LBNL-1004131

Lawrence Berkeley National Laboratory

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

Arian Aghajanzadeh , Aimee McKane, Craig Wray, Peter Therkelsen

Lawrence Berkeley National Laboratory, Berkeley, CA., U.S.A.

August 2015

The work described in this report was coordinated by the Demand Response Research Center and funded by the Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy and Office of Electricity Delivery and Energy Reliability, under Contract No. DE-AC02-05CH11231 and by the California Energy Commission (CEC), Public Interest Energy Research (PIER) Program, under Work for Others Contract No. 500-03-026.
The authors thank Anish Gautam and the California Energy Commission for their continued support of Demand Response Research in the Industrial, Agriculture, and Water sectors.

Disclaimer

Energy Research and Development Division
FINAL PROJECT REPORT

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

Prepared for: California Energy Commission
Prepared by: Lawrence Berkeley National Laboratory

AUGUST 2015
CEC-500-2015-XXX

PREPARED BY:

Primary Author(s):
Arian Aghajanzadeh
Aimee McKane
Craig Wray
Peter Therkelsen

Lawrence Berkeley National Laboratory
1 Cyclotron Road
Berkeley, CA 97420
Phone: 510-495-2145
http://www.lbl.gov

Contract Number: 500-03-026

Prepared for:

California Energy Commission

David Hungerford
Contract Manager

Virginia Lew
Office Manager
Energy Efficiency Research Office

Laurie ten Hope
Deputy Director
ENERGY RESEARCH AND DEVELOPMENT DIVISION

Robert P. Oglesby
Executive Director

ACKNOWLEDGEMENTS

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PREFACE

The California Energy Commission Energy Research and Development Division supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The Energy Research and Development Division conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

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- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

2006-2015 Research Summary of Demand Response Potential in California Industry, Agriculture, and Water Sectors is the final report for the Demand Response End Use Analysis and Field Studies in Industrial, Agricultural and Water Systems project (contract number 500-03-026, work authorization number WA1-10.1-1) conducted by the Lawrence Berkeley National Laboratory. The information from this project contributes to Energy Research and Development Division's Industrial/Agricultural/Water End-Use Energy Efficiency Program.

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ABSTRACT

In 2006, the Industrial Demand Response Team of the Demand Response Research Center (DRRC) started its research into the potential for Demand Response (DR) and Automated Demand Response (Auto-DR) in the Industrial, Agricultural, and Water (IAW) sectors.

DR involves electricity end-use customers reducing their electricity usage over a given time period (shed), or shifting that usage to another time period (shift), in response to a price signal, a financial incentive, an environmental condition, or a reliability signal.[1] Two approaches to DR are manual DR programs and Auto-DR programs. California industry currently participates primarily in manual DR programs (e.g., demand bidding, base interruptible programs). However, Auto DR, in which loads are shed automatically in response to grid control signals (unless the customer opts-out), has the potential to be used for ancillary services, which are growing in importance due to the load uncertainty and variability caused by the integration of large shares of renewables. The California Independent System Operator (CAISO) is interested in "hardening" demand response across participating sectors through the use of Auto DR. While there have been notable exceptions in some industrial subsectors (e.g., industrial gases, refrigerated warehouses), only a small number of industrial sites are participating in Auto-DR.

The industrial sector provides opportunities for large sheds or shifts from relatively few facilities. Through years of industrial DR studies, Lawrence Berkeley National Laboratory (LBNL) conducted research about wastewater treatment, agricultural irrigation, refrigerated warehouse, data center, cement, and dairy processing industries. This research identified several opportunities and barriers for achieving Auto-DR in the industries of interest. The outcomes of the past decade of industrial DR research are summarized in this report.

Keywords: Demand Response, Energy Efficiency, Automated Demand Response, Auto-DR, Load Shifting, Grid Flexibility, Controls, Agriculture, Irrigation, Pumping, Dairy Processing, Dairy, Wastewater, Data Center, Cement, Refrigerated Warehouses, Cold Storage.

Please use the following citation for this report:

Aghajanzadeh, Arian; Aimee McKane; Craig Wray. (Lawrence Berkeley National Laboratory). 2015. ***2006-2015 Research Summary of Demand Response Potential in California Industry, Agriculture, and Water Sectors .*** California Energy Commission. Publication number: CEC-500-2015-XXX.

[1] California Public Utilities Commission http://www.cpuc.ca.gov/PUC/energy/Demand+Response/

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EXECUTIVE SUMMARY

Introduction

This report describes the work of the Industrial Demand Response Team of Lawrence Berkeley National Laboratory's (LBNL) Demand Response Research Center (DRRC) in the context of its mandate to conduct and disseminate research that broadens the knowledge base of demand response (DR) strategies. This report focuses on efforts related to the industrial, agricultural, and water (IAW) sectors from 2006 to 2015.

Project Purpose

The objective of this research was to increase the knowledge of what, where, for how long, and under what conditions industrial facilities will shed or shift load in response to an automated signal. In 2006, California industries were already participating extensively in DR programs (1,857 MW for reliability and 1,044 MW for "day ahead" notification programs). The goal of using Auto-DR in industry is to provide a more "hardened" response to Auto-DR signals based on price or reliability. The focus of the past decade of DR study was to develop event-based as well as continuous (shorter time frame, quick acting) DR capabilities in California industry, and aggregating these capacities to harness system-wide synergies to maximize benefits. Over time, these will be achieved by identifying implementation strategies, guiding policy development, and quantifying the economic benefits, which together form a "roadmap" for adoption.

Project Results

Challenges for industrial Auto-DR include: the variation in loads and processes across and within sectors, resource-dependent loading patterns that are driven by outside factors such as customer orders or time-critical processing (e.g., irrigation scheduling), the perceived lack of control inherent in the term "Auto-DR", and aversion to risk, especially due to unplanned impacts on production or operations.

The four key outcomes from a decade of DR research by the LBNL DR Team are the following:

1. **Auto-DR opportunity validation:**
   There is a wide range of sometimes substantial opportunities for Auto-DR in selected industries through load shedding/shifting. This finding was supported by case studies and field tests.
2. **Control capabilities matter:**
   Auto-DR is compatible with energy efficiency and load management in industrial facilities, but many industries have limited controls capabilities, especially for supporting or non-core systems that may be especially suited for Auto-DR. Emergence of inexpensive wireless sensor technologies (e.g., soil moisture, temperature, and humidity sensors) can result in increased Auto-DR participation for industries such as agriculture and refrigerated warehouses.
3. **Auto-DR inclusion in integrated audits:**
   Tools (e.g., spreadsheet-based templates) can help utility technical assistance providers in screening potential DR candidates and assist utility energy auditors in obtaining better quality information about Auto-DR potential through integrated audits. This

research also focused on collecting and analyzing data from utility integrated audits to support Auto-DR recommendations.

4. **Characterization, guides, and tools to support participation:**
   Market studies, DR strategy guides, and DR software tools can provide targeted subsectors with sector-specific information on effective shed/shift strategies, while the guides and tools help users understand Auto-DR event impacts on their processes and better position themselves for Auto-DR participation. Examples of products produced by the Team include: the Refrigerated Warehouses Demand Response Strategy Guide, the Demand Response Quick Assessment Tool for Refrigerated Warehouses (DRQAT-RW), and the Agricultural Irrigation Demand Response Estimation Tool (AIDRET).

Project Benefits

There appears to be great potential for Auto-DR in industrial facilities, but the drivers for participation differ by company and by sector and are hindered by aversion to risk generally and, more specifically, the perceived lack of control inherent in the term "Auto-DR". The greatest potential for Auto-DR is believed to be in sectors with flexible production schedules and batch processes. To overcome those barriers, the team identified barriers to implementing industrial Auto-DR and next steps for research. Opportunities for further study in each sector are summarized below:

1. **Wastewater Treatment Facilities:**
   a. Studying the effect that modulating variable demand aeration loads has on effluent quality.
   b. Conducting a further study to understand the prevalence of cogeneration in wastewater treatment facilities and its relationship to Auto-DR potential, including utilizing schedulable self-generation and self-starting generation units to contribute to Auto-DR.
   c. Studying emerging purification technologies (ultraviolet lights and membrane technology) and their energy intensities.
2. **Agricultural Irrigation Pumping:**
   a. Conducting an updated study on current electricity consumption related to agricultural water pumping.
   b. Developing more detailed information on irrigation water sources, and irrigation methods (e.g., flood, gravity, micro, drip).
   c. Conducting surveys of large growers to determine their motivations (or lack thereof) for participating in Auto-DR.
   d. Developing methodologies that use emerging sensor and farm automation technologies to provide real-time estimates of DR availability and their impact on the soil moisture.
3. **Refrigerated Warehouses:**
   a. Developing a financial justification for Auto-DR based on electricity cost savings resulting from participation in time-of-use (TOU) and real time electricity pricing programs vs. equipment upgrade capital costs, any additional operational costs, and operational risks.

   b. Conducting a qualitative discussion of intangible benefits and strategic value propositions, such as environmental issues and corporate social responsibility, in the context of their relative importance to a facility.
   c. Promoting and testing the DRQAT-RW software developed by LBNL at various refrigerated warehouses. Expanding on the software's capabilities based on the outcome of field testing.

4. **Data Centers:**
   a. Conducting field demonstrations of all or a subset of Auto-DR strategies for data centers to determine effective strategies, and to evaluate the whole facility load reduction potential against existing baselines.
   b. Identifying emerging data center technologies, vendors, and control strategies to reduce peak electrical loads from data center information technology (IT) and HVAC equipment operation.
5. **Cement Industry:**
   a. Manual tests of DR in cement plants to demonstrate the achievable magnitude, shape, and response time of load reductions.
   b. Development of a strategy guide for DR in cement plants, describing proven approaches to DR implementation and solutions to common obstacles.
   c. A study of the financial value of participation in DR programs compared to other tariff structures, some of which may preclude DR participation.
6. **Dairy Processing Industry:**
   a. Obtaining demand profiles for dairy processing plants in California.
   b. Further analyzing and quantifying the DR potential.
   c. Identifying suitable shed or shift strategies.
   d. Quantifying the risks associated with the identified shed or shift strategies.
   e. Surveying the control capabilities in place.
   f. Addressing specific sub-sectors of the dairy processing industry, particularly cheese making, ice cream, and frozen desserts

CHAPTER 1: Introduction

In 2010, California's peak electric load was approximately 60 GW. The California Energy Commission (CEC) has a goal to achieve 7 to 10 GW of total peak demand reduction and 1 GW of storage capacity, both by 2020 (CEC 2010).

