Streams and Spare Parts Inventory. Each of these factors can be weighted differently based on site-specific priorities and should be evaluated on a case-by-case basis. Using a Consequence of Failure Analysis (CoFA) and Risk of failure estimate, we apply a weight and score for the Risk Assessment ranking. These can be user-identified weighting, depending on site specific characteristics and priorities. For example, Revenue Streams risk (column AH) may be the greatest consideration from a risk perspective for many communities in a COVID-19 impacted local economy. Labor costs may be a greater risk, based on nationwide unemployment trends. A rebounded economy may change the assessment at any time.

- **Demand Response Program Applicability**: Previous and current water and wastewater agency enrollments in existing DR programs was used to develop a list of applicable programs and the individual opportunity applicability to each, or multiple. The programs identified include: Capacity Bidding, Base Interruptible, Demand Response Auction Mechanism, Agriculture Pumping Interruptible, Critical Peak Pricing and Local Capacity Requirements. The greater number of programs that a measure is eligible to participate in, the higher the Demand Response Potential (column AP) score.
- **Summary Rankings:** Based on the above identification and ranking systems, overall ratings for each measure were developed encompassing: Demand Response Potential, Impact on System Process, Risk Assessment and finally, a Total Impact Potential. The scoring is a 1-100 scale, with 100 being the optimal measure.

The DR Matrix can be used to identify potential opportunities in different treatment plant configurations. The following graphic is intended to be illustrative of the scoring and ranking methodology, described above. The Excel is embedded as Appendix B for further review.

	DR Type				DR Duration Potential						Sector		Affected System Process									Potential Risk Factors									DR Program Applicability						Overall Rating			
Demand Response Opportunity	Shape	Shift	Shed	Shimmy	<1 hr	1-2 hr	2-6 hr	24 hr	Multi-Day	Seasonal	Potable Water	Wastewater	Distribution System	Collection System	Headworks	Primary Treatment	Internal Pumping Systems	Secondary Treatment	Tertiary Treatment	Solids Handling	Digestion & Cogeneration	Health & Safety	Environmental Compliance	Process Upset	Equipment Failure	Labor Costs	Cost/Rates to Customers	Public Relations	Revenue Streams	Spare Parts Inventory	Capacity Bidding	Base Interruptible	DRAM	Ag Pumping Interruptible	Critical Peak Pricing	Local Capacity Requirements	DR Potential	Impact on System Process	Risk Assessment*	Total Impact Potential
Increase Resevoir Operating Capacity	X	X		X				X	X	X	X		X			X						Low	Med	Low	Low	Low	Low	Low	Low	Low	X			X	X	X	77	22	95	81
Increase Wet-Well Level Operations				X	X	X	X	X			X	X		X	X		X	X	X			High	High	Med	Med	Med	Low	Med	Low	Low	X		X	X	X	X	33	59	58	50
Bypass Influent Flows to Strategic Treatment Plants	X				X	X	X					X	X	X	X	X	X	X	X	X	X	Med	High	Med	Med	High	Low	Med	Med	Low	X	X	X		X	X	38	100	58	56
Trucked-in Waste Controls	X	X			X	X	X	X				X			X	X		X		X	X	High	Med	Med	Low	Med	Low	Med	Med	Low	X				X		58	52	63	60
Equalization (EQ) Basin flow modification	X	X			X	X	X	X				X				X	X	X	X	X	X	Med	High	Med	Med	High	Low	Med	Med	Low	X	X	X		X	X	58	74	58	60
Reduce Frequency/Turn Off Primary Sludge Pumps			X	X	X	X	X	X			X	X				X	X			X	X	Low	Low	Med	Low	Med	Low	Low	Low	Low	X		X		X		37	44	93	69
Primary Effluent Storage	X	X			X	X	X					X				X	X	X	X	X	X	Med	Med	High	Low	Low	Low	Med	Low	Low	X	X	X		X	X	48	74	73	65
Reduced Secondary Aeration Rate, DO and Mixed Liquor Recycle (MLR) Pumping		X			X	X	X					X						X				Low	Low	Med	Med	Low	Low	Low	Low	Low	X		X		X		29	19	90	62
Secondary Treatment Over-Oxygenation		X			X	X	X					X				X	X	X				Med	Med	Med	Low	Low	Low	Low	Low	Low	X				X		29	44	83	61
Low Energy Pulsed Large Bubble Mixing and Micronized Oxygen Infusion		X			X	X	X					X				X	X	X				Med	Med	Med	Low	Low	Low	Low	Low	Low	X				X		29	44	83	61
Temporary Reduction of Dissolve Oxygen (DO) Level	X	X			X	X	X	X				X						X	X			Med	High	High	Med	Low	Low	Low	Low	Low	X		X		X		58	30	68	60
Combination: Turn Off MLR Pumps + High-Pressure WAS Pumps + Reduce RAS Pumps		X	X		X	X	X					X					X	X		X	X	Med	High	High	Low	Med	Low	Low	Low	Low	X		X		X		33	52	70	56
Turn Off Foam Air Spray to Reduce Utility Water Pressure and Feed Pumps			X	X	X	X	X	X	X			X			X	X	X	X				Med	Med	High	Med	Med	Low	Med	Low	Low	X					X	50	48	65	58
Combination: Turn Off Channel Agitation Blowers and Reduce Odor Scrubber Output to Minimum Permit Levels			X		X	X	X					X			X	X		X		X	X	Low	Med	Med	Low	Low	Low	Low	Low	Low	X		X		X		23	52	90	63
Bypass Fixed Growth Reactors (Trickling Filters)			X		X	X						X					X	X				Low	Med	High	Med	Med	Low	Low	Low	Low	X		X		X	X	15	33	78	52
Reduce Speed/Turn-Off Fixed Growth Reactor Blowers Within Air Quality Permit Limits			X	X	X	X	X	X				X						X				Med	Med	Low	Low	Low	Low	Low	Low	Low	X		X		X		35	19	88	63
Reschedule Biosolids Thickening and Dewatering (centrifuges, screw presses, etc.)		X			X	X	X	X				X				X		X		X		Low	Low	Med	Med	Med	Low	Low	Low	Low	X				X	X	38	41	88	66
Delay Dewatering Pressate or Centrate Recycling	X	X			X	X	X					X			X	X	X	X				Low	Low	Med	Low	Med	Low	Low	Med	Low	X				X		48	48	88	70
Disable aerobic digester aeration mixers	X	X			X	X	X					X				X	X	X			X	High	High	Med	Low	Low	Low	High	Low	Low	X				X		48	52	60	55
Lengthen Time Between Backwash Filter Air Scouring			X		X	X	X	X	X		X	X							X			Med	Med	Med	Low	Low	Low	Low	Low	Low	X				X		50	11	83	64
Disable Backwash Filter Air Scouring			X	X	X	X	X	X	X	X	X	X							X			Med	Med	High	Med	Low	Low	Low	Low	Low	X				X		71	11	73	65
Reduce/Turn Off Tertiary Filters			X		X	X	X				X	X					X		X			Med	Med	Low	Low	Low	Low	High	High	Low	X		X		X		25	26	68	49
Reschedule Filter Backwash Cycle		X			X	X	X	X			X	X							X			Low	Low	Low	Low	Low	Low	Low	Low	Low	X				X	X	40	11	100	70
Delay Recycle Water Production	X	X			X	X	X	X				X	X				X		X			Low	Med	Med	Low	Med	Med	High	High	Low	X				X		58	37	65	60
Automatic Transfer to Running Onsite Power Generators During Peak Demand Periods	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X	X	Low	Med	Low	Med	Med	Low	Low	Low	Med	X	X	X		X	X	56	100	85	77

FIGURE 8. DR MATRIX - 25 DR MEASURES EVALUATED AND SCORED, WITH A TOTAL IMPACT POTENTIAL SCORE BETWEEN 1-100

Figure 9 shows the Potential Risk Factors and Overall Ratings. Users can adjust the weighting factors used for each individual Risk Factor to customize the analysis for local conditions. As described above, the risk of failure (unmitigated) is scored in conjunction with the consequence of failure. A higher risk number is scored as a low risk strategy for the purposes of the scoring methodology.

	Potential Risk Factors									Overall Rating			
Demand Response Opportunity	Health & Safety	Environmental Compliance	Process Upset	Equipment Failure	Labor Costs	Cost/Rates to Customers	Public Relations	Revenue Streams	Spare Parts Inventory	DR Potential	Impact on System Process	Risk Assessment*	Total Impact Potential
Increase Resevoir Operating Capacity	Low	Med	Low	Low	Low	Low	Low	Low	Low	77	22	95	**81**
Increase Wet-Well Level Operations	High	High	Med	Med	Med	Low	Med	Low	Low	33	59	58	**50**
Bypass Influent Flows to Strategic Treatment Plants	Med	High	Med	Med	High	Low	Med	Med	Low	38	100	58	**56**
Trucked-in Waste Controls	High	Med	Med	Low	Med	Low	Med	Med	Low	58	52	63	**60**
Equalization (EQ) Basin flow modification	Med	High	Med	Med	High	Low	Med	Med	Low	58	74	58	**60**
Reduce Frequency/Turn Off Primary Sludge Pumps	Low	Low	Med	Low	Med	Low	Low	Low	Low	37	44	93	**69**
Primary Effluent Storage	Med	Med	High	Low	Low	Low	Med	Low	Low	48	74	73	**65**
Reduced Secondary Aeration Rate, DO and Mixed Liquor Recycle (MLR) Pumping	Low	Low	Med	Med	Low	Low	Low	Low	Low	29	19	90	**62**
Secondary Treatment Over-Oxygenation	Med	Med	Med	Low	Low	Low	Low	Low	Low	29	44	83	**61**
Low Energy Pulsed Large Bubble Mixing and Micronized Oxygen Infusion	Med	Med	Med	Low	Low	Low	Low	Low	Low	29	44	83	**61**
Temporary Reduction of Dissolve Oxygen (DO) Level	Med	High	High	Med	Low	Low	Low	Low	Low	58	30	68	**60**
Turn Off MLR Pumps + High-Pressure WAS Pumps + Reduce RAS Pumps	Med	High	High	Low	Med	Low	Low	Low	Low	33	52	70	**56**
Turn Off Foam Air Spray to Reduce Utility Water Pressure and Feed Pumps	Med	Med	High	Med	Med	Low	Med	Low	Low	50	48	65	**58**
Turn Off Channel Agitation Blowers and Reduce Odor Scrubber Output to Minimum Permit Levels	Low	Med	Med	Low	Low	Low	Low	Low	Low	23	52	90	**63**
Bypass Fixed Growth Reactors (Trickling Filters)	Low	Med	High	Med	Med	Low	Low	Low	Low	15	33	78	**52**
Reduce Speed/Turn-Off Fixed Growth Reactor Blowers Within Air Quality Permit Limits	Med	Med	Low	Low	Low	Low	Low	Low	Low	35	19	88	**63**
Reschedule Biosolids Thickening and Dewatering (centrifuges, screw presses, etc.)	Low	Low	Med	Med	Med	Low	Low	Low	Low	38	41	88	**66**
Delay Dewatering Pressate or Centrate Recycling	Low	Low	Med	Low	Med	Low	Low	Med	Low	48	48	88	**70**
Disable aerobic digester aeration mixers	High	High	Med	Low	Low	Low	High	Low	Low	48	52	60	**55**
Lengthen Time Between Backwash Filter Air Scouring	Med	Med	Med	Low	Low	Low	Low	Low	Low	50	11	83	**64**
Disable Backwash Filter Air Scouring	Med	Med	High	Med	Low	Low	Low	Low	Low	71	11	73	**65**
Reduce/Turn Off Tertiary Filters	Med	Med	Low	Low	Low	Low	High	High	Low	25	26	68	**49**
Reschedule Filter Backwash Cycle	Low	Low	Low	Low	Low	Low	Low	Low	Low	40	11	100	**70**
Delay Recycle Water Production	Low	Med	Med	Low	Med	Med	High	High	Low	58	37	65	**60**
Automatic Transfer to Running Onsite Power Generators During Peak Demand Periods	Low	Med	Low	Med	Med	Low	Low	Low	Med	56	100	85	**77**

FIGURE 9. OVERVIEW OF RISK RANKING IN DR MATRIX

Figure 10 shows the DR Potential scoring and Overall Ratings.