Demand response (DR) is a set of actions taken to reduce electric loads when contingencies such as emergencies or congestion occur that threaten supply-demand balance and/or when market conditions occur that raise electric supply costs. A real-time automated demand response (Auto-DR) infrastructure to optimally manage and link electric supply and demand side systems is becoming increasingly important in the context of the CEC's goals. In 2012 and 2013, two industrial participants contributed 50% of the load reduction for Pacific Gas & Electric's demand bidding program (DBP) and another two industrial participants contributed 25% of Southern California Edison's DBP load reduction.[2] However, they were not participating in Auto-DR. To be most effective, this infrastructure must be compatible with the requirements of electric system grid operators and electric utility companies, including those arising from the assimilation of a greater amount of renewable and clean energy generation capacity, while continuing to serve the loads and needs of electricity customers (Goli et al. 2011).

The Industrial, Agricultural, and Water (IAW) sector accounted for about 30% of California's peak electric load in 2010 and has the potential to be a key contributor to DR and energy efficiency (EE) goals in California. Related benefits could include:

- Jobs, economy - DR implementation requires specialized skills that leverage a history of technology innovation, renewable energy resources, investment capital, and supportive government policies. California is already a national leader in IAW DR and EE programs. As a result, California-based companies could be in a position to provide DR implementation services and technical support to IAW sectors in the rest of the country.
- Industry - Reliability benefits arise from the fact that DR lowers the likelihood and consequences of forced outages that impose operational and financial burden on industrial consumers.
- Market - Lower wholesale market prices, because DR reduces the need to use the most costly-to-run power plants during periods of otherwise high demand, thus driving down overall per unit production costs.
- Ratepayers - Sustained DR lowers aggregate system capacity requirements, allowing utilities to build less new capacity, thus avoiding costs that would otherwise be passed on to retail customers.
- 2020 needs of the grid - DR helps address challenges arising from the assimilation of a greater amount of intermittent renewable and low-carbon generation capacity, while continuing to reliably serve the loads and needs of electricity customers.

[2]California Public Utilities Commission proceedings from November 12, 2014: Demand Response Measurement and Evaluation Committee (DRMEC) Process Evaluation Workshop

1.1 Role of the Demand Response Research Center

Since its formation in 2006, the goal of the Demand Response Research Center's (DRRC) industrial team has been to facilitate deployment of IAW DR that is economically attractive and technologically feasible. To address this goal, the DRRC has spearheaded multi-disciplinary research initiatives involving:

- Customer technology and behavior.
- Policies and tariffs.
- The state of utility markets and technology.

The objectives of these efforts have been to:

- Reduce total utility load during times of critical demand and market conditions.
- Improve the operation of the power grid so that utilities can supply power more reliably.
- Improve the efficiency of the power grid by allowing greater integration of intermittent renewable generation and eliminating the need for inefficient peaker plants.
- In turn, lower the average electricity cost to the consumer.

The IAW area is diverse and an early challenge was to identify specific sectors of promise. However, industrial facilities are not primarily concerned with DR. Instead, their focus is on their own production. So, unless the technology platform is showcased, operational flexibilities are demonstrated, and financial incentives are evident, many facilities are unwilling to consider the potential benefits of DR. In particular, it seems likely that only energy users with Auto-DR capability and economic motivation will reliably contribute to Auto-DR events. This framework guides the IAW research, with the goal of assisting the CEC, the California Public Utilities Commission (CPUC), and the investor-owned utilities (IOU) to more effectively target their Auto-DR efforts.

1.2 Report Overview

The goal of this report is to summarize the end-use analyses and field studies that LBNL carried out over the past decade to improve the understanding of the benefits and challenges involved in implementing Auto-DR in IAW sectors. Chapter 2 describes the market sectors of interest and rationale for selecting them. It also summarizes a 2009 controls survey that identified additional sectors with Auto DR potential. Chapter 3 summarizes the DR-related analyses and field study results in the selected sectors. In particular, it summarizes the contents of sector-specific related papers, Auto-DR Implementation Strategy Guides, software tools, and research reports that have been produced. Chapter 4 summarizes the key outcomes based on the case studies, site measurements, and load shed or shift data from Auto-DR participants. Chapter 5 describes areas of future research that are still needed.

CHAPTER 2: Market Sectors of Interest

Based on preliminary research, refrigerated warehouses, data centers, wastewater/water, aerospace products, and beverage sectors were initially short-listed as low-hanging fruits. After conducting analyses of energy consumption and demand profiles of California industries to identify a better list of ones with the greatest potential for Auto-DR, the IAW team consulted with a technical advisory group of industry experts to vet preliminary findings. The team then conducted in-depth analyses of the selected industrial subsectors, namely: (1) wastewater treatment, (2) agricultural irrigation pumping, (3) refrigerated warehouses, and (4) data centers. An initial study conducted on the cement industry also identified DR opportunities, but further research was not conducted due to the limited number of facilities in California. The dairy processing industry was added to the list of sectors later on. In addition, an industrial controls survey was conducted to determine whether there is a relationship between controls capability (current and planned) and interest in Auto-DR participation.

Throughout this research, the team engaged with industry experts. Building a relationship with industry experts helped to determine further opportunities in particular sectors. For each sector studied, the team defined the market and determined what to research. The results of the market characterization for each sector are discussed below.

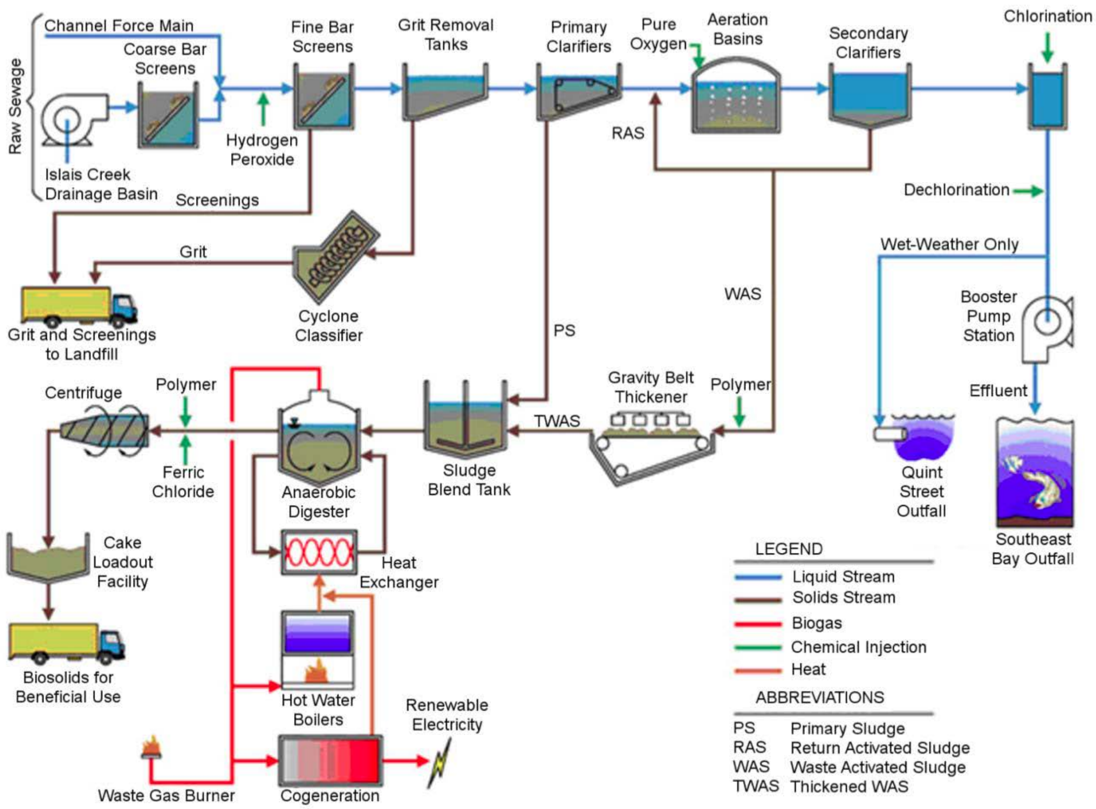
2.1 Wastewater Treatment

The United States uses between 75 and 100 billion kWh annually to treat water and wastewater. Total wastewater treatment needs translate to an average of 100 gallons per day per person and up to a third of a municipality's energy bill. In California, municipal water and wastewater treatment consumes over 13 billion kWh, or about 5% of total energy use in the state. The values mentioned in this paragraph are expected to increase by 20% over the next 15 years due to population growth and in response to more stringent water quality regulations.

In general, as illustrated in Figure 1, wastewater treatment is performed in the following manner:

1. Coarse and suspended solids as well as organic matter are removed through screens and sedimentation in the primary treatment process.
2. Wastewater is then aerated in secondary treatment to raise the dissolved oxygen levels, which helps to promote the growth of microorganisms that remove the remaining soluble and organic material.
3. Finally, nutrients and toxic compounds are removed and the water is chemically disinfected (Thompson et al. 2008). However, the current trend is for facilities to replace their chemical disinfection process with ultraviolet (UV) lights.

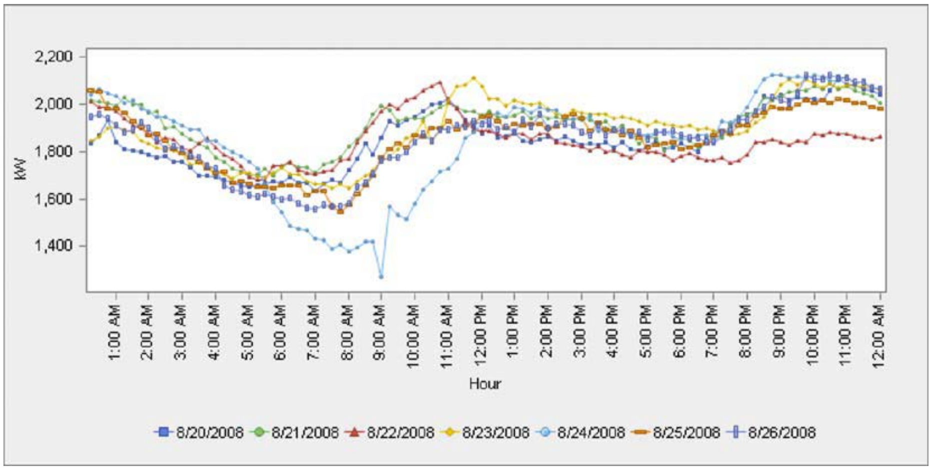
Figure 1: Wastewater treatment process



During the treatment process, a significant portion of the overall expense is for electricity use (Lekov et al. 2009). The majority of this usage is due to the operation of specific energy-intensive equipment such as pumps and aerator fans. For example, the energy required for influent wastewater pumping can range from 15 to 70 percent of the total electrical energy used, depending on the wastewater treatment facility's site elevation and influent sewer elevation. Furthermore, wastewater treatment facilities with diffused aeration systems can use 50 to 90 percent of their facility's power demand to run aerator blower motors. Due to these large values, it is important to examine the energy use of individual equipment in the wastewater treatment process when formulating automated demand response strategies.

Aside from individual equipment use, another consideration when looking at DR strategies in wastewater treatment is load variation. Load variation depends on many factors, which include: seasonal and daily load patterns, location, population size, and whether facilities are municipal or industrial types. For municipal treatment facilities, wastewater flows typically follow a diurnal pattern where the peak flows occur twice a day when wastewater from the peak water use reaches the treatment facility: once in the late morning and a second peak flow during the early evening. Figure 2 shows a sample summer load pattern for a municipal wastewater treatment facility. Industrial wastewater flow rates tend to be less regular and vary depending on the time of day, day of week, season of year, or sometimes the nature of the discharge (Thompson et al. 2008).

Figure 2: Power consumption of a wastewater treatment facility over one week



Control systems are essential for automating demand response strategies in wastewater treatment facilities. The use of centralized computer controls, such as Supervisory Control and Data Acquisition (SCADA) systems in wastewater treatment facilities is increasing by about five percent annually (ARC 2007). The introduction of centralized controls integrates existing standalone controls or distributed control systems, thus improving operational efficiency and facilitating the automation of DR strategies (Goli et al. 2011). Centralized control systems also allow for more efficient overall operation of all facility systems, and provide an entry point to the facility to implement Auto-DR strategies.

In summary, wastewater treatment facilities were selected as one of the focus areas for the following reasons (Lekov et al. 2009):

- Wastewater treatment facilities are energy-intensive facilities and have significant electricity demand during utility peak periods.
- Some wastewater treatment facilities have already implemented energy efficiency measures that can provide a base for participation in Open Automated Demand Response (OpenADR) programs and tariffs.
- Some technologies and control strategies have already enabled successful energy efficiency improvements in municipal wastewater treatment facilities and have the potential to be used for Auto-DR as well.

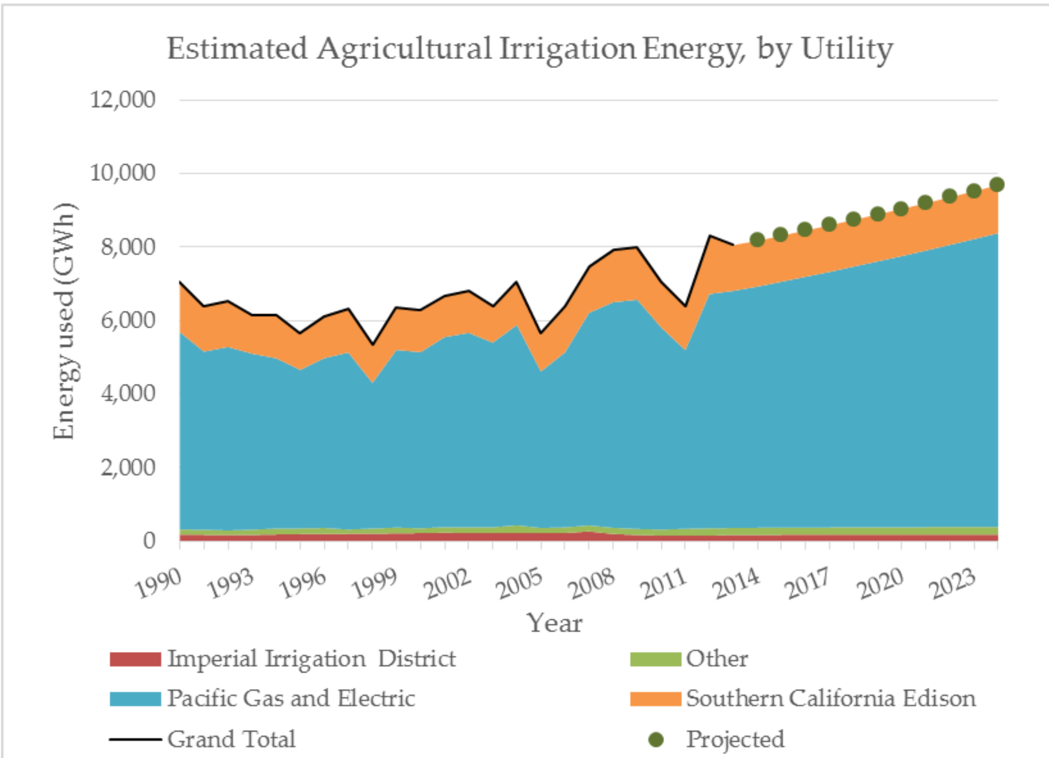
Overall, the potential to schedule the usage of energy intensive process equipment makes this a key sector with promising DR potential. However, because wastewater treatment facilities are often peripheral to major electricity-using industries, they are frequently overlooked for Auto-DR opportunities (Thompson et al. 2008).

2.2 Agricultural Irrigation Pumping

Electrical energy used for agricultural irrigation in California has been estimated by the Irrigation Training & Research Center (ITRC) as approximately 10 million megawatt-hours per year, or 10 terawatt-hours (Burt et al. 2003). This includes energy used by irrigation districts to pump surface water and groundwater, energy used on-farm for groundwater pumping and booster pumping, and energy used to convey water to irrigation districts.

The Energy Commission predicts an annualized growth rate of approximately 1.6 percent per year from 2014 through 2024, as seen in Figure 3. They estimate the total energy consumption of agricultural irrigation to be 8.3 TWh in 2015, and to grow to 9.0 TWh by 2020.

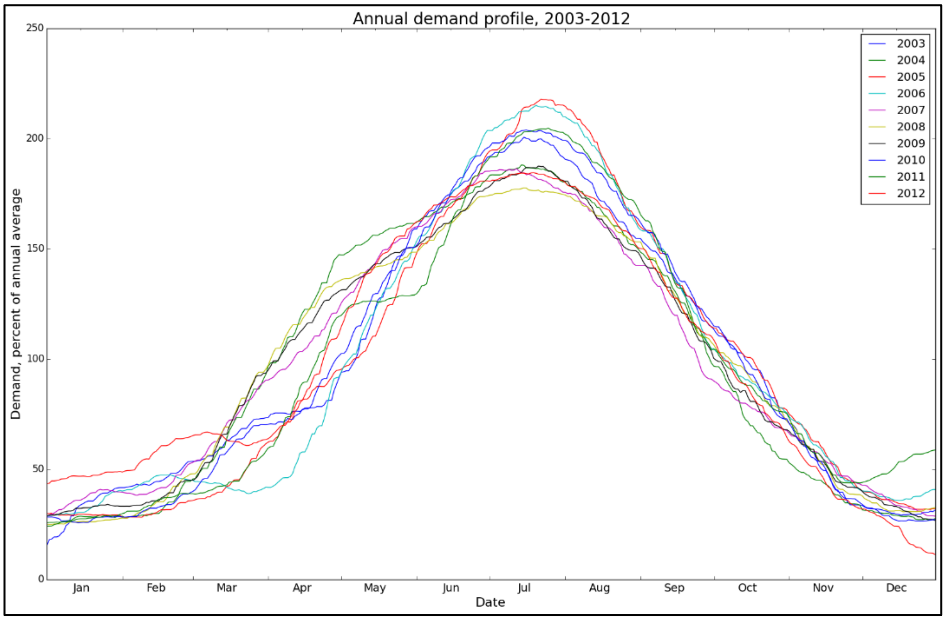
Figure 3: Estimated Agricultural Irrigation Energy



These load growth estimates may significantly underestimate the load growth since 2013, due to the ongoing California drought; the ITRC has estimated that average energy intensity for agricultural water can be twice as high during a sustained drought, compared to a baseline year (Burt and Howes 2005). In a drought, growers must augment dwindling surface water allocations by pumping groundwater, which requires more energy per unit of water. Additionally, sustained groundwater pumping during a drought increases the energy intensity of groundwater because pumps must pull water from deeper in the ground. The combination of these factors can significantly increase the energy intensity of irrigation water.

Because many of the irrigation schedules are intrinsically flexible, significant potential exists to reduce stress on the grid through DR, permanent load shifting, and EE measures aimed at agricultural irrigation power use. Agricultural load is highly concentrated in the summer months, and coincident with the peak demand of the grid as a whole. For example, Figure 4 shows the annual load profile for a large subset of PG&E's agricultural customers.

Figure 4: Annual demand profile for a subset of PG&E agricultural customers, 2003-2012



If agricultural irrigation peak demand is assumed to have increased at the same rate as overall electricity consumption, peak demand should exceed 1,300 MW in 2015, and 1,400 MW by 2020. Assuming a shed rate of 80 percent, the technical potential exists for over 1 GW of DR from agricultural irrigation in 2015, and over 1.1 GW by 2020. With a participation rate of 15 percent, this represents approximately 160 MW of DR potential in 2015, and 175 MW of DR potential by 2020. Therefore, through Auto-DR, irrigation can supplement California's quick response shed capacity, contributing 175 MW to the 4 GW of ancillary services anticipated to be required to maintain grid stability in the context of the 2020 renewable portfolio standards (RPS) deployment goals (Masiello et al. 2010). Furthermore, as California's electricity markets move toward dynamic (real-time) pricing, growers may be significantly motivated to adopt Auto-DR for their irrigation systems in response to price signals.