	DR Type				DR Duration Potential						Overall Rating			
Demand Response Opportunity	Shape	Shift	Shed	Shimmy	<1 hr	1-2 hr	2-6 hr	24 hr	Multi-Day	Seasonal	DR Potential	Impact on System Process	Risk Assessment*	Total Impact Potential
Increase Resevoir Operating Capacity	X	X		X				X	X	X	77	22	95	81
Increase Wet-Well Level Operations				X	X	X	X	X			33	59	58	50
Bypass Influent Flows to Strategic Treatment Plants	X				X	X	X				38	100	58	56
Trucked-in Waste Controls	X	X			X	X	X	X			58	52	63	60
Equalization (EQ) Basin flow modification	X	X			X	X	X	X			58	74	58	60
Reduce Frequency/Turn Off Primary Sludge Pumps			X	X	X	X	X	X			37	44	93	69
Primary Effluent Storage	X	X			X	X	X				48	74	73	65
Reduced Secondary Aeration Rate, DO and Mixed Liquor Recycle (MLR) Pumping		X			X	X	X				29	19	90	62
Secondary Treatment Over-Oxygenation		X			X	X	X				29	44	83	61
Low Energy Pulsed Large Bubble Mixing and Micronized Oxygen Infusion		X			X	X	X				29	44	83	61
Temporary Reduction of Dissolve Oxygen (DO) Level	X	X			X	X	X	X			58	30	68	60
Turn Off MLR Pumps + High-Pressure WAS Pumps + Reduce RAS Pumps		X	X		X	X	X				33	52	70	56
Turn Off Foam Air Spray to Reduce Utility Water Pressure and Feed Pumps			X	X	X	X	X	X	X		50	48	65	58
Turn Off Channel Agitation Blowers and Reduce Odor Scrubber Output to Minimum Permit Levels			X		X	X	X				23	52	90	63
Bypass Fixed Growth Reactors (Trickling Filters)			X		X	X					15	33	78	52
Reduce Speed/Turn-Off Fixed Growth Reactor Blowers Within Air Quality Permit Limits			X	X	X	X	X	X			35	19	88	63
Reschedule Biosolids Thickening and Dewatering (centrifuges, screw presses, etc.)		X			X	X	X	X			38	41	88	66
Delay Dewatering Pressate or Centrate Recycling	X	X			X	X	X				48	48	88	70
Disable aerobic digester aeration mixers	X	X			X	X	X				48	52	60	55
Lengthen Time Between Backwash Filter Air Scouring			X		X	X	X	X	X		50	11	83	64
Disable Backwash Filter Air Scouring			X	X	X	X	X	X	X	X	71	11	73	65
Reduce/Turn Off Tertiary Filters			X		X	X	X				25	26	68	49
Reschedule Filter Backwash Cycle		X			X	X	X	X			40	11	100	70
Delay Recycle Water Production	X	X			X	X	X	X			58	37	65	60
Automatic Transfer to Running Onsite Power Generators During Peak Demand Periods	X	X	X	X	X	X	X				56	100	85	77

FIGURE 10. SUMMARY OF DR POTENTIAL SCORING CATEGORIES IN DR MATRIX

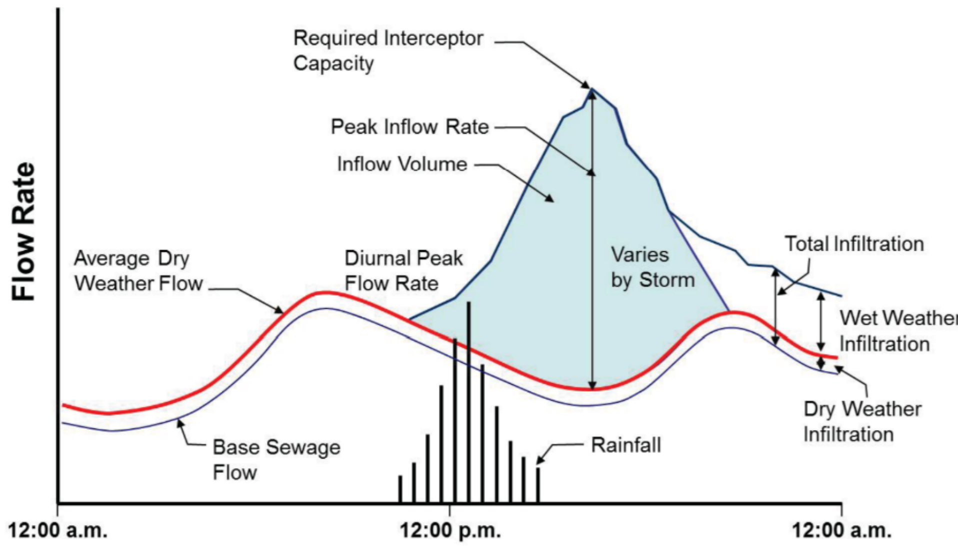
Figure 11 shows the Affected System Process and Overall Ratings. Users can modify the classification of measures to customize the analysis for local conditions.

	Affected System Process									Overall Rating			
Demand Response Opportunity	Distribution System	Collection System	Headworks	Primary Treatment	Internal Pumping Systems	Secondary Treatment	Tertiary Treatment	Solids Handling	Digestion & Cogeneration	DR Potential	Impact on System Process	Risk Assessment*	Total Impact Potential
Increase Resevoir Operating Capacity	X			X						77	22	95	81
Increase Wet-Well Level Operations		X	X		X	X	X			33	59	58	50
Bypass Influent Flows to Strategic Treatment Plants	X	X	X	X	X	X	X	X	X	38	100	58	56
Trucked-in Waste Controls			X	X		X		X	X	58	52	63	60
Equalization (EQ) Basin flow modification				X	X	X	X	X	X	58	74	58	60
Reduce Frequency/Turn Off Primary Sludge Pumps				X	X			X	X	37	44	93	69
Primary Effluent Storage				X	X	X	X	X	X	48	74	73	65
Reduced Secondary Aeration Rate, DO and Mixed Liquor Recycle (MLR) Pumping						X				29	19	90	62
Secondary Treatment Over-Oxygenation				X	X	X				29	44	83	61
Low Energy Pulsed Large Bubble Mixing and Micronized Oxygen Infusion				X	X	X				29	44	83	61
Temporary Reduction of Dissolve Oxygen (DO) Level						X	X			58	30	68	60
Turn Off MLR Pumps + High-Pressure WAS Pumps + Reduce RAS Pumps					X	X		X	X	33	52	70	56
Turn Off Foam Air Spray to Reduce Utility Water Pressure and Feed Pumps			X	X	X	X				50	48	65	58
Turn Off Channel Agitation Blowers and Reduce Odor Scrubber Output to Minimum Permit Levels			X	X		X		X	X	23	52	90	63
Bypass Fixed Growth Reactors (Trickling Filters)					X	X				15	33	78	52
Reduce Speed/Turn-Off Fixed Growth Reactor Blowers Within Air Quality Permit Limits						X				35	19	88	63
Reschedule Biosolids Thickening and Dewatering (centrifuges, screw presses, etc.)				X		X		X		38	41	88	66
Delay Dewatering Pressate or Centrate Recycling			X	X	X	X				48	48	88	70
Disable aerobic digester aeration mixers				X	X	X			X	48	52	60	55
Lengthen Time Between Backwash Filter Air Scouring							X			50	11	83	64
Disable Backwash Filter Air Scouring							X			71	11	73	65
Reduce/Turn Off Tertiary Filters					X		X			25	26	68	49
Reschedule Filter Backwash Cycle							X			40	11	100	70
Delay Recycle Water Production	X				X		X			58	37	65	60
Automatic Transfer to Running Onsite Power Generators During Peak Demand Periods	X	X	X	X	X	X	X	X	X	56	100	85	77

FIGURE 11. SUMMARY OF AFFECTED SYSTEM PROCESS RANKING IN DR MATRIX

GENERAL CONSIDERATION OF DR EVENTS IN WATER AND WASTEWATER SYSTEMS

Wastewater collection, conveyance and treatment is provided on a continuous basis. Water production, conveyance, treatment and distribution is also a continuous process, but responds to both supply and demand constraints and trends. For wastewater, the flow rate and loadings through collection and treatment systems vary significantly during the day. Most facilities experience peak flows (their highest flow rates) during early morning and early evening periods. This varies facility to facility depending upon demographics, system size and geography. That said, the flow and loadings to a treatment facility generally parallel the demand for energy by a community. People use more energy and produce more water and wastewater while at home in the morning and after work. Wastewater facilities sited in areas with large industrial sewage loads or high concentrations of commercial/retail/food service/hospitality businesses will experience different flow patterns than those that treat primarily residential loads.



Sewage Collection and Conveyance

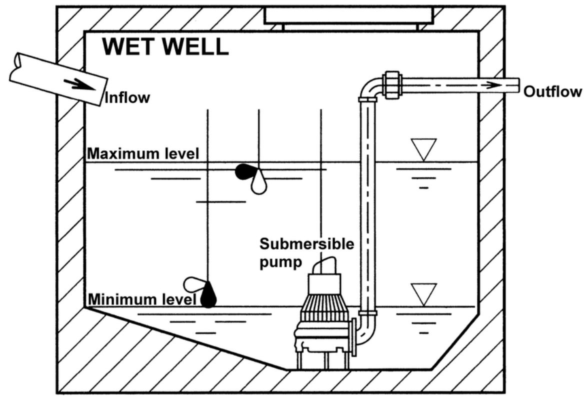
System Function:

Sewer systems were designed as a physical conveyance system to collect sewage from communities and transport it safely and efficiently to the treatment plants. Most sewage collection conveyance systems are designed with a hydraulic capacity that exceeds the needs of the service area. This extra capacity is generally associated with that needed for additional flow for build-out, or to accommodate storm flow events. With the impact of residential water conservation and water-use efficiency, this additional hydraulic capacity is further exaggerated, especially during warm, dry months.

As a result of widespread water conservation in the Southwest, sewer systems do have excess capacity, but they have also evolved from simply a physical conveyance system to a biological reactor—sewage is decaying in the sewer and releasing unreassurable organics upstream, instead of at the treatment plant.

Opportunity

This excess capacity, while challenging, can facilitate storage capacity during abbreviated DR events, allowing for additional shaping of the electric profile. Additionally, in advance of a DR event pump station wet wells could be drawn down to minimum levels to provide additional system resiliency and absorptive capacity. DR strategies in this sector will require special planning, monitoring and support to prevent sewage spills and discharges to the environment which present public health concerns and regulatory violations. Further, as flow to the treatment facility may be reduced or curtailed for a period, all the stored flow will require treatment at a higher rate when service is resumed due to the elongated period of conveyance which could increase septicity.



Headworks

System Function

Most treatment facilities have structures and systems in the headworks to provide for removal of debris that may damage or reduce capacity of downstream treatment systems. This may include influent pumping of raw wastewater, and typically automated as well as manual screening with rag removal and compaction, grit removal, washing and conveyance.

Opportunity

With many of these systems, except perhaps influent pumping, their operation can be curtailed, or frequency of operation delayed to support a DR event. However, coordination with collection system pumping and storage, as described in the previous section, is required to account for the delay of raw influent flow to the headworks system.

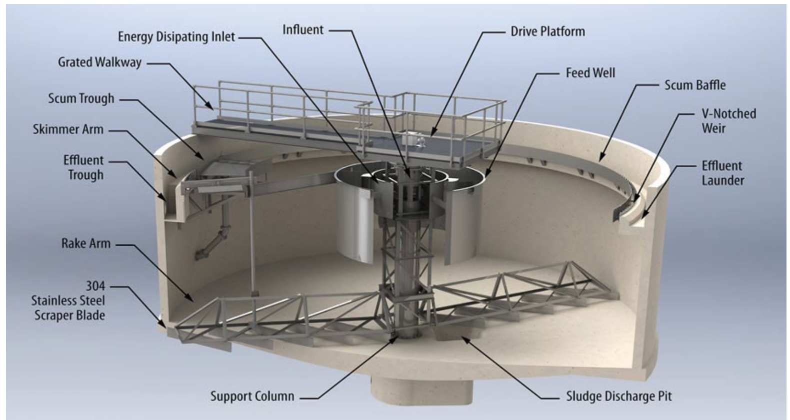
Primary Clarifiers & Sludge Pumping

System Function

The function of primary clarifiers is to allow physical separation of floatable and settleable material from the main flow of sewage. This process is present in most larger treatment plants, usually 2 MGD or larger. In most facilities with primary clarifiers, there are redundant physical infrastructure to accommodate future flow and elevated flow during wet periods and winter months. During dry, warm months, these excess clarifiers may be taken out of service.

OPPORTUNITY

Strategies have been practiced for many years to enhance the removal efficiency of primary clarifiers using chemical coagulation, commonly referred to as Chemically Enhanced Primary Sedimentation (CEPS). The use of chemicals increases the weight and settling velocity of particles to improve the removal of energy-consuming particulates. This practice allows increased hydraulic loading to the clarifiers, sometimes by as much as 50%, allowing additional units to be removed from service. As such, these tanks may be available for short-term storage of flow during a DR event. Duration of storage is dependent upon the size and number of available tanks, as well as the relative sewage flow rate at the time of the DR event. This storage may augment storage in other locations, both upstream and downstream of the primary clarifiers. Further, storage of primary flow can be coupled with reduced pumping and aeration in the subsequent secondary and tertiary treatment processes.



Additionally, pumping of primary sludge is not a time critical process in most facilities. In a DR event, primary sludge pumps could be turned off for extended periods of time without significant impacts on the treatment process. This would also allow any related sludge thickening and feed systems between the primary clarifiers and digestion units to be curtailed.

COAGULATION AND SEDIMENTATION

SYSTEM FUNCTION

The function of coagulation/sedimentation processes in both water processing and water reclamation systems is to remove particulates and colloidal material prior to filtration. This meets Public Health requirements and improves both the downstream filtration process and assurance of proper disinfection of the product water.

OPPORTUNITY

Two general considerations for energy management would be to over-produce water ahead of a DR event, and then reduce the use of coagulation and sedimentation process energy during the DR event. This requires multiple decisions and management strategies that affect both the facility and end users. First, to over-produce water, the discharge storage needs to be coordinated with user and reservoir storage capacity. Over-production is limited where output storage capacity is limited, as there is not enough space to store water ahead of a DR event. Where it can be used, reservoirs need to be managed to maximize the use of over-produced water. This must be coordinated with and by the water distribution group or entity. During a DR event, the coagulation/sedimentation system can be idled or reduced. The distribution group would need to coordinate the use rate to prevent a water outage as reservoirs are drawn down. This requires close monitoring of remote systems and would likely require advanced notification and management of end-user consumption, such as in an emergency reduction in water usage.

Cessation of the coagulation/sedimentation function can be a simple SCADA control action that turns off large energy-consuming mixers and flocculation systems, as well as sludge pumping and recirculation. This is relatively simple, but again requires coordination with end users as the water supply production is curtailed during the DR period, and then reservoirs are subsequently refilled.

Where coagulation/sedimentation must continue for whatever reason, alternative means of flocculation can be considered, such as use of large-bubble mixing and removal of electro-mechanical mixers. A DR event can be accommodated by oversized storage of a sufficient amount of compressed air to span the duration of the DR event without activating the compressor for the air handling unit.

Equalization and Storage

System Function

Flow equalization is the process in water/wastewater treatment is used to mitigate changes in flow rate through a portion of a system by providing storage during periods of excess quantity, and to supply during periods of low flow or demand. In many treatment systems, it is useful to implement flow equalization upstream of the plant, as the treatment processes downstream work more efficiently with steady throughput. In treating wastewater, the diurnal flow patterns may vary dramatically throughout the day, so it is convenient to equalize the flow before feeding it to the subsequent treatment processes.

Opportunity

Equalization strategies usually include "freeboard" guidelines to provide a safety margin to prevent overflow, which can be up to 25% of the design capacity, or more at some facilities. With advanced coordination and planning, EQ basins can be emptied ahead of a DR event to provide extended storage capacity. Again, as with other storage opportunities, the DR strategy must include consideration of flow and loading constraints on downstream systems once the DR event is concluded. This may limit resiliency for multi-day (i.e. PSPS) or repetitious DR events.

Use of EQ basins during DR events will also allow reduction and possible shut-down of downstream aeration and pumping systems, which are typically the largest energy-demanding units in a treatment plant. This energy demand must be managed after the DR event to avoid excessive demand surges and cost. This may be further constrained or sensitive, depending upon the specific tariff rate for the facility.

Sludge Digestion (Anaerobic and Aerobic)

System Function

Most wastewater treatment facilities include some form of bio-solids digestion. The function of these processes is to stabilize the biomass into a non-putrescible state and reduce the solids mass prior to disposal. There are two basic forms of digestion: aerobic and anaerobic.

Aerobic digestion is common to treatment systems smaller than 4 MGD, and usually designed without primary sedimentation. Air is used to oxidize the accumulated bio-solids, which is a highly energy-intensive process. Anaerobic digestion is a series of biological processes in which microorganisms break down biodegradable material in the absence of oxygen. This process does not utilize air but requires energy-intensive pumping and mixing systems. The function of the anaerobic digester is intrinsically tied to inlet pumping and mixing efficiency.

OPPORTUNITY

In most aerobic digestion facilities, the blowers or aeration mixers can be shut off for extended periods of time, usually up to 4 hours or more, without incurring significant consequences, such as odors or process upsets. This provides an excellent opportunity for DR participation. Anaerobic digestion process interruption of inlet pumping and internal mixing can upset the digester functionality; however this does not completely restrict or prevent such curtailment in a DR event, especially for short duration events.

Additionally, digesters, whether aerobic or anaerobic, provide an opportunity for storage of solids and curtailment of sludge dewatering systems. Sludge dewatering equipment is ubiquitous in wastewater treatment facilities due to the high-water content of sewage sludge. An activated sludge wastewater treatment facility typically uses 7% of its total energy for solids dewatering. This is especially important in facilities that utilize high-energy dewatering systems, such as centrifuges. So, while anaerobic digesters may not reduce internal energy during DR events, they can provide interim storage to support shut down of a dewatering system.

Activated Sludge and Biological Nutrient Removal

System Function

Activated Sludge (AS) is a biological treatment process for municipal and industrial wastewater developed around 1912-1914. This can involve a wide variety of design, however, in principle, all AS consist of 3 major components: an aeration tank serving as the bioreactor, a settling tank or a clarifier for separation of the activated sludge solids and the treated wastewater and return activated sludge (RAS) equipment to transfer settled AS from the clarifier to the influent of the aeration tank. Atmospheric air or in rare cases pure oxygen is introduced to a mixture of primary treated or screened sewage combined with microorganisms to develop a biological floc, known as mixed liquor.

This is a suspended growth (meaning mixed in a fluid) biological treatment system used to stabilize and remove organic and nitrogenous compounds from wastewater. There are many forms and variations of the activated sludge process. However, in general, it is usually the most energy intensive system in a treatment facility. For over a hundred years, the basic concept for this process has used low-pressure compressed air in one form or another to provide oxygen to bacteria to perform oxidation and uptake of organic carbon and in some cases to oxidize ammonia and phosphorus for biological uptake and conversion to non-pollutant states. In more recent decades this function has been performed primarily by using aeration systems to push air deep into tanks where it is released as fine bubbles through a diffuser matrix. The rising bubbles provide both mixing of biology with the organics and air for oxidation. While historically this is the most common form of aerobic treatment, it is generally energy inefficient. Most of the energy is consumed to pressurize the air to deliver it to the bottom of a tank, and concurrently moving 80% of the air volume that provides no treatment (nitrogen and carbon dioxide).

Opportunity

A DR event would expect the blower energy demand to decrease significantly for several hours. While this could occur any time of the day, it would most likely occur in the late afternoon or early evening when the hydraulic and organic loading is relatively high. If the air supply was to simply shut down, both oxidation and mixing would cease. The biology would settle to the bottom of the aeration tanks and the untreated sewage would short-circuit the process. By storing the untreated liquid ahead of the aeration basins, the key opportunity is to provide treatment at a later time, provide mixing and oxidation by some other means, or to turn down aeration to a minimum level to reduce demand.

Storing untreated or partially treated wastewater in the collection system, equalization basins or vacant primary clarifiers and aeration basins could provide time to shut down or reduce the load to the activated sludge process for up to several hours. Restarting would be relatively simple but could result in mild to moderate upset conditions that may take several hours and operationally intensive measures. Instead of being shut down, blower aeration can be reduced to 50-80%. Aeration of multiple tanks could be alternated to maintain some modicum of treatment.

New technologies are also emerging that provide pure oxygen and decoupled mixing systems. Low-energy mixing systems can be activated and coupled with micronized oxygen at 60-80% less energy demand than conventional aeration systems. Pure oxygen can be used to supersaturate either primary or secondary effluent, which can be recirculated via pumps to the aeration basins. These systems could be sized to provide short-term treatment for DR events, until the capital investment in replacing the existing blower/diffuser system is economically feasible for full a scale project.

Blowers and Pumps

System Function

Activated sludge processes include an array of pumping systems as well as aeration blowers, typically configured for redundancy. Two examples of pumping systems with high energy intensity serve the Return Activated Sludge (RAS) and Waste Activated Sludge (WAS) processes. As previously mentioned, RAS pumps recirculate settled biological sludge from secondary clarifiers back to the front end of aeration basins to resupply the treatment system with biology for treatment. WAS pumps are used to remove excess biological sludge created during the treatment process. Blowers are used throughout the treatment process to provide aeration for the activated sludge process, as well as facilitating solids suspension in channels and aerated grit chambers. These blower systems are often designed with redundancy and typically have varying unit sizes.

Opportunity

RAS pumping rates can often be slowed during DR events if treatment must continue, with minimal process impacts. It can be ceased if the main flow is stopped and stored during the DR event, in the event secondary treatment is shifted to a different time. WAS pumping can be ceased during DR events representing an opportunity to shed load, as its continuous flow is not critical to most systems. Additionally, during a DR event, it is often possible to reconfigure the blower output to reduce or increase the air flow rate and equivalent energy demand for short periods of time. This requires careful coordination with the cascading treatment processes to preserve the integrity of the effluent flow.

Trickling Filter

System Function

Trickling filtration is a type of aerobic treatment of wastewater wherein the wastewater is generally pumped from a recirculation tank or compartment, dispersed over a media bed and is allowed to drain back into the recirculation tank. The media bed may consist of a variety of media such as tire chips, stone and rigid plastics configured into a number of shapes (i.e., honeycomb blocks, rings or cylinders). The trickling filter is the combination of three processes- filtration, adsorption and assimilation, for removal of the contaminants from wastewater. The wastewater flows in a thin film over the media to allow time for treatment. The media of a trickling filter serves as a substrate on which a biological film grows continuously, eventually exceeding its ability to stick on the media due to its own weight and breaks off, washing through the media, either returning to the recirculation tank or settling in the clarifier. Effluent passing through the trickling filter can return to the recirculation tank or a portion of the flow can be directed to the final treatment and dispersal component.

Trickling filters require energy for influent pumping and circulation. The filter is a porous seal that covers a rock or plastic packing. The wastewater trickles downward through the packing to the underdrain where the effluent liquid is collected and passed to a sedimentation tank where the effluent is separated. Recirculation pumping is typically 70-150% of the total influent flow for the treatment plant. That means that a plant that receives an Average Daily Flow (ADF) of 10 MGD can send as much as 15 MGD through the trickling filter. In some cases, the vertical trickling filter structure is augmented by ventilation blowers to assure availability of oxygen and air movement.

OPPORTUNITY
In most cases, recirculation pumping and ventilation blower operation can cease for several hours without significant impacts on process performance. Minimal pumping is recommended to prevent the attached biomass from drying out, but often the relative humidity in the trickling filters is sufficient to afford shut down for a few hours.

SECONDARY CLARIFICATION

SYSTEM FUNCTION
The function of secondary clarifiers is to provide quiescent conditions for the effluent flow to allow separation and setting of biological sludge from treated water. The settled sludge blanket is collected at the bottom of the tank and is pumped back to the treatment unit at a fraction of the total flow. Secondary clarifiers usually contain mechanical systems to collect and move the sludge to submerged hoppers.

OPPORTUNITY
In a DR event, the collector systems and recirculation pumping (RAS) can be shut down for a few hours without significant consequence to treatment processes or effluent quality.

MEMBRANE FILTRATION

SYSTEM FUNCTION
A membrane is a thin layer of semi-permeable material that separates substances when a driving force is applied across the membrane. Membrane processes are widely being used for removal of bacteria, microorganisms, particulates, and natural organic material, which can impart color, tastes and odors to water and react with disinfectants to form disinfection byproducts. The membrane processes discussed here are microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO).

A backwash process is designed to remove contaminants accumulated on the membrane. Each membrane unit is backwashed separately and in a staggered pattern to minimize the number of units in simultaneous operation at any given time. During a backwash cycle, the direction of flow is reversed from the direction of wastewater flow. The force and direction of the flow dislodge the contaminants at the membrane surface and wash accumulated solids out through the discharge line. The backwash process reduces system productivity 5 to 10% due to the volume of filtrate used during backwash. This process is mainly for Micro and Ultra filtration.

In recent decades, membrane filtration has come into vogue as replacement of secondary clarifiers and tertiary filtration to provide high-quality effluent with minimal footprint on site. However, it comes at an elevated cost of energy. Membrane Bioreactors (MBR) operate with a much higher concentration of activated sludge than conventional units, which allows for smaller tanks. However, the nature of the thicker activated sludge causes adhesion to the plastic membranes. This can foul the membrane and seriously inhibit flow. For that reason, agitation air is added to cause release of the biosolids from the membranes.

OPPORTUNITY

Much like conventional activated sludge, aeration can be reduced and possibly turned off during a DR event. However, unlike conventional activated sludge processes, MBR technology is very sensitive to changes in flow rate, especially rapid increases in flow rate. For this reason, a DR strategy would require very careful consideration and process planning before attempting shutdowns of even short duration.

DEWATERING

SYSTEM FUNCTION

Dewatering is a physical unit operation used to separate the solid matter and water in the sludge or biosolids resulting in a high solids content stream called “cake” and a liquid stream. The liquid stream contains fine, low-density solids and a high concentration of nutrients when anaerobically digested sludge is dewatered and is either returned to the wastewater treatment system or treated separately to reduce nutrient loading to the main treatment system.

Technologies typically employed include solid bowl centrifuges, belt filter presses, recessed plate filter presses, rotary presses, screw presses, electro-dewatering, sludge drying beds and sludge lagoons. Each of these systems have varying characteristics with regards to energy density, with centrifuges often being the most energy intensive and widely used throughout the industry.

Opportunity

Generally, dewatering of digested sludge is an interruptible function. Seldom is it a continuous process, allowing for flexibility in timing of the dewatering function to support a DR event. This would be most valuable in high-energy dewatering systems, such as high-horsepower centrifuges, and less beneficial with low-energy intensive equipment, such as rotary screens and belt presses. Additionally, most enclosed dewatering systems include powered ventilation, which with proper safety and gas monitoring, could be shut down for a short period. The dewatering schedule can be modified rather easily in most cases, with many facilities currently implementing the scheduling of this process during off-peak or nighttime hours.

Effluent Disinfection

System Function

Disinfection is the final process in water and wastewater treatment wherein a significant percentage of pathogenic organisms are killed or controlled. Disinfection efficacy is most often measured using 'indicator organisms' that coexist in high quantities where pathogens are present, such as Total Coliform (TC) and Fecal Coliform (FC).