2.3 Refrigerated Warehouses

The electrical load from California’s industrial refrigerated warehouses in 2008 was about 360 MW with a theoretical potential demand reduction ranging from 45 to 90 MW. These warehouses are well-suited to shift or shed electrical loads in response to utility financial incentives and were selected in 2008 as one of the foci of LBNL’s EE and DR research because:

- They have significant power demand especially during utility peak periods.
- Refrigeration loads account for a significant portion of the facilities’ total energy usage.
- Most processes are not sensitive to short-term (two to four hours) power reductions, so DR activities are often not disruptive to facility operations.
- The thermal mass of the stored product in the insulated spaces can often tolerate reduced cooling capacity for a few hours when needed.
- The number of processes is limited and relatively well understood.

- Past experience with some DR strategies that have been successful in commercial buildings may apply to refrigerated warehouses.

Since robust control systems are considered key to reliable and safe DR participation, an evaluation of 294 facilities was undertaken to identify the current landscape of industrial refrigeration control systems found in the state. The evaluation included a review of the information database developed to characterize these facilities as well as phone conversations with several facility managers. The survey of facility managers and analyses of the facility database yielded the following information concerning the current state of industrial refrigeration controls in California:

- 61% of the 294 surveyed facilities have integrated control systems where each component of the refrigeration system is under the supervisory control of a central controller. Integrated control systems are viewed as the most desirable starting point for control upgrades needed for DR functionality.
- Facilities with integrated control systems tend to be more efficient than their peers; three-fourths of the facilities with integrated control systems were judged to be moderate to high efficiency.
- All facility managers surveyed indicated that an integrated controls system is key to successful and safe DR participation.
- Most of the facility managers surveyed were able to shut off all their cold storage areas for 3 to 6 hours without negatively affecting products.

2.4 Data Centers

Data centers as a sector have large electricity demand (500 MW of peak electricity load in PG&E alone) and are expanding more rapidly than any other industrial sector (EPA 2007). In particular, servers and data centers consume nearly 3 percent of the state's electricity (CEC 2012). This sector has the potential for energy savings and DR by way of prioritizing certain non-time-sensitive data processes (which account for the bulk of the energy usage), and by reducing the amount of "error on the side of caution" overcooling.

Figure 5 shows average daily summer and winter electrical loads with standard deviations, compared to maximum and minimum loads for a mixed data center facility. Higher demand during peak hours (especially in summer months) suggests that data centers are good candidates for DR.

Figure 5: Load pattern for a mixed-use data center facility summer 2007

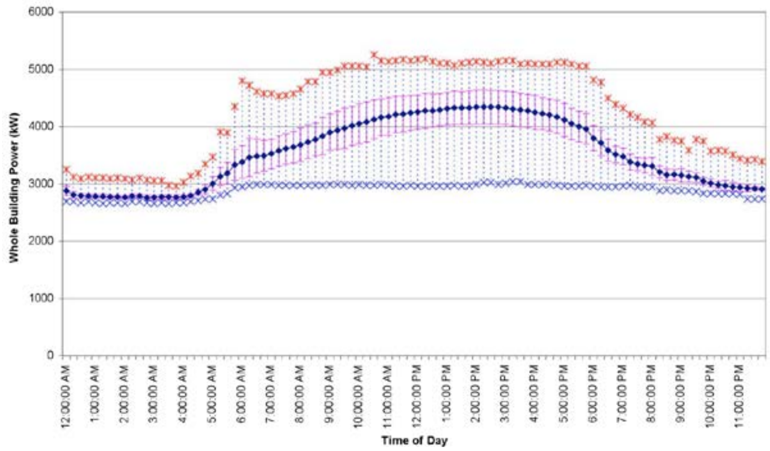
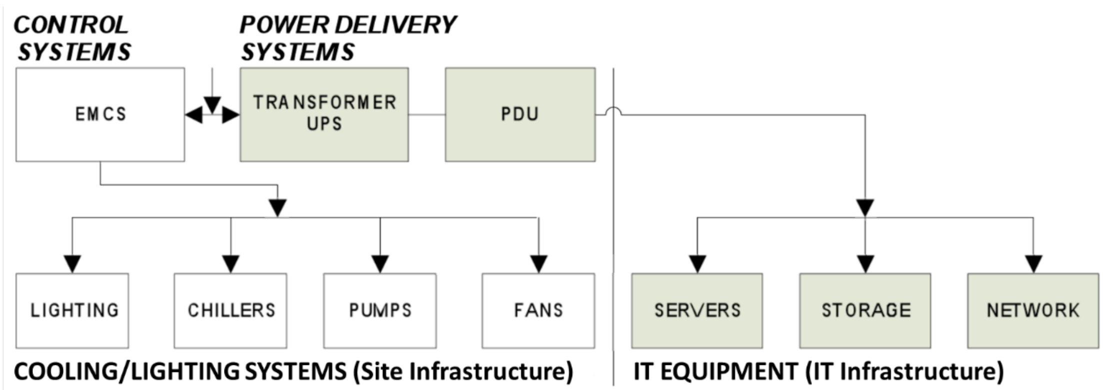


Figure 6 shows a typical data center power distribution architecture. Typically, energy management control systems (EMCS) regulate site infrastructure loads (cooling, lighting, and power delivery systems). If there is no EMCS, energy to these loads is distributed directly by the switchgear (i.e., electric power system), commonly known as the electricity grid.

Figure 6: Typical data center power consumption and distribution architecture



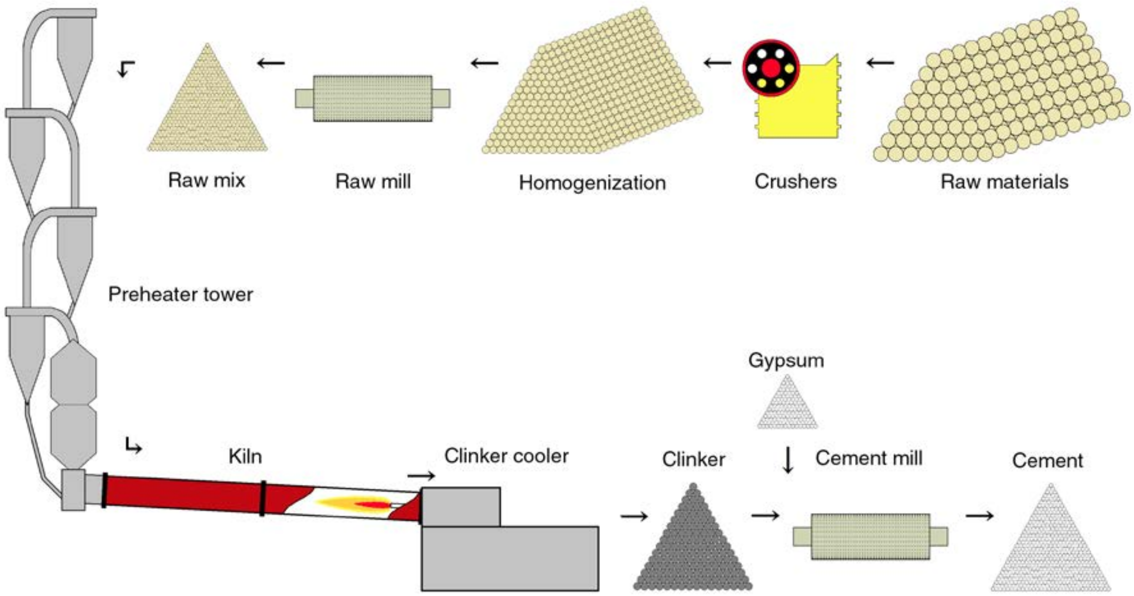
Source: Olsen et. al. 2010

2.5 Cement Industry

Cement plants in California produce more cement than any other state in the nation, and this production represents over 150 MW of electric load. Because the electric load is concentrated in less than a dozen plants, each implementation of DR could yield considerable peak load reduction. A 2005 case study of 31 sites comprising the California cement industry estimated potential annual energy savings of 360 million kWh of electricity and 7.8 trillion Btu of fuel, which together is a 20% reduction compared to 2005 energy use (Coito et al. 2005).

Figure 7 shows an overview of the cement making process and highlights the key equipment.

Figure 7: Diagram of the cement manufacturing process at a modern cement plant



The chemical reactions required to make cement occur only in the cement kiln, and intermediate products are routinely stored between processing stages without negative effects. Cement plants also operate continuously for months at a time between shutdowns, allowing flexibility in operational scheduling.

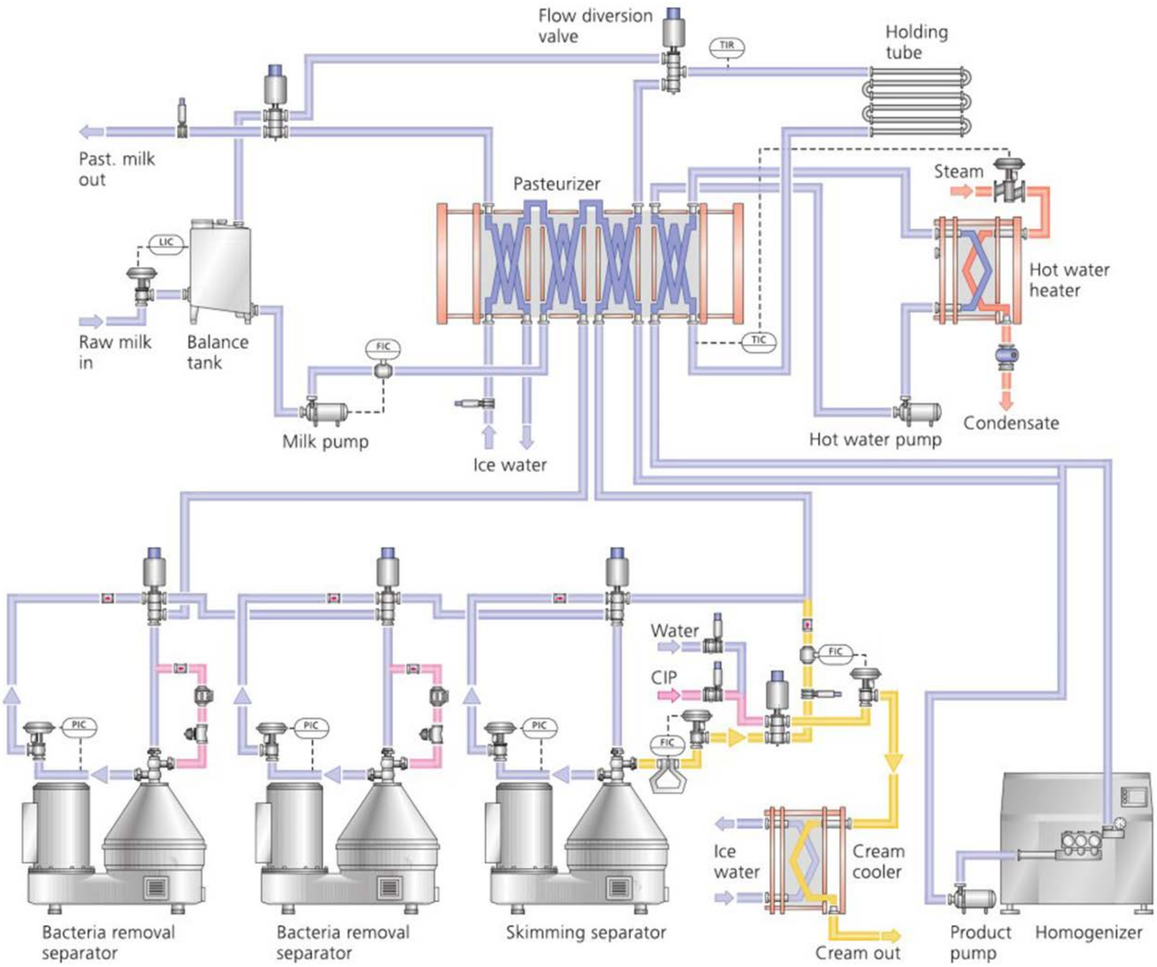
Thus, large energy savings are possible by upgrading mills, separators, and fan drives to more modern, energy efficient models.

2.6 Dairy Processing

The dairy processing industry is a large consumer of energy. In the United States, energy use by the dairy processing industry in 2010 was 30,500 GWh (104 trillion Btu), about a third of which was electricity. Dairy processing involves a diverse group of products and processes and a particular plant may be involved in only one or several different product types. Because of the variety of dairy processing plants, energy intensities can range from 0.11 kWh/L to 0.29 kWh/L.

A representative diagram of the fluid milk production process is shown in Figure 8, which highlights some of the key equipment used in dairy processing facilities. Some plants, however, do not carry out the operations in the same order as shown in this diagram.

Figure 8: Process diagram for fluid milk production



Source: GEA Wesfalia 2010

2.7 Control Systems Capacity

Due to the lack of information on the current state of controls in California industry, in 2009 LBNL conducted a web-based survey (different from refrigerated warehouses control survey mentioned earlier) to gather information on facilities' control capabilities, as well as other factors believed to be pertinent to DR participation. Specifically, there are a set of characteristics that support DR participation, including advanced control systems, predictable loads, and a history of energy efficiency measures. Also, within broad industrial sectors there are many smaller sub-sectors whose operational nuances and thus potential for DR cannot be captured at the broad-sector level. The team worked with key trade associations to initiate the survey.

The survey was tested and deployed, and survey responses were analyzed to ascertain the prevalence of sophisticated control systems and the validity of the researchers' assumptions regarding the link between facilities' operational and technical characteristics and their DR potential. Outreach by LBNL, the California League of Food Processors, and various industry contacts yielded 46 valid survey responses. Preliminary findings obtained from these responses were presented to a group of industrial control experts, whose feedback was used to refine the conclusion.

Analyses of the survey responses showed that, while the vast majority of industrial facilities have semi- or fully automated control systems, participation in DR programs is still low due to perceived barriers. The results also showed that the facilities that use continuous processes are good DR candidates. When comparing facilities participating in DR to those not participating, several similarities and differences emerged. DR-participating and non-participating facilities had similar timings of peak energy use, similar production processes, and similar participation in energy audits. The key characteristics of DR-participating facilities are:

- Higher energy consumption.
- More automated controls.
- More centralized controls.
- Use of controls for peak management.
- On-site generation.
- Delegation of DR decision-making authority to production and facility-level staff.

The results from this study contributed to the industry's technical capacity to voluntarily receive and respond to OpenADR signals that are currently offered by California IOUs. The results also provided an understanding of shifting or shedding non-essential electrical load, and more importantly, helped shape public policies to effectively assist industry in meeting the challenges of real-time pricing in California.

CHAPTER 3: Demand Response in Selected Sectors

3.1 Wastewater Treatment

Research conducted by the IAW Team showed that energy-intensive equipment in the wastewater treatment sector can offer significant potential for DR. Loads can be shed or shifted by: lowering the throughput of aerator blowers, pumps, and other equipment; temporarily transitioning to onsite power generators; anticipatory over-oxygenation of wastewater; or storing wastewater for processing during off-peak periods. In particular, large load reductions can be achieved by targeting effluent pumps and centrifuges.

Opportunities for load *shedding* during DR events include turning non-essential equipment off and transitioning essential equipment to onsite power generators. Generation equipment using diesel or natural gas may be subject to restrictions on annual operating hours, but if biogas can be stored, then it can be used to effectively shift loads outside of peak periods or DR events. Equipment loads that can be potentially shed during peak hours include aerator blowers, pumps, and facility heating ventilation and air conditioning (HVAC) systems. Alternatively, facilities can use variable frequency drives (VFD) to operate this equipment at lower capacity which reduces demand and better matches the requirements for operation within regulatory limits. Centralized control systems can provide wastewater treatment facilities with an automatic transfer to running onsite power generators during peak demand periods. Onsite power generators running on anaerobic digester gas, a byproduct of the treatment process, can also provide off-grid power during DR events. This strategy has been proven successful in municipal wastewater treatment facilities. The East Bay Municipal Utilities District (EBMUD) has implemented a load management strategy that includes a digester cover that stores anaerobic digester gas until it can be used during peak-demand periods.

Implementing load *shifting* strategies in wastewater treatment facilities allows the main energy-intensive treatment processes to be rescheduled to off-peak hours. A major opportunity for shifting wastewater treatment loads from peak demand hours to off-peak hours is over-oxygenating stored wastewater prior to a DR event. This allows aerators to be turned off during the peak period. However, facilities must be careful to monitor and maintain the correct range of aeration since excessive oxygenation due to prolonged detention time can also adversely affect effluent quality. Further, if site conditions allow, wastewater treatment facilities can utilize excess storage capacity to store untreated wastewater during DR events and process it during off-peak hours. Facility processes such as backwash pumps, biosolids thickening, dewatering, and anaerobic digestion can be rescheduled for operation during off-peak periods, thus providing peak demand reductions in wastewater treatment facilities.

To better understand DR at wastewater treatment facilities, three case studies were carried out by LBNL. These 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. A submetering project at the San Luis Rey wastewater treatment plant in Oceanside, CA, confirmed the hypothesized DR potential of centrifuges and effluent pumps, but showed that reductions in aeration load can be unacceptably detrimental to effluent quality. Successful DR was demonstrated at two 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 plant, while there appeared to be significant potential, the facility staff were reluctant to undertake any significant DR testing for operational and organizational reasons (Olsen et al. 2012).

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.

The research indicates that, under the appropriate conditions, wastewater treatment facilities are excellent candidates for OpenADR and that, of the sectors studied, the major opportunities for DR are most applicable to wastewater treatment facilities in the food processing industry as well as in municipalities. Key findings of this work are summarized below:

- 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.

3.2 Agricultural Irrigation Pumping

An initial scoping study in the agricultural sector (Marks et al. 2013), which was funded by the PIER program, generated interest in Auto-DR for irrigation pumps. The scoping study was carried out with the following objectives:

- Parse the California irrigation load into categories using criteria such as growing regions, water sources, irrigation methods, and crop types. Then, examine the categories to determine how to focus efforts to gain the highest potential impact from DR and permanent load shifting programs.
- Determine where the best opportunities lie for DR and permanent load shifting programs in California agricultural irrigation.
- Suggest possible DR and EE solutions where applicable.
- Make an initial limited determination for potential acceptance among California growers and what challenges and obstacles might exist for DR and permanent load shifting programs.
- Identify follow-up studies for the best opportunities for DR and EE including more extensive field studies and surveys of growers to assess potential acceptance.

Some of the positive benefits of DR in the agricultural irrigation water pumping sector may potentially be accomplished effectively with permanent load shifting, which are often incentivized by way of Time-of-Use (TOU) programs. However, it is expected that there would still be a significant opportunity for peak-period DR, because not all irrigation would be shifted off-peak. At certain times of the year, some crops are irrigated nearly continuously because the capacity of the irrigation system is close to the needs of the crops during highest evapotranspiration periods, or because of the nature of the crop itself. Furthermore, DR events are not restricted to peak times, so even when an irrigation system is run exclusively during off-peak times, there is still potential for DR participation.

DR programs tailored toward agricultural irrigation customers have been successfully launched by many utilities throughout the Midwest and western United states. Notable examples that have published their approaches and results include Idaho Power's Irrigation Peak Rewards program, Rocky Mountain Power's Irrigation Load Control program, and Southern California Edison's Agricultural and Pumping Interruptible tariff. Table 1 provides details about these programs, as well as four others.

Table 1: Summary of irrigation demand response programs

Utility	Program Name	Dates of Case Studies	Shed Rate	Largest Shed Magnitude
Pacific Gas and Electric Company	Aggregator Managed Program	June 2011 - Sept. 2013	68% (average)	15 MW (8/9/2012)
	Capacity Bidding Program	June 2011 - Sept. 2013	76% (average)	9.2 MW (7/10/2012)
	Peak Day Pricing	June 2011 - Sept. 2013	35% (average)	0.9 MW (7/19/2013)
Southern California Edison	Agricultural and Pumping Interruptible	2008, 2010-2012	57%-85% (by event)	40 MW (7/29/2010)
Idaho Power	Irrigation Peak Rewards	2005, 2007 -2012	*Not available*	221 MW (7/9/2010)
Rocky Mountain Power	Irrigation Load Control (Idaho)	2009-2011, 2013	*Not available*	247 MW (2009 avg.)
	Irrigation Load Control (Utah)	2009-2013	*Not available*	49 MW (2010 avg.)
Midwest Energy	Pump Curtailment Rider (Pump$mart)	2010-2013	*Not available*	23 MW (controlled)
NV Energy	Interruptible Irrigation Service	2009-2013	~70% (estimate)	~25 MW (7/19/2009)
Golden Spread Electricity Cooperative	Irrigation Load Control	2009-2012	*Not available*	58 MW (7/6/2012)

There are constraints, however, that limit the participation of growers in DR programs. These constraints include limitations in the following areas:

- **Irrigation capacity**: Many farms have irrigation systems that are sized to just barely meet crop water demands during the peak of summer, and may even be under-sized, precluding participation in DR events. This constraint can be mitigated by upgrading irrigation systems or reconfiguring systems to operate more efficiently.
- **Water delivery schedules**: Farms that receive surface water deliveries are often not allowed to change their delivery schedule without significant advance notice. This constraint can be relaxed with greater flexibility from irrigation districts.