There are two fundamental methods of disinfection practiced in the wastewater industry: (1) chemical disinfection with some form of chlorine, and (2) Ultra-Violet (UV) disinfection. Disinfection, when required, must be provided and effective during discharge or reuse of treated effluent and can only be interrupted when flow is stopped or diverted. UV light provides rapid, effective inactivation of microorganisms through a physical process. When bacteria, viruses and protozoa are exposed to the germicidal wavelengths of UV light, they are rendered incapable of reproducing and infecting. Chlorine (in the form of Chlorine gas or hypochlorite solution) is the most widely used disinfectant in wastewater, targeting organisms by oxidizing the cellular material. Chlorine disinfection uses very little energy, which is primarily associated with chemical pumping and minor mixing. The DR benefit is very low.

Opportunity

UV disinfection is very energy intensive; however, any reduction in energy throughput would violate the purpose and performance expectation of the system. The only potential for curtailment or shutdown during a DR event would be flow reduction, cessation or diversion. This would require emergency storage or diversion, which is feasible in certain systems where the flow of the effluent product can be interrupted.

Tertiary Treatment System

System Function

Tertiary or advanced filtration takes place after secondary wastewater treatment to provide a final treatment stage before it is reused, recycled or discharged to the environment. Options include coagulation assisted filtration and absolute barrier filtration and nutrient removal, which include biological denitrification and chemical phosphorus removal. This process provides for additional removal of suspended solids from the secondary effluent and a further reduction of the biochemical oxygen demand (BOD). As wastewater is purified to higher degrees by such treatment processes, the treated effluent can then be reused for irrigation, recreational use or water recharge. These array of filtration systems can be energy intensive. Most of the energy used in tertiary treatment is associated with pumping and, in some cases, backwash aeration. Secondary effluent can flow by gravity to tertiary filters, but it is often stored in EQ basins and is then pumped, in whole or in part, to the filters. Pump sizing and rate is proportional to the flow to and through the tertiary filters, in addition to backwash recirculation.

Opportunity

There is some DR opportunity for the inlet pumping, but the principal opportunity is in the scheduling of the backwashing cycle. In a DR event, it may be possible to reduce or stop the physical filtration process by turning off the inlet pumps and storing the water in the EQ or filter feed basin. Separately, backwash cycles can usually be easily rescheduled around the DR event, especially with advanced notification.

Cessation of filtration would have an impact on downstream users of the water. Water delivery would be interrupted and interfere with reuse activities, agreements and expectations. Storage and deliveries would need to be considered in the planning of DR events.

Non-Process Plant-Wide Opportunities

System Function

Wastewater treatment plants include many ancillary subsystems, many of which could play a measurable role in DR response.

- *Odor Control* – Wastewater and treatment processes can be very odorous. Odor control systems are designed to meet specific regulatory, health and safety requirements.
- *Utility Water* – Most treatment plants recirculate treated water as a high-pressure internal utility service for washdown, sprays and seal water.
- *Compressed Air* – This is used in many larger plants to support treatment processes and pneumatic pumps. Compressed air is also used in maintenance shops to serve tools and maintenance equipment.
- *Lighting and HVAC* – Treatment facilities include various buildings and storage areas, equipped with lighting and HVAC systems. Additionally, facilities have general lighting servicing staff and safety purposes for the various processes during the nighttime periods.

Opportunity

- *Odor Control* – The operation can be modified or interrupted to support a DR event. Often solids handling systems, such as dewatering and hauling facilities, can be shut down during a DR event. As such, it may be possible and permissible to shut down the respective odor control system, which often includes high-horsepower blowers and fans. Similarly, odor control fans and scrubbers over treatment processes may be temporarily shut down or modified to operate at reduced speed for short periods of time, pending air permit allowance.
- *Utility Water* – The pressurization systems, such as pump seal water, may provide DR support if it is not critical to equipment integrity. For this non-critical pressurization system equipment, there may be opportunities to replace water seals with mechanical seals and eliminate the need for seal water. The pressure of most systems can be reduced for extended periods of time and the cycling of the pressurization system can be reduced, if not its demand.
- *Compressed Air* – Many of these services can be curtailed for periods of time to support of DR events.
- *Lighting, Ventilation and HVAC* – A scheduled DR event may benefit from shutting down local building lighting, ventilation and HVAC systems for a few hours. Where critical, smaller systems and usage could continue while de-energizing large area systems and usage, especially during non-work or non-occupied periods.

Water Distribution

System Function

Water sources are obtained from local resources, such as streams, rivers, and local groundwater sources. Other systems rely primarily on imported supplies, such as Metropolitan Water District of Southern California, the State Water Project, or the All American Canal. Although limited, other water may be provided by desalination systems, such as those in San Diego and Santa Barbara. Distribution of each of these sources have unique and variable hydraulic characteristics. Recycled water for industrial, commercial, landscape and agricultural use is an alternate source. This is typically linked to wastewater treatment facilities, but the application of the water is managed by separate entities.

OPPORTUNITY

Water systems serve the public need for potable water and must meet minimum service demands, as well as public health standards. As such, participation in DR programs and preparation for PSPS events require careful planning and may likely be much more restricted or constrained than with wastewater facilities. Related DR opportunities with regards to recycled water would not necessarily be managed or overseen by the producing entity (the WWTP), but rather by a reuse management group through agreement with the source provider. For both scenarios, DR opportunity exists in the implementation of interruption and excess storage capacity within the conveyance systems or downstream of the primary supply.

Recycled water service often involves multiple layers of responsibility and control that can affect DR options. In the case of multi-agency services and multiple function users, DR programs require more complex coordination and need a higher level of management. Where recycled water is provided wholesale to a water retailer, the DR events must be coordinated by or through the retailer, rather than the wholesaler. Separately, depending upon the criticality of the end user need for the water, the retailer may not have contractual authority to interrupt service to the user, such as a high-value industry, refinery, or power plants, or otherwise ramp up those customer transfers in over-generation scenarios.

In these complex situations, DR may be feasible, but would require a unique set of plans and triggers, most likely coordinated through approved aggregators to manage this complexity on behalf of both the customer and the electric utility. Through aggregation, DR opportunities can be amplified by coordinating with end users as well as retail recycled water providers.

RAW WATER PUMPING SYSTEMS

SYSTEM FUNCTION

Raw water is delivered into retail water agencies from various sources, typically requiring a combination of gravity flow and pumping systems and requires some level of treatment. In simple systems, this may occur at the well-head of a groundwater pumping system, where source water comes from a stream, river surface impoundment, or reservoir, before being pumped into the treatment facility.

Opportunity

DR opportunities may exist in the raw water pumping systems, especially in those that have significant reserve capacity and storage that allow intermittent pumping. This also relates to downstream storage capacity in excess of normal demand rates for water service. Many systems that have implemented significant measures for conservation and water use efficiency may benefit from excess storage capacity and reduced service demand rates that will increasingly support DR measures, especially during warm Summer months when water use restrictions are typically in effect. Additionally, DR events can be implemented in pumping systems where water demands can be adequately met during the DR window by previous filling and use of safety margin within raw water reservoirs. This would allow pumping to be curtailed while still meeting water supply demands. Furthermore, pumping rates may be reduced with VFDs on existing pumps to vary flow or to transfer flow to smaller pony pumps.

Reservoir Management Strategies

System Function

Reservoirs serve multiple use functions in water systems. Their principal function is to provide capacity to meet water use demands. They also serve to meet demands and reduce stress on processing and delivery systems. Typically, reservoir management strategies are managed via SCADA or on-site, simple high-low control systems. The conventional pumping logic is to activate feed pumps when or as the reservoir hits a low-level, and a sensor signals the feed pumps to activate.

Opportunity

In DR events, these strategies can be modified with coordination with First Responders, especially fire departments, to assure adequate water supply and service pressure is provided to maintain fire flow capabilities.

Reservoir DR opportunities exist in the following areas:

- Pre-fill reservoirs to high level prior to the DR event to provide adequate water supply without activating pumping systems.
- Utilize out-of-service reservoirs that are available due to normal, reduced service demands.
- Reduce pumping and reservoir demands by advising communities to reduce water usage associated with landscape and golf course irrigation ahead of and during DR events.

Pressure Zone Management

System Function

Water supply systems often have multiple pressure zones related to general geography and elevation differentials. Pressure zones are controlled via pumps and reservoirs. Often, reservoir capacities to support pressure zones are more than adequate to sustain interrupted pumping and pressurization.

Opportunity

DR opportunities are the same as noted above for Pumping and Reservoir management but can be further enhanced when adjusted for actual connected load associated with each zone. Lesser population or high vacancy factors can provide greater support of DR impacts, when seasonal variations exist. Additionally, utilizing reservoir capacity to the full extent is often not employed, which can further improve the storage potential for DR events.

INTERVIEW DATA

The following agencies were solicited for input regarding their existing DR strategies in place, potential for DR implementation and recommendations for a water sector electric reliability program.

DELTA DIABLO SANITATION DISTRICT

Delta Diablo Sanitation District (DDSD) provides wastewater conveyance and treatment services for approximately 213,000 customers in the cities of Antioch and Pittsburg, and the unincorporated community of Bay Point. DDSD wastewater treatment plant is a conventional activated sludge plant with anaerobic digestion and tertiary treatment, operating at an average influent flow rate of 13 MGD.

The District does not currently implement any DR strategies at the wastewater treatment plant, as they believe the cogeneration equipment onsite would provide minimal impact. They believe the most potential for DR strategy at their facility is in the dewatering process, specifically scheduling of operations to nighttime periods. Previously, they looked at DR strategies at various pump stations; however, they elected not to proceed with these measures due to the low impact.

The District believes that the potential for flexible DR strategies lies best in its facilities without cogeneration. Much of their power demand is accounted for by their cogeneration system, with minimal purchases from the Utility. One flexible strategy suggested was the shutdown of cogeneration equipment during periods of grid overgeneration, storage of biogas, and purchasing electricity from the Utility grid as needed. However, the storage of biogas is seen as a large capital investment as the internal rate of return exceeds a typical 10-year period of expectancy. It was noted that most wastewater facilities are risk adverse, and typically wait for other agencies to implement strategies that seem aggressive or high-risk. The clean water treatment and distribution sectors was suggested as a better fit at the current state, due to more flexibility and underutilization of rated capacity.

FAIRFIELD-SUISUN SEWER DISTRICT

The Fairfield-Suisun Sewer District (FSSD) serves more than 135,000 residential, commercial and industrial customers in central Solano County, about 40 miles northeast of San Francisco. The FSSD wastewater treatment plant is a conventional activated sludge plant with anaerobic digestion and tertiary treatment, operating at an average influent flow rate of 13.6 MGD.

The District currently implements demand response strategies at a few of the pump stations, on a manual basis; however, they have noted the impact and frequency of these DR events is highly limited. In 2011, a 1 MW solar array was installed at the treatment plant, so it is believed that DR strategy implementation at the facility is counterintuitive to the constraints of the solar agreement. Their current operating theory is to operate as much demand during the solar production time ~10 a.m. – 6 p.m. However, FSSD does have goals of keeping the overall demand down, through equipment startup procedures and generally running only equipment that is needed. The site is currently investigating a new cogeneration system, as well as battery energy storage, to be coupled with their onsite generating equipment.

The consensus on an automatic demand response mechanism was the potential to not meet their three mission critical goals, thus adding more risk on the District's part: 1) meet permit, 2) public safety, and 3) equipment safety (i.e. some equipment can't be turned on and off and some critical equipment requires manual sequencing.) The site values manual control of all portions of the treatment process to ensure these three items can continuously be met. Additionally, FSSD believes they have the backbone infrastructure in place, as far as communications (SCADA), but see a disconnect between their systems and the Utility. If the Utility could provide them with real-time data, they could easily integrate into their systems; however, an operator's decision is likely to be made based on a process driven goal before energy. In general, they understand the course of DR direction, but would like to ensure it is a mutually beneficial practice between the Utility and District. This would be through tariff restructuring, more lucrative onsite generation export options, and understanding of previous agreements that may warrant site-specific changes.

Lake Arrowhead Community Services District

The Lake Arrowhead Community Services District (LACSD) serves approximately 8,500 water connections and 10,500 wastewater connections. The district staff operate two water treatment plants, 19 water pumping stations, two wastewater treatment plants, 21 wastewater pumping stations and 20 reservoir tanks. The community served is at an elevation of 4,500 feet to over 6,000 feet and encompass approximately 15 square miles.

LACSD is a participant in the automatic demand response mechanism in which a signal comes in, and the facility decides to either opt in or opt out manually, their priorities being 1) permit requirements, 2) public safety and 3) equipment reliability. The District has implemented demand response strategies at all the water pump stations and the water treatment plants, on a manual basis for over 10 years now. All the processes in the water treatment plants, including internal pumping and pumping from pump stations, are limited or turned off during these events. The plants perform equally well during the DR events that occur from 4 p.m. to 9 p.m.