- **Application method**: Certain irrigation methods (e.g., flood irrigation) are not as flexible in stopping and re-starting irrigation as others (e.g., sprinkler irrigation). This constraint can be mitigated by changing irrigation methods.
- **Flexibility of labor**: Because many irrigation methods require onsite labor to oversee or operate irrigation equipment, this labor must be willing to adjust their schedule as necessary to participate in DR events. This constraint can be mitigated by the installation of automated and/or remotely controlled irrigation systems.
- **Communications and controls**: Successful DR load sheds require that the grower be notified of the event with sufficient time to adjust pumping loads, and this notification results in successful control of the pumps. This constraint can be mitigated by installing automated controls and communication equipment.
- **Insufficient financial incentives**: Because growers are first and foremost operating a business, the financial incentives must make DR participation compelling. This constraint can be mitigated by increasing the incentives available to growers and by reducing the costs to automate, control, and connect irrigation systems.

Despite these constraints, irrigation DR programs have been successful. In the review of DR programs (Table 1), shed rates of 80 percent are common (relative to baseline load), and participation rates have been as high as 20 percent. When these values are applied to the estimated peak load of irrigation pumps in California, they represent approximately 160 MW of DR potential in 2015, and an anticipated 175 MW of DR potential in 2020. The technical potential (assuming full participation) could be as much as 1 GW in 2015 and 1.1 GW in 2020.

This potential is large, but it must be exercised carefully. Many of the major crops grown in California are high-value crops (e.g., orchards, vineyards, nut trees, vegetables), and therefore the cost of irrigation electricity is a smaller fraction of the value of the crops, compared to crops such as grains or hay. This means DR participation entails a higher risk-to-reward ratio to growers of high-value crops, and consequently these growers may be less willing to participate. In addition, agricultural distribution feeders often have low diversity in their types of customer loads, and the exercise of a large number of irrigation pumps on a single feeder can cause over-voltage issues, as has been observed in Rocky Mountain Power's Irrigation Load Control program. This issue can be ameliorated by strategic staging of pump shutdowns, which requires a higher level of controls and automation.

As a direct result of the scoping study described at the start of this section, PG&E funded the team to develop an Agricultural Irrigation Demand Response Estimation Tool (AIDRET). AIDRET creates a consistent and standardized methodology for assessing a farm's DR potential. The long term goal for AIDRET is that it will be used for screening utility DR candidates. Developing the tool has resulted in a greater appreciation for the parameters that need to be evaluated to determine a farm's DR potential. Additional funding from the CEC led to further enhancements of AIDRET and the development of an Interactive Public Tool for Irrigation Pumping. Throughout this process, the team partnered with academic (Center for Irrigation Technology at Fresno State University) and industry (Observant Inc.) representatives, which resulted in further ongoing agricultural irrigation Auto-DR research.

Key findings of this research are summarized below:

- Most of the energy used for irrigation occurs in the Central Valley of California (Sacramento and San Joaquin Valleys combined), especially in the San Joaquin Valley.
- The greatest energy per unit of water applied occurs in the coastal growing regions.
- The greatest energy use by water source comes from the on-farm sources, and in particular, from ground water sources.
- There is a continuing trend toward converting from flood to drip/micro irrigation, which while reducing the amount of water applied, increases the amount of energy used.
- There is a strong Pareto Principle[3] correlation of grower size with regard to acres irrigated and therefore to irrigation energy use. About 14% of the growers (approximately 6,500) irrigate 84% of the irrigated acres in California agriculture, or roughly 6.2 million acres.
- The growing regions' utility coverage is dominated by a few utilities, but especially by PG&E.
- Adoption of more advanced farm management hardware and software technologies (VFDs, pump monitoring, controls, soil moisture sensing, and irrigation scheduling) will increase DR participation. These technologies will also provide better on-farm energy and water management.
- On-site grid-tied solar power, which generates peak-power mid-day coincident with the grid's peak periods, would offset a part of the daytime pumping load and move a greater share of the agricultural pumping energy off-peak.
- Floating photovoltaic (PV) installations on irrigations ponds can help farmers utilize unused land, reduce loss of water through evaporation, and increase PV efficiency by keeping them cooler than ground-mounted installations.

3.3 Refrigerated Warehouses

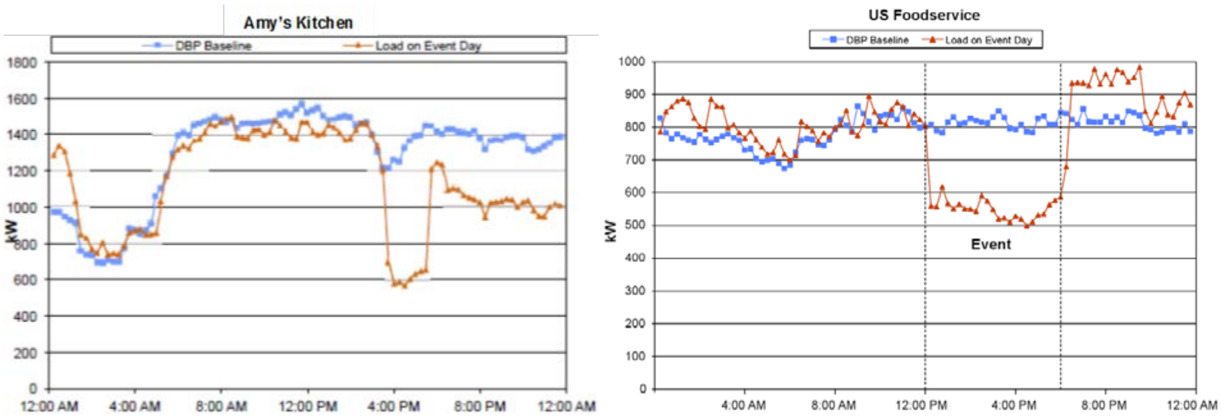
Industrial refrigerated warehouses that have implemented EE measures and have centralized control systems can be excellent candidates for Auto-DR due to equipment synergies, and the receptivity of facility managers to strategies that control energy costs without disrupting facility operations. In particular, there is a potential for load sheds and shifts from baseline electricity use in response to DR events.

Two case studies and analyses of operating data from several facilities in PG&E’s territory confirmed the DR abilities inherent to refrigerated warehouses, but showed that there can be significant variations across facilities (Figure 9). For example, several studies of utility-incentivized Auto-DR implementations were carried out involving Amy’s Kitchen and U.S. Foodservices. Amy’s Kitchen successfully curtailed its electricity demand by 580 kW (about 36% of facility’s baseline demand). U.S. Foodservice was able to shed an average of 25% of its load

[3] The Pareto Principle (also known as the "80-20 rule" or the "law of the vital few") states that in many systems, roughly 80% of the effects come from 20% of the causes. Though the number 80% is not mathematically significant, this rule of thumb is a good approximation in many real-world examples.

(more than 200 kW) during testing without adverse effects, with a maximum shed of 41% (330 kW).

Figure 9: Energy performance of Amy's Kitchen and U.S. Foodservices



In addition, manual DR data from nine PG&E industrial refrigerated warehouse customers were analyzed for load sheds and load shifts from baseline during the 2009 critical peak pricing (CPP) season (May 1, 2009 to October 31, 2009). The facilities studied had baseline electricity consumptions ranging from 150 kW to 1.3 MW and typical load sheds of 20 to 40% were observed. A food processing facility achieved a peak 90% shed via manual DR.

Other findings of the years of studies in refrigerated warehouses are listed below:

- Facilities that had implemented Auto-DR programs demonstrated consistent DR results.
- Improved controls associated with Auto-DR may prepare facilities to be more receptive to EE and DR in general due to both increased confidence in the opportunities for controlling energy cost/use and access to real-time data.
- It was also noted that control technologies installed for EE and load management purposes can often be adapted to use the OpenADR protocol at a reduced incremental cost.
- While cold storage provides a significant potential for load reduction, other facility end uses may also offer opportunities for load reduction. One facility analyzed was able to reduce its load by 28 percent primarily with cold storage reductions. Another site was able to reduce its load by 21 percent primarily by reducing other end-use demand. Cold storage was shown to comprise a large percent of the electricity load in refrigerated warehouses, making it the primary target for load shedding or shifting.

As a result of the above-mentioned studies, LBNL and VaCom Technologies collaborated on drafting a "Refrigerated Warehouses Demand Response Strategy Guide". The guide is intended to assist refrigerated warehouse owners and operators in making strategic decisions related to implementing an electric demand management strategy at their facility, including DR. This guide expands on the complex relationship between EE and DR. The work explores which EE measures increase operating flexibility (e.g., improved DR), when coupled with smart controls; as well as which measures and methods serve a dual purpose (i.e., to the benefit of both EE and DR). The work also points out where certain measures could work at cross purposes (i.e., with competing objectives to the detriment of DR, EE, or owner's cost), and how these competing objectives can be balanced through more integrative analysis, design, and control. Finally, the guide also distinguishes between DR and permanent load-shift strategies, and weighs the benefits and challenges of both approaches.

The guide incorporates the findings from field studies that were conducted at several different refrigerated warehouses in California, in which air temperature and product surface temperature were measured before, during, and after simulated demand response events. The guide explores the role played by air temperature, product mass, building mass, and various construction features on the space temperature during steady-state operation, and the temperature rise during demand response events. The guide also describes which warehouse usage characteristics, maintenance circumstances, and design features combined to produce local areas of relatively warm air during steady-state operation, and/or contribute the most to space temperature rise during demand response events. Factors such as air circulation, space geometry, construction vintage, infiltration air volume, management tactics, and evaporator fan speed are considered.