On the other hand, the Grass Valley Treatment Plant, the 3.5 MGD wastewater treatment plant, has participated in only five of last year's DR events; opting out over 75% of the time when an event is called. This is mainly because it is serving the adjacent Recycled Water Facility that demands recycled water most of the time. Meeting their demands is challenging if participating in a DR event, since most of the operations are manually turned on and off, leading to a lag time in recycled water production. The plant looks forward to participating in the program more often this year, since the microfilter membrane modules have been replaced and are now more efficient.

The District is participating in a lottery for a 1.5 MW Tesla Battery grant, to shed peak load and serve as a generator for the Grass Valley Treatment Plant. This opens doors for the plant to engage in DR activities more often, without compromising recycled water demand or treatment efficiency.

DISCUSSION AND RECOMMENDATIONS

California's energy landscape is unique, aiming to balance the State's ambitious energy and greenhouse gas emissions goals with an aging infrastructure and non-routine events as a result of climate change and other external stressors. Innovative solutions are needed to address this paradigm shift in the California grid and to address local needs.

Traditional resource adequacy demand response programs offered benefits of reliability, mitigation of additional infrastructure and balancing of the wholesale energy market and has provided significant economic benefits to both LSEs and ratepayers, as well as environmental benefits in avoiding unnecessary greenhouse gas emissions. However, traditional DR programs no longer serve the needs of the state. As a result of California's climate action goals and a transition to 100% renewable energy, as well as a requirement to address climate and fire risks, demand response programs are being overhauled. The ability to enable load flexibility at customers sites while not disrupting core functions and productivity, is at a premium. It is critical to advance knowledge, technology, and programs to help customers "do the dance", whether Shed, Shift, Shape or Shimmy, and provide maximum benefits to the grid.

California's water sector, with more than 2100 agencies, presents high value potential to serve these grid needs. Trends in the water sector, including environmental and climate impacts, water sector consolidation, workforce shifts, increasing energy costs and technology advancements present new opportunities to take a fresh look at how to engage the sector and bring strategies to the table that provide both grid and customer co-benefits. Implementation of flexible demand response initiatives can offer mutually beneficial solutions between LSEs and the individual agencies.

However, many of the reasons for a historical lackluster level participation – risk aversion, focus on mission critical goals of public health and safety and regulatory compliance, lack of technical resources, inherent financial disincentives, cogeneration related challenges – are still present and have not been solved. While the potential benefits and potential for load management have been identified, major structural barriers between agencies and LSEs must be overcome.

RATES AND TARIFF STRUCTURES

Many water and wastewater facilities are on TOU rate tariffs, where rates vary according to the time of day, season, and day type (weekday or weekend/holiday). Higher rates are charged during the peak demand hours (typically 4 p.m. to 9 p.m.) and lower rates during the off-peak demand hours (typically 9 p.m. to 4 p.m.). A flexible demand response model would attempt to alleviate the issue of overgeneration by calling upon water and wastewater entities to increase usage during these periods (typically 12 p.m. to 6 p.m.) to balance the supply and demand of the electrical grid. This creates an economic disadvantage for the agencies, due to the overlap of the request for increased usage and higher energy prices.

A re-evaluation of the existing rate tariff structure is necessary to overcome the economic disadvantage of the proposed case scenario. Three items need to be addressed:

- TOU pricing
- Standby demand charges
- Incentive to assume risk on part of the agencies.

LSEs may consider a dual tariff structure, where participants' TOU pricing is altered to alleviate elevated energy costs during the flexible demand response events.

Secondly, during these events, participants will likely increase their instantaneous energy demand, thus leading to increased standby demand charges. The structure should be evaluated based on an integrated baseline approach, wherein the increase in demand is able to be evaluated. This should also be coupled with an agency side approach of staging equipment operation to alleviate peak demand spikes (i.e., staging start up cycles of various equipment).

Finally, agencies should be provided with a financial incentive to implement these strategies on either a kW or kWh basis, as a compensation for the inherent operational and asset strains.

DR Program Design Structure

DR programs enroll individual service accounts, while often water agencies operate with multiple service accounts that have interactive effects. Often, proposed DR opportunities have cascading effects on systems that may operate under different service accounts. The coordination of the various systems should be considered, with enrollment in DR programs under an entity-wide structure as a possible solution.

Building on this concept, expanding the DR system boundary outside of the locational energy using systems would allow for a more comprehensive integration of an effective flexible demand response program. There are interrelated relationships and load impacts between water distribution companies, retail water providers, and end use customers. Nested strategies for DR coordination and integration between agencies and end-use customers should be explored, for example, in cases where there is an exchange of commodity (e.g. recycled water).

Additionally, with regards to the relationship between the agencies and the LSEs, better communication protocols are needed to facilitate real-time decision-making signals.

Improve Visibility of Energy Impacts Within Control Systems

Advancements in energy sub-metering technology allows for better mapping of energy density throughout a facility. This allows facilities to operate equipment more efficiently from an energy perspective and provides operators with valuable information regarding efficiency degradation and proper sequencing of redundant equipment.

Integrating real-time pricing signals and grid conditions to existing facility control systems allows for operators and automated systems to make energy focused decisions and forecast energy usage for planned operations.

Most facilities are equipped with the infrastructure to support integration of this through existing SCADA and AMI systems. In the event the infrastructure does not exist, an economic incentive should be provided to offset large capital costs of these systems.

Evaluate and Highlight Customer Co-Benefits of DR Control

Integration of demand response facilitating technologies and strategies also serves to better equip agencies to deliver energy efficiency benefits, provide capacity to handle extreme weather events, PSPS events, pandemics and other non-routine events that present unprecedent scenarios in the treatment process. Being able to equalize flow, utilize excess storage, and maximize the flexibility of installed energy storage systems are examples of DR opportunities serving a purpose outside of the original intent, providing the capacity to handle non-routine events. These non-routine events require reactive responses that are inherently more energy intensive. Therefore, considering maximum grid flexibility in the design of these systems can provide a mutual benefit to the LSE and to the grid.

Overcome Co-Generation Related DR Barriers

The presence of co-generation and distributed generation contracts at a facility can hinder participation in load flexibility programs. A byproduct of the digestion process at many facilities is biogas, which is used to produce onsite power and limit purchases from the grid. This is a nearly continuous process, with some facilities producing 100% of the power requirements through this renewable resource. In this scenario, implementation of DR opportunities or curtailment of systems does not benefit the grid and presents an additional burden on the operational staff. This is also the case with other forms of distributed generation, such as solar and wind technologies.

For both scenarios, the ability to employ energy or resource storage is critical to allow for a beneficial load shaping scenario. In the case of cogeneration, biogas storage and automatic transfer of power sources to the grid, as well as direct injection are possible remedies although the capital investment is often not practical. Other sources of energy storage, such as battery storage, can also serve to overcome this barrier in both traditional and flexible demand response scenarios. Energy storage technologies are a more practical solution that have gained traction within the industry as advancements in proprietary algorithms, equipment reliability and economic feasibility have been made.

Deploy Locational and Load Potential-Based Targeting

California IOU's are developing advanced tools to support local resource adequacy and local distribution planning and deferral decision making. These tools are ideal to better match locational grid needs with potential load flexibility assets in the region, or to assess clusters of customers that could together relieve grid pressures in a coordinated fashion. For example, SCE's DR PEP website enables users to gain valuable insight into SCE's grid needs at the regional and hyper-local level. In combination with tools such as the DR Matrix, SCE could more effectively target customers for load management initiatives.

Leverage Integrated Demand Side Management Funds

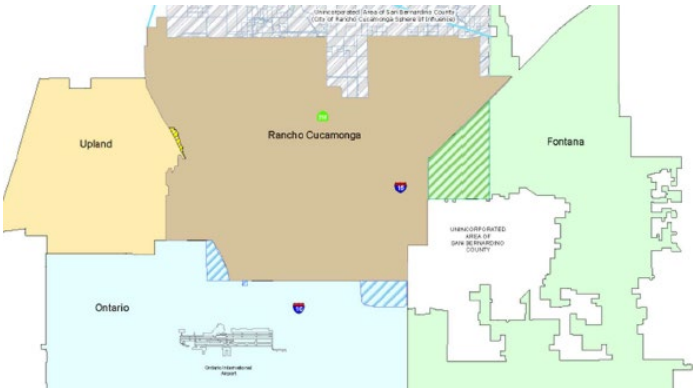
There are significant opportunities to integrate co-beneficial design strategies at water agencies through integrated demand side management and the application of subject matter expertise. More coordinated effort and funding to support these strategies in the engagement and technical services provided to agencies would enable more cost-effective programs and better customer outcomes. Existing integrated demand side management enabling funding mechanisms available through demand response and energy efficiency programs should be more fully leveraged.

APPENDICES

APPENDIX A: SUMMARY OF CASE STUDIES

CUCAMONGA VALLEY WATER DISTRICT

Capacity



22 Booster Stations
35 Reservoirs
95 MG of Storage
29 Wells

Characteristics

CVWD's water supply is provided from the following sources:

- *Imported Water*: The District purchases water from Inland Empire Utilities Agency (IEUA), a member agency of Metropolitan Water District (MWD). Imported water accounts for about 47% of the District's supply.
- *Local Canyon Sources*: Sources include Cucamonga Canyon, Day/East Canyon, Deer Canyon, Lytle Creek, Smith Canyon Group, and the Golf Course Tunnel; however, the main three sources are Cucamonga, Deer, and Day/East Canyons. Local Canyon water accounts for approximately 6.5% of the District's total supply.
- *Groundwater*: The District obtains groundwater from the Chino Basin and the Cucamonga Basin. Groundwater accounts for about 45% of the District's total supply.
- *Recycled Water*: IEUA recharges recycled water in Chino Basin and CVWD has a share based on its contribution to wastewater influent. The District's recycled water supply is small, averaging 1.6% of its total supply between 2005 and 2015.

Facilities	
3 Surface Water Treatment Facilities	22 Booster Stations
13 Pressure Zones (8 primary)	7 Disinfection Systems
24 Reservoir Sites	29 Wells (20 operating)
35 Reservoirs	3 Imported Water Connections
95 Million Gallons of Storage	33 Pressure Reducing Valves
703 Miles of Pipeline	

DR Strategy

One of the District's priorities has been achieving operational improvements through customized SCADA-integrated Water-Energy Management Systems ("SWEMS"). SCADA enhancements including real-time energy monitoring and management has been implemented via several strategic partnerships. In 2015, the University of California Riverside (UCR) was awarded an EPIC grant of $3,017,034 for "Bringing Energy Efficiency Solutions to California's Water Sector With the use of Customized Energy Management Systems (EMS) and SCADA". The goal of the project is to demonstrate that technology and hardware can create greater efficiencies while reducing peak electric loads and electricity costs of treating and delivering water. CVWD was one of several water utilities that participated in UCR's pilot project.

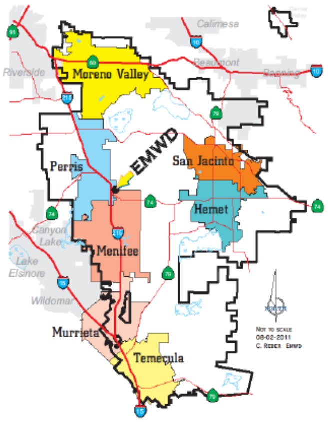
The site selected for the Pilot was CVWD's Reservoir 1c that is comprised of 3 wells and 5 booster pumps with a potential electric demand of 2,095 kW. The first iteration was conducted by the University of California at Riverside (UCR) as a "proof of concept". Specifically, UCR collected real-time electric data and helped CVWD correlate that data with real-time water production. The objective of the first iteration was to determine whether the data could be integrated into CVWD's SCADA system to help Operators manage electric demand charges. The second iteration was designed to implement the findings of the first iteration. Specifically, since the electric and water data calibrated well, CVWD integrated the data into its existing SCADA system with the aim of integrating demand management into daily operational strategies. Specifically, CVWD integrated the real-time electric data into the portion of its SCADA system that conducts pump sequencing. This provided operators with real-time kWh/AF performance, automated pump sequencing, and maximum allowable pumps by flow rate. Integration of real-time and historical electric data into its SCADA system has enabled CVWD Operators to reduce electric demand charges by an average of 41%.

Recommendations for a Water Sector Electric Reliability Program

- Demand Charges: The current structure of demand charges in traditional customer energy programs contradict the goals of over-generation mitigation that encourage increasing electric use during certain hours of the day. To encourage participation, these charges would need to be reduced or eliminated for all participating facilities.
- Specify Targeted Electric Impacts: The electric impact targeted by SCE and the CAISO and how those impacts can be achieved through water and wastewater systems needs to be clearly defined.
- Pilots: The District encourages conducting near-term pilot demonstration projects to achieve a deeper understanding of what is possible, and how best to achieve the targeted locational electric reliability benefits.
- Data: Improved integration with SCE's real-time electric meter and cost data are needed to increase water sector's ability to develop cost-effective strategies that provide benefits for both water and electric ratepayers. Synchronizing billing periods for all SCE metered accounts (e.g., to calendar month bases) would help water and wastewater utilities understand the energy cost implications of options.
- Timing: A clear understanding as to what time periods and seasons are most in need of electric reliability support would enable water sector operators to make plans.

EASTERN MUNICIPAL WATER DISTRICT

Capacity



Facility	Capacity
Wastewater Treatment Plant	43 MGD
San Jacinto Valley WRP	14 MGD
Moreno Valley WRP	16 MGD
Perris Valley WRP	22 MGD
Sun City WRP	3 MGD
Temecula Valley WRP	18 MGD

Characteristics

EMWD provides wastewater services to approximately 239,000 customers within its service area and currently treats approximately 43 million gallons per day of wastewater at its four active regional water reclamation facilities through 1,813 miles of sewer pipelines. EMWD has five regional water reclamation facilities which treat approximately 46 million gallons of wastewater every day.

Three of the Utility service accounts are enrolled the Base Interruptible Program (BIP), contracted for 6 MW of DR, and additional 20 Utility accounts enrolled in the Agricultural Pumping Interruptible (AP-I) program contracted for an additional 2.5 MW of DR. In addition, seven accounts are enrolled with third-party DR implementers for a total contracted amount of 3.1 MW of DR. In total, approximately one-third of the service accounts are enabled to participate and receive benefits from demand response.

DR Strategy

The strategies implemented entail curtailment only schemes, based on the temporary shutdown of strategically identified pumps and ancillary equipment throughout the WRPs during demand response events.

Through this, EMWD integrated flexibility into systems design and operations to enable load shifting strategies be implemented through advanced controls and SCADA. They also further integrated storage (water, wastewater, electric, and/or gas) where beneficial to minimize on-peak electricity.

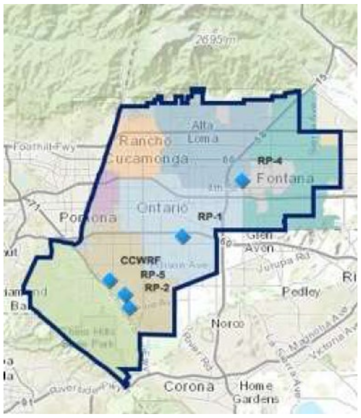
An example of a third-party DR strategy is through Enel X, where During a DR dispatch, the agency receives thirty-minute advanced notification from Enel X, then manually shuts down its Hemet Water Filtration Plant and Perris Water Filtration Plant. This is based on the determination that sufficient redundant resources are available for supplying water temporarily. It is believed that these two facilities can be shut down for two to four hours without any effect on service.

Recommendations for a Water Sector Electric Reliability Program

- A close relationship between water agencies and energy utilities is instrumental to achieving significant energy savings in the water sector.
- Technology risk and the need for investment prioritization may prevent water agencies from installing certain efficiency measures.
- Integrating all energy management activities into one central location can prove challenging for water agencies.

Inland Empire Utilities Agency

Capacity



Facility	Capacity
Regional Water Recycling Plant No. 1	44 MGD
Regional Water Recycling Plant No. 2	Solids Only
Regional Water Recycling Plant No. 4	14 MGD
Regional Water Recycling Plant No. 5	16.3 MGD
Carbon Canyon Water Recycling Facility	11.4 MGD

Characteristics

Four Regional Water Recycling Plants (RWRPs) produce Title 22 recycled water for indirect reuse and groundwater recharge. All have primary, secondary, and tertiary treatment and recycled water pumping facilities that are interconnected in a regional network. Sewage bypass and diversion facilities enable Agency operators to optimize flows and capacity utilization. In general, flows are routed between RWRPs to maximize recycled water deliveries while minimizing overall pumping and treatment costs.

DR Strategy

Over the past 7 years, IEUA completed installation of over 180 submeters at its major facilities. Critical submeters of loads greater than 200 kW are being integrated into the Agency's SCADA system, along with historical data. The submeters connect to the SCADA system to monitor kW, kWh, amperes, and load factor. These data help the Agency understand operating patterns and efficiencies to help reduce energy demand charges and identify malfunctioning equipment. The Agency anticipates that its enhanced SCADA system will enable operators to determine whether and how to shift electric usage to over-generation time periods. Additionally, the enhanced SCADA dashboard will help the Agency's operators make informed real-time decisions about whether it will be both technically and operationally feasible, and economically beneficial to provide electric reliability support at any point in time and at any particular location.

The Agency was an early adopter of new technologies since 1990 when it invested in its first internal combustion engines to produce electricity from biogas, IEUA followed this early innovation with solar, wind, fuel cells, battery energy storage - and most recently, electrochemical batteries operated in conjunction with a solar PV system at the Inland Empire Regional Composting Facility (IERCF). In addition to a diverse supply of renewable energy resources, Agency staff noted that there are multiple locations in its systems where surplus capacity could be leveraged to provide Flexible Electric Resources. Staff also stated that designing future expansions with a mix of equipment sizes would increase operational flexibility while concurrently increasing the Agency's ability to efficiently meet load growth over time.

Recommendations for a Water Sector Electric Reliability Program

- Utility Incentives: The biggest barrier for the Agency is the high capital cost of new and enhanced infrastructure and equipment. Any proposed capital improvement that may have an electric reliability benefit needs to compete for funding with mission-critical infrastructure. Incentives can help to offset a portion of the incremental capital costs that may be needed to increase the Agency's ability to provide Flexible Electric Resources.
- Education: Operators need to understand the value of their actions. Energy is the Agency's largest expense next to labor so having clarity as to the cost of each plant's processes enables operators to understand the economic impacts of their decisions.
- Trust: Trust and enhanced communication is essential to facilitating understanding and transparency between water utilities and SCE so that more "out-of-the-box" projects can be done.
- Partnering: The Agency is very effective in partnering with other agencies and has been able to optimize both its water and energy resources based on those relationships.
- Tools: Hydraulic modeling would help water and wastewater utilities optimize system efficiencies.
- Data Transparency: There are opportunities for the Agency and SCE to collaborate on improving energy data management and visibility for increased savings and efficiencies.

LBNL Case Study Sample

Capacity

As part of the 2006-2015 Research Summary of Demand Response Potential in California Industry, Agriculture, and Water Sectors, LBNL ran multiple case studies at wastewater facilities to better understand demand response. Only one of the four sites, San Luis Rey Wastewater Treatment Plant (13 MGD), was confirmed.

Characteristics

This effort involved sub-metering the electricity consumption of the three major process areas that typically account for half of a wastewater treatment facility's total usage, namely, influent/effluent storage pumps, solids separation centrifuges, and aeration area equipment.

DR Strategy

Submetering at the San Luis Rey wastewater treatment plant in Oceanside, CA, confirmed the hypothesized DR potential of centrifuges and effluent pumps (shifting period of operation to outside of peak demand period), but showed that reductions in aeration load (anticipatory over-oxygenation of wastewater) can be unacceptably detrimental to effluent quality.

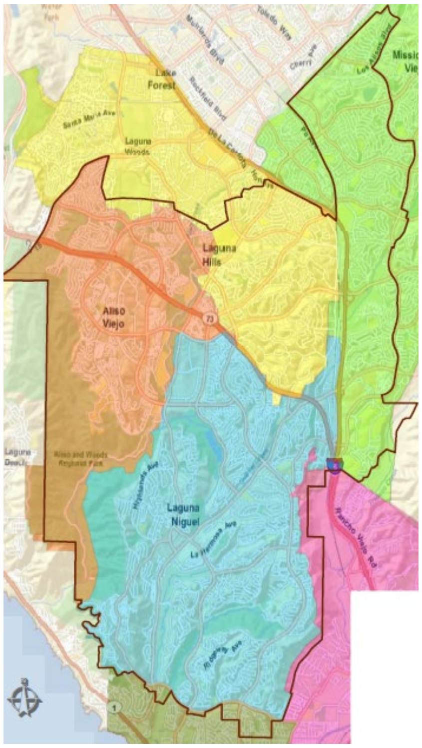
Successful DR was demonstrated at two unknown plants, as well as the theoretical possibility for Auto-DR, for pumps (36% of peak load) and solids separation centrifuges (30% of peak load). For the other unknown plant, while there appeared to be significant potential, the facility staff were reluctant to undertake any significant DR testing for operational and organizational reasons. Several other wastewater treatment facilities documented the implementation of load management and EE measures. For example, a wastewater treatment facility in San Diego County reduced average demand by 540 kW or 30% of total demand by implementing Auto-DR.

Recommendations for a Water Sector Electric Reliability Program

- Further investigate the downstream process impacts of demand response measures outside of the energy outlook.
- Further investigate the prevalence of cogeneration in wastewater treatment facilities and its relationship to Auto-DRR potential, including utilizing schedulable self-generation and self-starting generation units to contribute to Auto-DR.
- Further explore technologies as a means of implementing demand response strategies to ensure process critical priorities are met.

MOULTEN NIGEL WATER DISTRICT

Capacity



Facilities	Quantity
Pump Stations	53
Reservoirs	39
Treatment Plants	4
Miles of Potable Water	663 (29.1 MGD)
Miles of Wastewater	504 (11.2 MGD)
Miles of Recycled Water	140

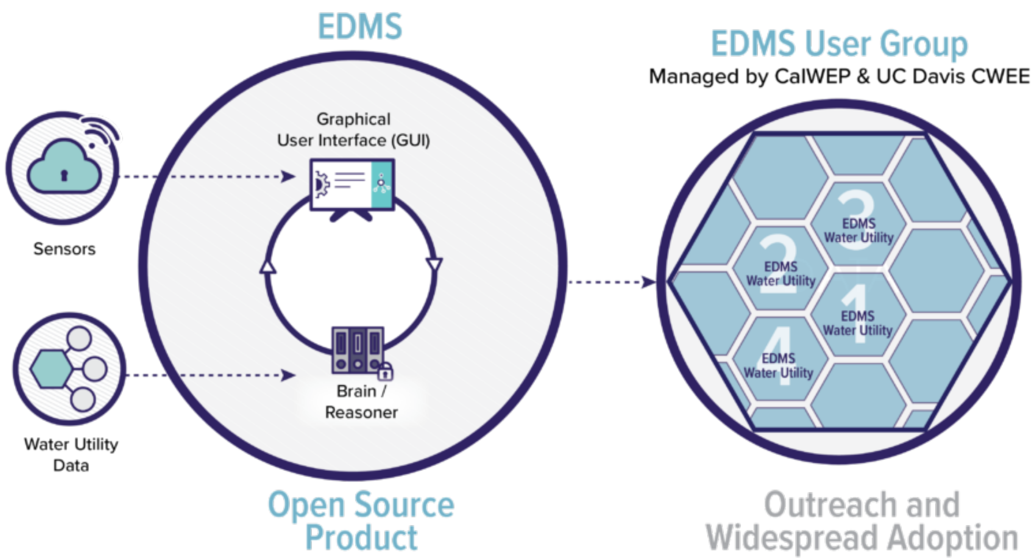
Characteristics

The District's service area, located in South Orange County, encompasses approximately 37 square miles and a population of 170,000 within the cities of Laguna Niguel, Aliso Viejo, Laguna Hills, Mission Viejo, and Dana Point. The District imports all of its potable water from the Metropolitan Water District of Southern California (MWD). These sources primarily include water imported from the Colorado River and the State Water Project. All of the District's potable water is treated at the Diemer Filtration Plant in Yorba Linda, and delivered through three major transmission facilities, the South County Pipeline, East Orange County Feeder #2, and the Allen-McColloch Pipeline. There is a total of 70 MG of storage capacity through operational reservoirs.

DR Strategy

The California Energy Commission sponsored this joint venture with UC Davis to develop and test a software suite to increase water utility participation in managing operational energy use. Analytical tools, dashboards, and extensions are being created and integrated with hydraulic modeling software to form the Energy Demand Management System (EDMS). This software will allow the operators to:

- Forecast and recommend optimized future operations.
- Forecast future energy demand profiles and energy costs.
- Facilitate on-site demand response participation.
- Be empowered to explore new operations based on the future energy rate structures or demand response participation.

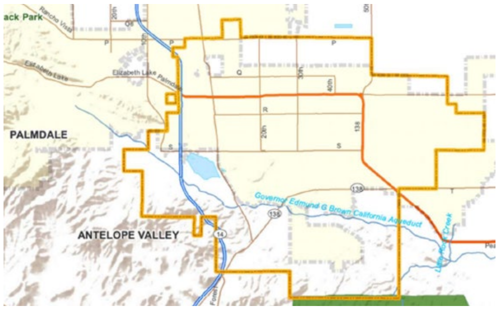


Recommendations for a Water Sector Electric Reliability Program

This project is still in progress; therefore, recommendations have not been determined at this stage.

PALMDALE WATER DISTRICT

Capacity



Facility	Quantity
Leslie O. Carter Water Treatment Plant	35 MGD
Storage Reservoirs	2,178 MG
Booster Pump Stations	15

Characteristics

PWD's potable water distribution system is divided into seven main pressure zones, which are labeled by the approximate hydraulic grade line (HGL) within the zone: the 2800 zone, 2850 zone, 2950 zone, 3000 zone, 3200 zone, 3250 zone, and the 3400 zone. There is an additional small zone at a remote location, the 3600 zone. Together, groundwater pumping and booster pumps account for 81% of the electricity (kWh) used by PWD during 2018 and 84% of the electric demand (kW).