As a final result, a Demand Response Quick Assessment Tool for Refrigerated Warehouses (DRQAT-RW) was developed and tested at a large cooler facility in Southern California. The tool can make accurate recommendations about EE and DR potential in individual refrigerated warehouses. The objective of this tool is to provide a reliable way for simulating the operations of individual refrigerated warehouse facilities. The results of this tool will help warehouse owners and operators to better position themselves for DR participation.

3.4 Data Centers

The research involved a series of field tests to evaluate and improve understanding of the feasibility and adoption of DR in data centers. It identified a set of potential DR strategies for site infrastructure (e.g., HVAC, lighting) and IT infrastructure (e.g., servers, storage, networking) loads for data centers.

The results from implementing manual DR strategies for both IT equipment (server, storage) and site infrastructure (cooling) showed that similar data centers can participate in DR programs with no impact to operations or service-level agreements, which were set by the data center operators. In certain instances, a small IT equipment load shed strategy produced a demand savings of 25% at the data center level or 10% to 12% at the whole building level. As data center site infrastructure becomes more efficient with lower power usage effectiveness (PUE), a large DR opportunity is within the IT equipment, with larger savings when combined with DR automation and integration with the cooling systems. With the growth in cloud computing, the load migration strategies that are unique to data centers can enable participation in DR and price-responsive programs such as ancillary services. The strategies can also address intermittency issues with renewables and other issues with minimal or no impact to a data center's day-to-day operation.

The following DR strategies were identified for data centers:

- Server and computer room air conditioning (CRAC) unit shutdown

- Load shifting or queuing IT jobs – Server idling
- Temperature set point adjustment
- Cooling relative to IT equipment load reduction
- Load migration between homogeneous and heterogeneous systems

The above mentioned strategies were field tested at four different data centers.[4] The DR tests resulted in 5 to 10 percent load sheds with response periods ranging from 2 to 22 minutes. 175 minutes of response time was recorded for the "Heterogeneous Load Migration[5]" strategy (Ghatikar et al. 2012).

Although the results are encouraging, it represents a small dataset. More field-tests of component-level performances, data center types, and automation is necessary for wide scale DR adoption. Obstacles to DR implementation in data centers include the perceived risk to equipment with increased temperature and humidity set points, the lack of control over some servers in certain data center configurations (such as co-location), and the current lack of information on DR activities at data centers. The enabling technologies need to link data center operational requirements with the supply side systems, and provide aggregation to visualize metered DR information. The evolving DR market design must describe the value proposition, the measurement and verification models, and how it can benefit a data center's social, economic, and efficiency goals.

3.5 Cement Industry

Research in this sector examined the ability of cement plants to shed or shift load to participate in DR. It indicated that DR strategies are indeed feasible, with the large grinding mills as the largest demand response targets. However, the specific strategy varies widely from site to site: DR strategies that are easy at one site may be impossible at another. Nevertheless, the potential for DR is high and significant reduction in energy demand during peak hours and critical peak times is possible.

As an example of the DR potential, energy use data were collected and analyzed from the Lehigh Permanente cement plant in Cupertino, California. During summer months, the plant's energy use is scheduled around an electricity tariff that incorporates weekday off-peak, partial-peak[6], and on-peak hours. During weekdays in August 2009, the average partial-peak demand was 5 MW less than during off-peak hours, and average on-peak demand was 9 MW less than during off-peak hours, as seen in Figure 10. Weekdays in September 2009, during a kiln shutdown, average on-peak demand was 6 MW less than during off-peak hours, as seen in Figure 11. These load shifts were accomplished by scheduling the raw mills and quarry

[4] Network Appliance (NetApp), LBNL Building 50, San Diego Supercomputer Center (SDSC), and University of California Berkeley's Shared Research Computing Services.

[5] Heterogeneous systems consist of different IT equipment and processing capabilities in two data centers between which the load migration is occurring.

[6] According to PG&E: Winter has two rate periods: off-peak and partial-peak. Summer has three: off-peak, partial-peak and peak.

operations based on time-of-use energy costs. Stores of crushed limestone and raw mix at the plant are large enough to last for days if necessary, so responding to a demand response event by shutting down raw mills and quarrying should have no impact on plant operation.

Figure 10: Electrical power used by Lehigh Permanente weekdays during August 2009

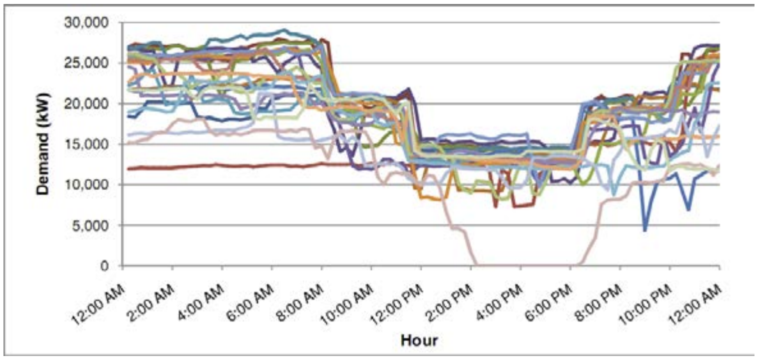
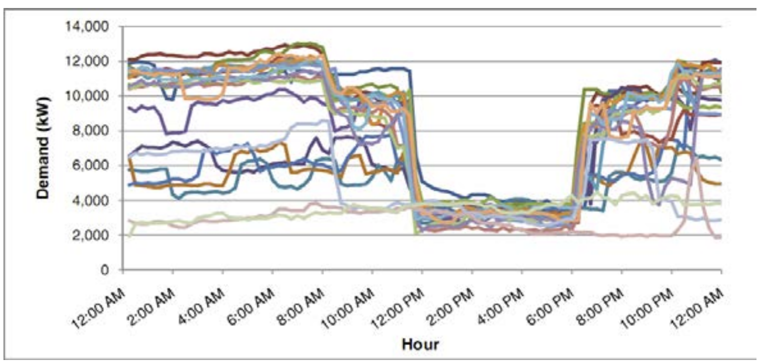


Figure 11: Electrical power used by Lehigh Permanente weekdays during September 2009



3.6 Dairy Processing

Work in this sector identified process cooling, refrigeration, packaging, separation, machine drives (e.g., churning and pumping) and "clean in place" as the major electricity consuming processes. Available data (Sikirica et al. 2003) indicate that dairy production and product energy intensities are flat year-round. This characteristic will result in a flat annual load profile. However, actual daily load profiles for dairy processing facilities are still needed to help us better quantify the demand response potential. This study also found that barriers for adopting demand response in the dairy industry include: perishability of products, little excess capacity, insufficient storage capacity relative to incoming shipments, the need to comply with a complex regulatory regime, and the need to clean if processes are interrupted (Homan et. al. 2015).

Despite limitations on major process equipment to participate in demand response, load sheds of 3.3 MW and 1 MW were achieved at two different facilities. There is also a large potential for plants to run on backup power, solar energy, or cogeneration. Also, dairy plants have energy uses that overlap with other sectors previously evaluated for demand response, including refrigerated warehouses and wastewater treatment. Lastly, dairy plants have generic energy uses common to many types of buildings such as facility HVAC and lighting, which can be good candidates for demand response.

Conducting further demand response case studies and facility submetering could shed more light on the full demand response potential of this sector.

CHAPTER 4: Conclusions

As of 2010, the Industrial-Agricultural-Water (IAW) sector accounts for 30% of the 60 GW of peak electric load in California in 2010, and thus has the potential to be a key contributor to the DR and EE space. In particular, it has the potential to generate a wide range of energy related benefits for the State of California. These include increased reliability of the electrical grid, lower costs of generating electricity, providing electricity "storage capacity" for the assimilation of a greater amount of intermittent renewable resource generation capacity, and the creation of associated specialized jobs.

The DRRC's IAW Team research has been primarily focused on the sectors of wastewater treatment, agricultural irrigation, refrigerated warehouses, and data centers. In addition, the Industrial Controls Survey identified characteristics that appear to be conducive to DR ability in these sectors. That is, adequately sophisticated control technologies installed for EE and load management purposes can often be adapted for DR and Auto-DR at reduced incremental cost. Auto-DR may be utilizable to more consistently achieve peak period load reduction without impacting operations.

The four key outcomes of this work were:

1. **Auto-DR opportunity validation:** The team determined that there is a wide range of sometimes substantial opportunities for Auto-DR in selected industries through load shedding/shifting. This finding was supported by case studies and field tests, examples of which include:
    a. The team's initial research led to some early success in identifying subsectors, such as industrial gases, that were particularly well suited to Auto-DR due to their controls and manufacturing processes. Three industrial gas facilities enrolled in Auto-DR during this period, representing most of the subsector, with a total shift capability of nearly 25 MW. Through collaboration with the utilities' technical assistance providers (e.g., Global Energy Partners), the total industrial Auto-DR participation rose to nearly 40MW by the end of 2008.
    b. A controls system upgrade at Amy's Kitchen in 2008 enabled Auto-DR there. Auto-DR tests at that refrigerated warehouse yielded better than expected results with no product loss or production delay. Auto-DR resulted in a 36% load shed at the facility, reducing 1,600 kW of baseline load to 580 kW, which was greater than the expected 162 kW.
    c. Several wastewater treatment facilities documented their implementation of load management and energy efficiency 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.
    d. A verification study was carried out on actual farm DR applications using the Agricultural Irrigation Demand Response Estimation Tool (AIDRET). Results

produced by AIDRET were within 7% of the DR recommendations made by a third party auditor.

   e. Throughout this research, the team engaged with industry experts. Building a relationship with industry experts helped to determine further opportunities in particular subsectors.