Type of Facility	Number of SCE Electric Meters	Total Electric Energy (kWh)		Maximum Electric Demand (kW)		Annual Electric Load Factor[1]	
		Total Electricity (kWh)	% kWh by Type of Facility	∑ Non-Coincident kW (NCP)[6]	% kW by Type of Facility	Utilized[2]	Unutilized[3]
Groundwater Well	28	5,501,278	48.72%	2,605.5	51.02%	24.10%	75.90%
Pump Station (Booster)	15	3,691,780	32.70%	1,658.8	32.48%	25.41%	74.59%
Water Treatment Plant	2	1,401,584	12.41%	544	10.65%	29.41%	70.59%
Lake/Littlerock Dam	3	76,035	0.67%	29	0.57%	29.93%	70.07%
Tanks	2	621	0.01%	1	0.02%	7.09%	92.91%
All Other Uses	4	619,861	5.49%	269	5.26%	26.30%	73.70%
Grand Total	**54**	**11,291,159**	**100%**	**5,107.3**	**100%**	**25.24%**	**74.76%**

DR Strategy

PWD has recently completed upgrades of the radio system and SCADA system for the potable water distribution system, providing real-time information about the status of all key infrastructure and allows operations staff to make decisions on critical data in a timely manner. The high level of understanding of the distribution system results from a consciously developed culture that emphasizes holistic knowledge of the system and its goals so that operational strategies can be constantly refined and optimized. This culture de-emphasizes operation based upon rote adherence to a schedule or set of memorized activities. With the data from the SCADA system, the operations staff identify challenges and solve them in real time.

According to the 2016 Water Facilities Master Plan, PWD has five active "large mover" wells that have a capacity of approximately equal to or greater than 1,000 gpm, and a motor with 500 hp or greater. At a minimum, these wells (well 2A, well 3A, well 7A, well 8A, and well 23) should be operational during the over-generation period.

The largest opportunity for future over-generation response can likely be found in PWD's proposed groundwater banking and recovery program. This includes a new 80-acre recharge basin on the 160-acre site. This project would construct recharge basins to bank PWD's SWP allocation when available. A blend of untreated SWP water and tertiary recycled water from the Palmdale Recycled Water Authority would be delivered to 4 spreading basins to recharge the Antelope Valley groundwater aquifer with up to 52,000 acre-feet per year (AFY). Targeted recovery is 15-30 Thousand Acre-Feet (TAF) per year (8-16 wells) that will either be chlorinated prior to delivery to customers or returned via the California Aqueduct to other State Water Contractors.

PWD is also removing 1,165,000 cubic yards of sediment to restore Littlerock Reservoir to its 1992 water storage levels. The Environmental Impact Report (EIR) was completed in March of 2017 and construction of a grade-control structure began in October of 2018. Removing the 1.1 million cubic yards of sediment is expected to take 7 to 12 years to bring water storage capacity back to 3,500 AF. Upon completion, PWD's water supply diversity and flexibility of sources would be further increased.

Recommendations for a Water Sector Electric Reliability Program

- Reduce or eliminate ALL meter-level facilities demand charges, including annual peak demand, maximum demand by TOU period, and back-up and standby services. PWD believes that removing price disincentives, such as facilities demand charges that penalize customers for providing overgeneration mitigation support, would enable water and wastewater utilities to produce more Flexible Electric Resources.
- Work with SCE to obtain and integrate real-time electric meter data from SCE's AMI system and information about electric price options into PWD's SCADA system and HMI interface. PWD believes optimization of water and wastewater resources and systems would benefit significantly by being able to access SCE's AMI data and integrating different types of pricing options so that operators can make better informed decisions about which pumps to dispatch and when.
- Partner with SCE on a technology partnership that would implement sub-metering and integrate the sub metered data into the SCADA system and

upgrade the SCADA HMI to integrate real-time energy cost information into the SCADA dashboard so that operators can consider the energy cost impacts of alternative operating scenarios.

- Continue partnering with SCE on pump tests. PWD believes SCE's pump tests are valuable in validating pump efficiency curves indicated by the SCADA system.

RANCHO CALIFORNIA WATER DISTRICT

Capacity

40 reservoirs
31 pump stations
14 pressure reducing stations
211 miles pipelines (20” and larger)
675 miles pipelines (16” and smaller)
4 MWD turnouts
48 production wells

Characteristics

The District’s potable water distribution system distinctly operates within two divisions: the Santa Rosa Division in the westerly half, and the Rancho Division in the easterly half. Each division provides water through a number of pressure zones ranging from 1060 to 2860 feet in the Santa Rosa Division, and 1305 to 2350 feet in the Rancho Division. Most of the water supplied to customers enters the District at the lowest elevation (1305) with smaller amounts entering the 1380 Zone, 1610 Zone and 1790 Zone. Because the District serves customers up to 1,500 feet above the 1380 Zone, the District consumes a large amount of electricity to pump water from pressure zones at low elevations to successively higher zones. The 1305 Zone provides service to the I-15 corridor and serves as the forebay zone for several pump stations that deliver water to higher zones within both Divisions. Treated water from MWD turnouts and the majority of groundwater production enters the District’s system in the 1305 zone. Some additional groundwater also enters the system in the 1380, 1610 and 1790 Zones of the Rancho Division.

Division	Zone	Pumping (GPM)				Storage (MG)			
		Pumping Capacity	% Pumping Capacity	Surplus Capacity	% Surplus	Storage Capacity	% Storage Capacity	Surplus Capacity	% Surplus
Combined	1305	128,309	40%	43,738	33%	22.71	16%	10.57	18%
Rancho	1380	37,987	12%	15,252	12%	17.86	12%	5.75	10%
	1485	20,400	6%	4,979	4%	22.15	15%	7.45	13%
	1550	2,500	1%	1,252	1%	3.43	2%	2.11	4%
	1610	13,655	4%	5,074	4%	6.44	4%	2.16	4%
	1760	13,919	4%	8,011	6%	9.20	6%	6.25	11%
	2070	6,040	2%	3,140	2%	4.51	3%	1.90	3%
	2350	1,500	0%	1,256	1%	0.53	0%	0.13	0%
Santa Rosa	1440	12,100	4%	3,445	3%	11.41	8%	3.28	6%
	1500	13,260	4%	7,603	6%	7.83	5%	2.56	4%
	1670	44,350	14%	23,180	18%	17.05	12%	4.26	7%
	1900	8,720	3%	4,019	3%	8.24	6%	3.74	6%
	2150	200	0%	131	0%				
	2160	5,700	2%	3,538	3%	2.27	2%	1.91	3%
	2260	1,450	0%	384	0%	2.20	2%	1.56	3%
	2550	6,520	2%	4,002	3%	6.93	5%	4.50	8%
	2825	950	0%	942	1%	0.54	0%	0.35	1%
	2860	1,000	0%	953	1%	1.06	1%	0.83	1%
	TOTALS	318,560	100%	130,899	100%	144.36	100%	59.31	100%
DIVISION TOTALS									
	Combined	128,309	40%	43,738	33%	22.71	16%	10.57	18%
	Rancho	96,001	30%	38,964	30%	64.12	44%	25.75	43%
	Santa Rosa	94,250	30%	48,197	37%	57.53	40%	22.99	39%
	TOTALS	318,560	100%	130,899	100%	144.36	100%	59.31	100%
SURPLUS CAPACITY DURING SUMMER MONTHS									
	TOTALS	318,560		130,899	41%	144.36		59.31	41%

DR Strategy

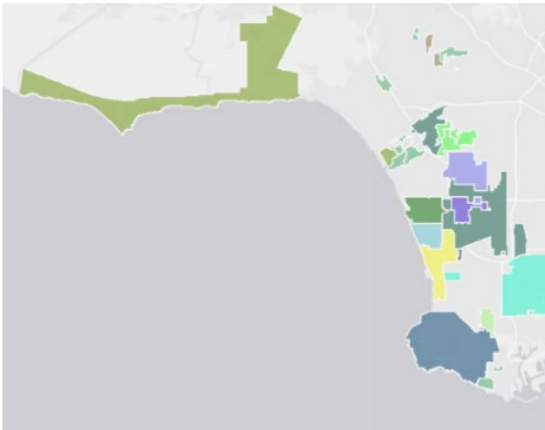
The District identified the opportunity for demand response based on the surplus of capacity that exists within its potable water systems. An estimated 17 MW of pumping from groundwater well and booster pump stations could be shifted to combat overgeneration. The District identified adequate capacity in the pumping (groundwater, imported water, and recycled water), storage (reservoirs and tanks), and conveyance (piping). The strategy implemented an operational change to utilize only a portion of the available pump capacity and pumps over a longer timeframe with minimal upstream or downstream impacts. Surplus capacity in the District's potable water system averages 41% during summer months and 30% of existing pumping and storage capacity in the winter. This could potentially provide electric reliability support from as much as 70% of its installed pumping and storage capacity.

Recommendations for a Water Sector Electric Reliability Program

- A single fully integrated tool that can directly import real-time data to help analyze electric bills, electric and gas usage and costs, and water grid operations. Synchronizing water and wastewater SCADA systems with real-time electric use data from SCE's AMI meters would improve real-time water sector decision-making and their ability to provide flexible electric resources.
- Existing demand response rules: The District identified 80 sites capable of providing flexible electric resources, however only 19 of these meters are in current SCE DR programs. This is due to the need to bid individual meters into the existing programs, discouraging meters upstream or downstream that are impacted by the cascading effect of the strategy. This District would recommend the Utility to allow water and wastewater utilities to enroll in DR and other electric reliability programs on an entity basis that allows the District to determine which, if any of their facilities can provide the requested DR support at any particular time.
- Existing electric program barriers: The District has 35 electric meters that benefit from solar PV output from eligible RES-BCT projects, which have been "grandfathered" under the old TOU rates enabling these customers to continue to earn the highest value for their solar PV output during Noon to 6 p.m. These meters must also honor the old TOU time periods, causing RCWD to avoid using electricity during noon to 4 p.m. (periods of overgeneration). Thus, it is an economic disadvantage to shift electric usage to overgeneration period (9 a.m. to 4 p.m.). The District would recommend a modified schedule that continues to provide the economic benefits of the solar, while allowing for enabling the flexible electric capacity in the pumping systems.

West Basin Municipal Water District

Capacity



Edward C. Little Water Recycling Facility
40 MGD

Characteristics

The Edward C. Little Water Recycling Facility (ECLWRF) is the largest water recycling facility of its kind in the United States and was recognized by the National Water Research Institute in 2002 as one of only six national centers for water treatment technologies. The ECLWRF is the only treatment facility in the country that produces five different qualities of "designer" or custom-made recycled water that meet the unique needs of West Basin's municipal, commercial and industrial customers. The five types of designer water include:

- Tertiary Water (Title 22) for a wide variety of industrial and irrigation uses.
- Nitrified Water for industrial cooling towers
- Softened Reverse Osmosis Water: Secondary treated wastewater purified by micro-filtration (MF), followed by reverse osmosis (RO), and disinfection for groundwater recharge.
- Pure Reverse Osmosis Water for refinery low-pressure boiler feed water
- Ultra-Pure Reverse Osmosis Water for refinery high-pressure boiler feed water

The facility produces approximately 40 million gallons of useable water every day, conserving enough drinking water to meet the needs of 80,000 households for a year.

DR Strategy

In late 2009, West Basin completed a major upgrade of the Supervisory Control and Data Acquisition (SCADA) system at the ECLWRF, receiving technology incentives of $272,000 from Southern California Edison (SCE) through the Technical Assistance and Technology Incentives (TA&TI) Program. West Basin's verified demand reduction capability equals 2.2 megawatts.

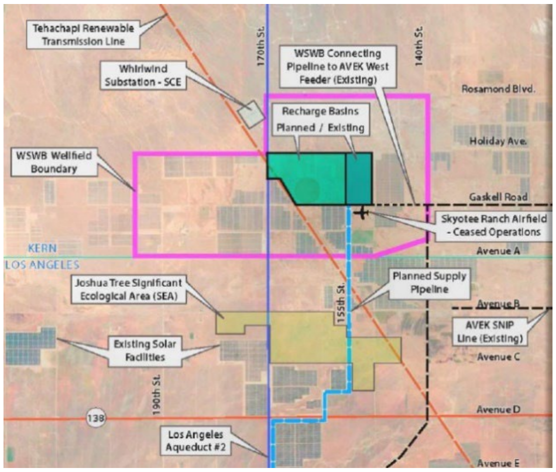
As a result, West Basin entered into a third-party Demand Response Contract (DRC), enabling it to reduce more than one megawatt of load when required and earn incentives in the process. This strategy goes beyond the district's standard procedure of shifting equipment use to off-peak periods as much as possible. In addition, West Basin takes advantage of SCE's free pump tests to look for opportunities to increase energy efficiency, reduce costs and improve system reliability. These tests use the latest in fluid flow and electronics measurement equipment.

Recommendations for a Water Sector Electric Reliability Program

This case study demonstrated the necessity of integrated controls and appropriate signals to facilitate demand response. No recommendations were made for a future reliability program.

WILLOW SPRINGS WATER BANK

Capacity



Sites
Antelope Valley-East Kern Feeder
320 acres of ponds
7 irrigation wells

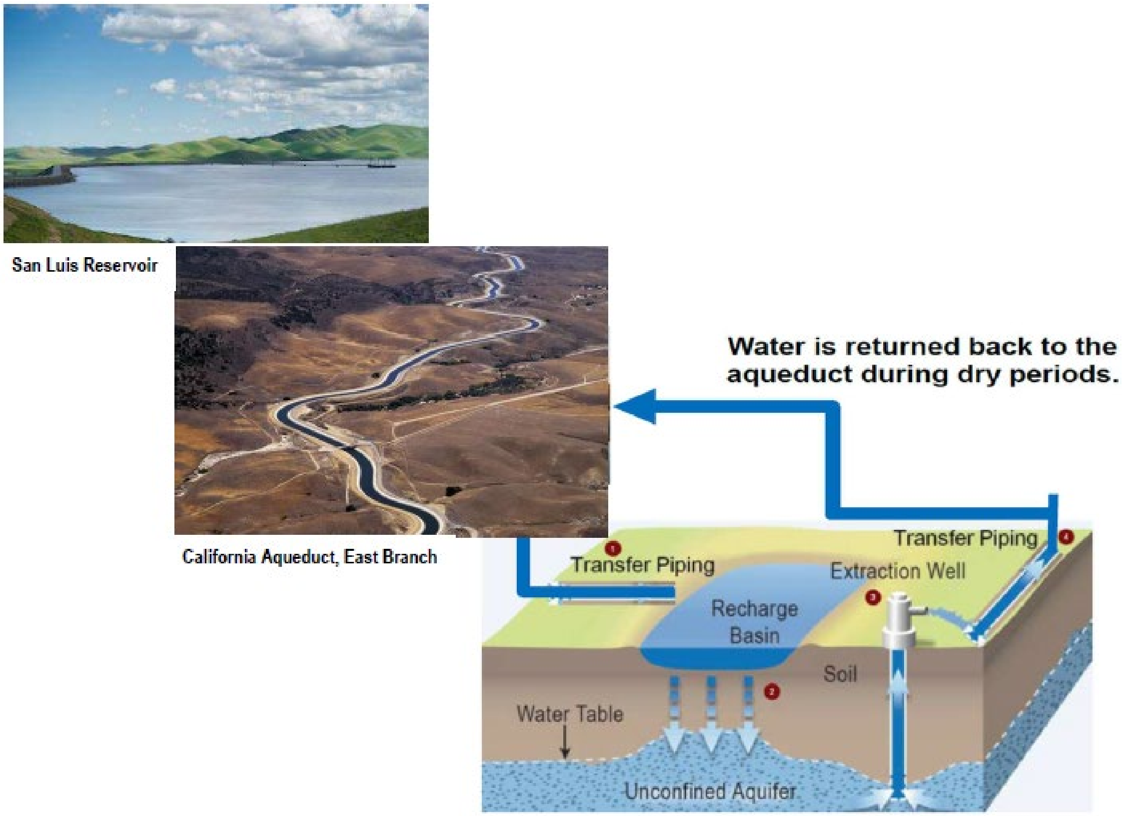
Characteristics

Willow Springs Water Bank (WSWB) is a groundwater recharge, recovery, and banking system located in the adjudicated Antelope Groundwater Basin (the Basin) near Rosamond, California. The Basin spans the northeastern border of Los Angeles County and with the southern border of Kern County. Three major aqueducts – the California Aqueduct, the Los Angeles Aqueduct, and the Antelope Valley – East Kern Water Agency – are nearby, providing an opportunity to optimize surface and groundwater resources “conjunctively.”

DR Strategy

WSWB and its technical consultants conducted extensive modeling of a variety of scenarios to estimate the incremental water, energy, climate, ecosystem, and other benefits that might be achievable through optimization of the State’s water and energy resources in Antelope Valley. In 2017, WSWB completed a study of “Groundwater Bank Energy Storage Systems” pursuant to an Electric Program Investment Charge (EPIC) grant administered by the California Energy Commission (CEC). This study modeled conceptual operations of a pumped storage hydropower configuration with a groundwater bank serving as the lower reservoir. The study concluded that a pumped storage hydropower configuration of this kind could cost-effectively reduce on-peak electric use. Under some conditions, in-conduit hydropower may also be economic.

A subsequent study was conducted that estimated the types of water, energy, climate, and other benefits that could be achieved by operating the WSWB conjunctively with the State Water Project (SWP). The operating scenarios were structured to maximize statewide benefits, i.e., instead of focusing on the economic performance of WSWB’s operations alone, the second study estimated the net benefits that could be achieved through coordinated (“conjunctive”) operations of WSWB and another entity, the State Water Project (SWP). WSWB proposes to operate conjunctively with the State Water Project (SWP) to maximize statewide water, energy, climate, environmental, and other benefits. Specifically, WSWB proposes operating its groundwater aquifer in a pumped-storage configuration that utilizes the SWP's San Luis Reservoir as the upper reservoir, and WSWB as the lower reservoir. When operated conjunctively in this pumped-storage configuration, WSWB anticipates being able to help SWP shift a significant portion of its summer electric requirements to fall and spring with no adverse impacts on SWP's contractual water deliveries. This would allow for a reduced electric demand during periods when the State is electric supply short (summer on-peak periods) and increasing electric demand during periods when the State has substantial quantities of surplus electricity (over-generation).



San Luis Reservoir
California Aqueduct, East Branch
Willow Springs Water Bank

Recommendations for a Water Sector Electric Reliability Program

Explore other candidates for similar proposed strategy of shifting imported water deliveries our of electric peak periods. Specific examples and a table of potential are provided below.

- The combined capacity of the Los Angeles (1,000 cfs) and Colorado River Aqueducts (1,700 cfs) exceed the 2,010 cfs SWP East Branch at Pearblossom Pump Station by 34%.
- The storage capacity of other groundwater banks in different aquifers total about 3.2 million acre-feet/year in recharge capacity, about 11 times the size of WSWB.
- In addition, many agricultural wells throughout the State's Central Valley may be candidates.

Aqueduct	Type	Units	Power*	Embedded Unit Energy	Upper/Lower Reservoir (TAF/TAF)
California Aqueduct [SWP]	Lift	12	1,080 MW	3,200 kWh/AF	San Luis/Castaic & Perris [2,010/325]
Colorado River Aqueduct (1700 cfs) [MWD]	Lift	8	275 MW	2,000 kWh/AF	Mead/Matthews [26, 100/325]
Los Angeles #1 (422 cfs) [LADWP]	Drop	3	122 MW	1,500 kWh/AF	Bouquet/none [34/0]
Hetch Hetchy [SFPUC]	Drop	3	384 MW	TBD	H.Hetchy/Calaveras [360/100]
Mokelumne [EBMUD]	Drop	5	34 MW	TBD	Pardee/Briones et al [198/155]
		Grand Total	**1,895 MW**		

APPENDIX B: DEMAND RESPONSE MATRIX

Matrix of DR Strategies.xlsx

APPENDIX C: ACKNOWLEDGEMENTS

We would like to thank the following contributors to this study:

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REFERENCES

1. A. Lekov et al. (2009), Opportunities for Energy Efficiency and Open Automated Demand Response in Wastewater Treatment Facilities in California – Phase I Report. Berkeley, CA, U.S.A: Lawrence Berkeley National Laboratory

2. "Activated Sludge Process." News, The International Water Association Publishing. n.d. Web.

3. Amanda Rupiper (2019), Energy and Water Savings from Onsite Water Reuse in the Wine Industry. Davis, CA, U.S.A: California Energy Commission

4. Amanda Rupiper (2019), Identifying and overcoming Barriers to Onsite Non-Potable Water Reuse in California from Local Stakeholder Perspectives. Davis, CA, U.S.A: University of California Davis

5. Amanda Rupiper (2019), Onsite Non-potable Water Systems: Challenges and Opportunities in the Wine Sector. Davis, CA, U.S.A: University of California Davis

6. Arian Aghajanzadeh et al. (2015), 2006-2015 Research summary of demand response potential in California industry, agriculture, and water sectors. Berkeley, CA, U.S.A: Lawrence Berkeley National Laboratory

7. Arian Aghajanzadeh et al. (2015), Opportunities for Automated Demand Response in California Wastewater Treatment Facilities. Berkeley, CA, U.S.A: Lawrence Berkeley National Laboratory

8. "Assembly Bill 32 Overview." Article. California Air Resources Board. 2014. Web.

9. "Climate Action Plan." Article. California Department of Water Resources. n.d. Web.

10. Bethany Sparn et al., (2015), Opportunities and Challenges for Water and Wastewater Industries to Provide Exchangeable Services. Golden, CO, U.S.A: National Renewable Energy Laboratory

11. Dehumidification & water purification demand response project. U.S.A: SDG&E

12. "Disinfection of water and wastewater." Technical Resources, Norweco. n.d. Web.

13. DR ET Water Saver Pilot. U.S.A: PG&E

14. Energy Efficiency in Water and Wastewater Facilities (2013). U.S.A: U.S Environmental Protection Agency

15. "Energy Research Innovations in Water Treatment, Delivery and Energy Recovery." Workshop Agenda. California Energy Commission. 2019. Web.

16. Faeza Hafiz et al. (2019), Utilizing Demand Response for Distribution Service Restoration to Achieve Grid Resiliency against Natural Disasters. U.S.A: Researchgate

17. "Flow Equalization." Article. University of Washington. n.d. Web.

18. Full-Scale and Demonstration-Scale Primary Filtration Projects Show Great Promise. U.S.A: Kennedy Jenks

19. Gerald Braun, Customer Choice for Energy Resilience Introduction and Summary Recommendations. U.S.A: California Public Utilities Commission

20. Glen Andersan et al. "Meeting energy needs with demand response." Article. National Conference of State Legislatures. 2019. Web.

21. "Grant Request Form: UC Davis." Form. California Energy Commission. 2017. Print.

22. Hana Biru et al. "INSIDER : Rethinking wastewater can help achieve both climate and development goals." News. World Resources Institute. 2017. Web.

23. Improving Water and Energy Efficiency in California's Dairy Industry. U.S.A: California Energy Commission

24. "Introduction to UV disinfection." Applications/Wastewater, Trojan UV. n.d. Web.

25. Lawrence Y.C. Leong (2008), Demand Response Feasibility Study for the Sewage Treatment Industry. CA, U.S.A: Southern California Edison

26. Lisa Thompson et al. (2008), Automated Demand Response Opportunities in Wastewater Treatment Facilities. Berkeley, CA, U.S.A: Lawrence Berkeley National Laboratory

27. M. Schäfer et al. (2017), Energetic flexibility on wastewater treatment plants. Germany: Water Science and Technology

28. Metcalf and Eddy, Wastewater engineering- Treatment and resource recovery. 5th Edition, U.S.A: McGraw-Hill Education

29. Michael Panfil et al. "Resiliency+: Demand Response can help prevent blackouts in the Northeast." Article. Environmental Defense Fund. 2014. Web.

30. "Minnesota Water Works Operations Manual, Chapter 19: Membrane Filtration." Manual. Minnesota Rural Water Association. 2009. Print.

31. Mojtaba Maktabifard et al. (2019), Energy neutrality versus carbon footprint minimization in municipal wastewater treatment plants. Poland: Bioresource Technology

32. Navigant Consulting, Inc. (2015), Measure, Application, Segment, Industry (MASI): Wastewater Treatment Facilities. CA, U.S.A: Southern California Edison

33. Nicholas Connell. "EPIC TAL Support." MEMO, APTIM. 2019. Print.

34. Onder Caliskaner et al. (2018), Performance of Full Scale and Demonstration-Scale Primary Filtration Projects. CA, U.S.A: WEFTEC

35. On-site sewage facilities. "Trickling Filter." Article. Texas A&M Agrilife extension. n.d. Web.

36. Park et al. (2019), Water Sector Over-Generation Mitigation and Flexible Demand Response Phase 2 Program Recommendations. CA, U.S.A: Water energy innovations

37. Park et al. (2019), Water Sector Over-Generation Mitigation and Flexible Demand Response. CA, U.S.A: Water energy innovations

38. Peter Alstone et al. (2017), 2025 California Demand Response Potential Study – Charting California's Demand Response Future: Final Report on Phase 2 Result. Berkeley, CA, U.S.A: Lawrence Berkeley National Laboratory

39. Rancho California Water District Innovations. "Best-In-Class Water Sector Flexible Electric Resources." Fact Sheet. South California Edison. 2019. Web.

40. Ray Bennett et al. (2017), Southern California Edison Water-Energy Pilot with Irvine Water Ranch District. CA, U.S.A: Southern California Edison

41. “Tertiary filters for advanced sewage/wastewater treatment.” Article. Pollution Control Systems, Inc. n.d. Web.

42. “Tertiary Wastewater Filtration.” Article. Evoqua. n.d. Web.

43. University of California Davis Center for Water-Energy Efficiency (2019), Measure and Verification of Winery Water and Energy Savings. Davis, CA, U.S.A: University of California Davis

44. Victor Pavlov et al. (2014), Best Practices in Water Asset Utilization for Renewable Energy Generation. Finland: University of Oulu

45. Vijay Israni et al. (2015), Low-cost, scalable, fast demand response for municipal wastewater and recycling facilities. Berkeley, CA, U.S.A: Lawrence Berkeley National Laboratory

46. Waste Sludge Reactivation and Recycling Project. MD, U.S.A: BDP EnviroTech

47. “Water District Pump Test Feedback.” Video. n.d. Web.

48. “Water Energy Nexus.” Article. California Department of Water Resources. n.d. Web.

49. “Wildfire Mitigation and Grid Resiliency.” Fact Sheet. South California Edison. n.d. Web.

50. Willow Springs Water Bank. “A Statewide Water-Energy Bank.” Fact Sheet. South California Edison. n.d. Web.