2. **Control capabilities matter:** The team determined that Auto-DR is compatible with energy efficiency and load management in industrial facilities, but many industries have limited controls capabilities, especially for supporting or non-core systems that may be suited for Auto-DR.
   a. **Importance of trade association collaboration:** The team worked with key trade associations to initiate a survey that establishes a link between Auto-DR participation and controls capability in California's industrial facilities.
   b. **Survey findings:** Characteristics supporting Auto-DR are: advanced control systems, high-energy use, predictable loads, a history of energy efficiency measures, and participation in energy decision-making by production and facilities managers.
3. **Auto-DR inclusion in integrated audits:** The team developed and used tools (e.g., spreadsheet-based templates) to assist utility technical assistance providers in screening potential DR candidates. Additionally, the team developed tools to assist utility energy auditors in obtaining better quality information about Auto-DR potential through integrated audits. This research also focused on collecting and analyzing data from utility integrated audits to support Auto-DR recommendations.
4. **Characterization, guides, and tools to support participation:** The team developed market studies, DR strategy guides, and DR software tools for the targeted sectors. Market studies supported by field tests helped the team to identify effective shed/shift strategies, while the guides and tools helped users understand Auto-DR event impacts on their processes and better positioned them for Auto-DR participation. Examples include:
   a. **Refrigerated Warehouses:** A market characterization study and partnership with VaCom Technologies (a Technical Advisory Group participant) resulted in development of an Auto-DR strategy guide for refrigerated warehouses. These studies led to the development of the Demand Response Quick Assessment Tool for Refrigerated Warehouses (DRQAT-RW).
   b. **Agricultural Irrigation Pumping:** An initial scoping study in the agricultural sector, which was funded by the PIER program generated interest in Auto-DR for irrigation pumps. As a direct result of this study, PG&E funded the team to develop an Agricultural Irrigation Demand Response Estimation Tool (AIDRET). Additional funding from the Commission led to further enhancements of AIDRET and the development of the Interactive Public Tool for Irrigation Pumping. Throughout this process, the team partnered with academic (Center for Irrigation Technology at Fresno State University) and industry (Observant Inc.) representatives, which resulted in further ongoing Agricultural Irrigation Auto-DR research.

CHAPTER 5: Areas of Future Research

Potential barriers and outstanding issues to be addressed through future research include the fact that industrial facilities are not primarily concerned with DR – instead, their focus is on their own production. Therefore, unless the technology platform is showcased, operational flexibilities are demonstrated, and financial incentives are evident, many facilities are not willing to consider the potential benefits of DR. Further research, case studies, and technology demonstrations are still needed to address these issues and promote Auto-DR in the IAW sector. Areas of future research for each sector are summarized below.

5.1 Wastewater Treatment

- Enhancing understanding of the effect of aeration blower shutdown on secondary effluent quality.
- Utilizing the results of the Industrial Controls Survey and discussions with control experts to better understand existing controls capability in wastewater treatment facilities.
- Conducting a further study to understand the prevalence of cogeneration in wastewater treatment facilities and its relationship to Auto-DR potential, including utilizing schedulable self-generation and self-starting generation units to contribute to Auto-DR.
- Continuing to survey the literature for case studies and technology advances that might affect OpenADR potential.
- Scaling and standardizing the OpenADR protocol for control systems to apply to wastewater treatment facilities to reduce implementation cost, and increase DR reliability and effectiveness.
- Improving the understanding of how facility operators impact the effectiveness of DR strategies and identifying the best operation practices and behaviors to enhance the impact of DR activities.
- Performing field studies to add to the body of knowledge about OpenADR implementation experience in wastewater treatment facilities.
- Develop the DR Quick Assessment Tool for wastewater treatment facilities, building on existing DR Quick Assessment Tools for office, retail, and refrigerated warehouses. This would benefit wastewater treatment facility operators by providing them with the capability to assess facility performance within some range of performance criteria, thus enhancing their capabilities to implement OpenADR.
- Wastewater treatment plants may have the flexibility to use their intermediate wastewater treatment stages as a non-thermal process/material storage medium. Evaluation of the conditions under which this characteristic can be harnessed for load shifting/shedding and grid response is recommended as part of the future research.
- Although not included in the scope of the previous work of the DRRC, innovations in renewable energy for use at wastewater plants (e.g., photovoltaics and methane capture for fuel cell application) have been identified for further review.

5.2 Agricultural Irrigation Pumping

Although we have been able to document the potential for DR in California agriculture and its constraints, there are still gaps in the knowledge base necessary to accurately predict DR. Further research to improve the robustness of this topic could include:

- An updated study on the current electricity consumption related to agricultural water.
- More detailed information on the population of California growers (e.g., crops grown, water sources, and irrigation methods).
- Surveys of large growers to determine their motivations (or lack thereof) for participating in demand response.
- Comprehensive studies on the current agricultural irrigation energy demand and estimates of DR potential.
- Analysis and recommendations on gaining grower acceptance for permanent load shifting, DR, and AutoDR.
- Field studies on the interactions between irrigation system, EE, and DR.
- Further testing and verification of AIDRET results and promoting the use of advanced software and hardware technologies for irrigation and agricultural DR.

5.3 Refrigerated Warehouses

For future research and to facilitate more effective outreach and targeting of the warehouses that are most capable of DR from a technical as well as operational standpoint, the recommended next steps are:

- Developing a financial justification for Auto-DR based on electricity cost savings resulting from participation in time-of-use (TOU) and real time electric pricing programs vs. equipment upgrade capital costs, any additional operational costs, and operational risks.
- Conducting a qualitative discussion of intangible benefits and strategic value propositions, such as environmental issues and corporate social responsibility, in the context of their relative importance to a facility.
- Continuing to perform field studies, or to team up with partners who are in a position to share such data, to add to the body of knowledge about OpenADR implementation experience in the refrigerated warehouse sector; and to collect data to quantify the impact and relationship between parameters that affect the success of automated demand response strategies, including the impact of product mass, storage facility envelope, cooling capability, and varying ambient conditions.
- Continuing to survey the literature for case studies and technology advances that might affect OpenADR potential.
- Coordinating with California utilities to develop a better understanding of the life cycle of the existing stock of refrigerated warehouses, both for equipment and structural.
- Scaling and standardizing the OpenADR for control systems to apply to refrigerated warehouses to reduce implementation cost, and to increase DR reliability and effectiveness.

- Improving the understanding of how facility operations impact the effectiveness of DR strategies and identifying the best operation practices and behaviors to enhance the impact of DR activities.
- Improving marketing and recruitment of industrial refrigerated warehouse sites for DR incentive programs to increase low participation rates. Emphasize the financial benefits of participation in DR, the improved consistency of participation resulting from Auto-DR, and the absence of adverse effects on operations arising from participation via Auto-DR.
- Categorizing and analyzing the different types of refrigerated warehouses to identify whether a particular type/size of refrigerated warehouse is more ideally suited for realizing these opportunities.
- Developing recommendations concerning how policies could be framed and grants/loans structured to incentivize facility managers and utilities to capitalize on these opportunities.
- Larger scale deployment and testing of the DRQAT-RW software tool. This effort would further validate the functionality of the tool and make improvements based on user feedback. LBNL would work with industry partners such as VaCom Technologies, Energy Solutions, and Investor Owned Utilities to promote the use of DRQAT-RW. The following enhancements can further enhance the tool’s functionality:
    - Automated optimization of EE and DR strategies to produce greatest demand and cost reductions while maintaining the food quality.
    - Make weather data customization more user friendly and enable real weather data use for simulation.
    - Develop a model auto-calibration procedure to improve the model prediction value.

5.4 Data Centers

- Conducting field demonstrations of all or a subset of Auto-DR strategies for data centers to determine effective strategies, and to evaluate the whole facility load reduction potential against existing baselines.
- Identifying emerging data center technologies, vendors, and control strategies to reduce peak electrical load(s) from data center IT and HVAC equipment operation.
- Evaluating data center data management approaches, monitoring systems, connectivity requirements, and control system designs that will lead to a better understanding of the sequence of operations needed for in-depth DR strategy analysis.
- Providing education and outreach aimed at high-tech companies and organizations, such as the Green Grid, to advance DR as a higher technical priority.
- Identifying DR-ready, scalable, vendor-neutral, energy-efficiency technologies that can integrate within the existing utility Auto-DR infrastructure.
- Evaluating measurement metrics for combined IT and site infrastructure performance during DR events to permit calculation of load shed, settlement, and economic value.

- With increasing grid integration with intermittent energy resources (such as wind/solar), determining the flexibility of data center loads to respond with different DR program dispatches.

5.5 Cement Industry

Even though a limited number of sites exist in California, the following areas are identified for further study:

- Manual tests of demand response in cement plants to demonstrate the achievable magnitude, shape, and response time of load reductions.
- Analysis of the potential for cement plants to participate in Auto-DR, incorporating technical and regulatory barriers.
- The development of a strategy guide for DR in cement plants, describing proven approaches to DR implementation and solutions to common obstacles.
- A study of the financial value of cement plant participation in DR programs compared to other tariff structures, some of which may preclude DR participation.

5.6 Dairy Processing

The purpose of this study was limited: to create an initial description of the dairy processing industry with regard to DR through review of the existing literature and consultation with industry representatives. Future research should focus on the following areas:

- Obtaining demand profiles for dairy processing plants in California.
- Further analyzing and quantifying the demand response potential.
- Identifying shed or shift strategies suitable for the dairy processing industry.
- Quantifying the risks associated with the identified shed or shift strategies.
- Surveying the control capabilities in place.
- Addressing specific sub-sectors of the dairy processing industry, particularly cheese making and the ice cream and frozen desert sector.

GLOSSARY

Term	Definition
AIDRET	Agricultural Irrigation Demand Response Estimation Tool
Auto-DR	Automated Demand Response
Btu	British Thermal Unit
CAISO	California Independent System Operator
CEC	California Energy Commission
CPUC	California Public Utilities Commission
CPP	Critical Peak Pricing
DBP	Demand Bidding Program
DOE	U.S. Department of Energy
DR	Demand Response
DRRC	Demand Response Research Center
DRQAT-RW	Demand Response Quick Assessment Tool for Refrigerated Warehouses
EBMUD	East Bay Municipal Utilities District
EE	Energy Efficiency
EMCS	Energy Management Control System
EPA	Environmental Protection Agency
GW	Gigawatt (10^9 Watt)
GWh	Gigawatt hour (10^9 Watt-hour)
HVAC	Heating, Ventilating, and Air Conditioning
IAW	Industrial, Agricultural, and Water
IOU	Investor-Owned Utilities
IT	Information Technology
ITRC	Irrigation Training & Research Center
kW	Kilowatt (10^3 Watt)
kWh	Kilowatt hour (10^3 Watt-hour)
LBNL	Lawrence Berkeley National Laboratory
MW	Megawatt (10^6 Watt)
OpenADR	Open Automated Demand Response
PG&E	Pacific Gas and Electric Company
PIER	Public Interest Energy Research
RPS	Renewable Portfolio Standards
SCADA	Supervisory Control and Data Acquisition
TOU	Time of Use
TWh	Terawatt hour (10^{12} Watt-hour)
UV	Ultra-Violet
VFD	Variable Frequency Drive

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