Energy Research and Development Division
FINAL PROJECT REPORT

# ENERGY EFFICIENCY IN WATER REUSE AND DESALINATION

## Five Individual Projects Which Address Energy Efficiency in both Water Reuse and Desalination

Prepared for: California Energy Commission
Prepared by: WateReuse Research Foundation

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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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- Renewable Energy Technologies
- Transportation

*Energy Efficiency in Water Reuse and Desalination: Five Individual Projects Which Address Energy Efficiency in both Water Reuse and Desalination* is the final report for the Energy Efficiency in Water Reuse and Desalination project (contract number 500-07-038) conducted by WateReuse Research Foundation. The information from this project contributes to Energy-Related Environmental Research Program.

For more information about the Energy Research and Development Division, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

# ABSTRACT

Water reuse and desalination are potential solutions to help meet the water demands of a growing population in states such as California. However, water reuse and desalination systems are energy intensive processes. This is of particular concern due to the rising costs of electricity and pollution concerns. The California Energy Commission and the WateReuse Research Foundation have joined forces to support five projects that identify opportunities to reduce energy demand.

The five projects covered three study areas:

1. Opportunities for new water sources in the energy industry,
2. Optimizing water reuse and desalination systems, and
3. Using water reuse and desalination to prepare for climate change.

The first study area explored opportunities that show high potential for water reuse as a new water source in the energy industry. A background report exploring this question thoroughly and a decision support tool were developed to bridge the gap between water reuse and energy industries. The results of the study show that there is great opportunity for water reuse in the energy industry; however the power and heat production sector has the most potential.

The second area explored was system optimization. In one study, a guidance manual with strategies for energy minimization and promotion of alternative energies was developed for water reuse and desalination utilities. Another study in this topic area focused specifically on energy recovery devices (ERD) for desalination and wastewater membrane plants. A model was created to assist water utilities in assessing whether an ERD is appropriate (i.e., cost effective) for a reverse osmosis (RO) application and, if so, to select the most appropriate ERD for the specific application.

The third topic area explored was the potential of using water reuse and desalination as part of the solution for climate change. In one study under this area, a guidance document was produced to direct water utilities in long- and short-term planning for climate change with a focus on water reuse. In a second study under this area, a computer model called WESim was also developed, allowing water utilities to integrate a theoretical water reuse or desalination system into their current water portfolio to determine if it is a prudent alternative from an energy and carbon use perspective.

**Keywords:** Water reuse, energy efficiency, ERD, desalination, energy minimization, alternative energy, biofuels, climate change

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# EXECUTIVE SUMMARY

To meet the fresh water demands of a growing population, states like California are looking at desalination and recycled water to replace potable water supplies. Given its climate independency, recycled water is an optimal solution to replace fresh water in industry (e.g. cooling towers), agricultural and landscape irrigation, and groundwater recharge. However, treatment and conveyance of reuse water require large amounts of energy. This is of particular concern in times of rising energy costs, climate uncertainty, and in the interest of reducing green house gas emissions.

For this reason, the California Energy Commission and the WateReuse Research Foundation have joined resources to identify opportunities and support programs to reduce (1) electricity demand related to the water supply system during peak hours, and (2) the energy needed to operate water conveyance and treatment systems per the California Energy Action Plan 2005.

Five projects were funded under this agreement. Each project falls into one of the following subject areas:

- Opportunities for new water sources in the energy industry
- Optimizing water reuse and desalination systems
- Using water reuse and desalination to prepare for climate change.

## Opportunities for New Water Sources in the Energy Industry

The first project (*WRF-08-12: Requirements and Opportunities for Water Reuse in Energy and Biofuels*) looked at the potential opportunities for recycled water in the following energy sectors: Power and Heat Production, Biofuel Processing and Production, Bioenergy Processing and Production and Biomass Feedstock Production. The project team performed a literature review and conducted a survey to determine demand, potential supply, water quality requirements, cost, and additional factors that influence selection of recycled water in the four energy sectors evaluated.

The results of the study identified several potential recycled water demands in the four energy sectors, the largest being power and heat production. Although there are specific parameters that need to be considered for each sector, water quality criteria is site specific. To make it attractive to potential users, the cost of recycled water must be minimized and supply needs to be emphasized. Other issues and barriers associated with adoption of use of recycled water include both supplier and user lack of knowledge; market uncertainty; regulatory and institutional issues; and establishment of long-term arrangements.

Guidelines and a decision support tool were developed to bridge the information gap between the recycled water industry and those in the four energy sectors evaluated. The intent was to develop a planning-level screening tool to provide both quantitative and qualitative guidance to water suppliers or potential users in the United States for development of recycled water sources. In addition, the tool provides guidance on suggested level of treatment, conveyance

facilities, potential demands, water quality requirements, and other project considerations including cost, which may influence the decision to use recycled water.

## Optimizing Water Reuse and Desalination Systems

The second project (*WRF-08-13: Renewable Energy Technologies and Energy Efficiency Strategies: Guidebook for Water Desalination and Reuse Systems to Optimize Energy Use and Reduce Green House Gas Emissions*) evaluated various strategies that water reuse and desalination utilities can implement to minimize energy consumption and promote renewable energy utilization. The project team performed a literature review and conducted a survey of desalination and water reuse utilities with conventional and renewable energy resource utilization.

Results show that a combination of several strategies needs to be considered to reduce energy consumption. These strategies include improved system design, utilization of high efficiency pumping, implementation of energy recovery devices, and non-process related conservation. All of the energy minimization strategies and technologies are well developed and proven. In addition, utilization of renewable energy technologies depends on the geography, technology, means of handling variability, and solving economic scale up and permitting issues.

As a result of this project, an easy-to-use guidebook was developed for water utilities and practitioners. The guidebook is best utilized during the concept development and the design phase of a project, but the guidelines can also be implemented during routine process operations and maintenance periods. The guidebook can be utilized for a new treatment facility design, upgrades, and retrofits to existing treatment facilities to improve energy efficiency. The guidebook also provides tools available for design and implementation, resource guides, technology updates and vendor information.

The third project (*WRF-08-14: Evaluation and Optimization of Emerging and Existing Energy Recovery Devices for Desalination and Wastewater Membrane Treatment Plants)* developed an Excel-based energy recovery device (ERD) tool that allows utilities, engineers, and plant operating staff to determine whether an ERD is appropriate (i.e., cost effective) for a RO application and, if so, to select the most appropriate ERD for the specific application. The evaluation is based on performance, applicability and life cycle costs. The ERD selection tool was developed based on the results of the literature review. The tool was later evaluated against five case studies.

Although ERDs are a potential strategy to optimize desalination and wastewater treatment membrane plants, review of the current desalination literature and tools indicate that no existing model (i.e., available on the market) is capable of conducting reverse osmosis projections, making comparative energy calculations, or providing cost estimates. To develop the model, the project team evaluated all commercially available ERDs and selected those with the highest efficiency, performance, and track record in the marketplace. The tool provides the following functionality:

- RO mass balance
- RO projections

- Incorporation of energy recovery devices
- Calculation of power consumption
- Estimation of capital costs

The tool was evaluated against five case studies. The results obtained from the tool were very accurate; results were within 7% or less of each case study data.

## Using Water Reuse and Desalination to Prepare for Climate Change

The purpose of *WRF-08-15: Evaluating Long- and Short-Term Planning under Climate Change Scenarios to Better Assess the Role of Water Reuse* was to develop a practical guidance document to plan for climate change and the role of water reuse as a climate preparation tool given its climate independent nature. To develop the guidelines, the project team conducted a thorough review of historical weather patterns, accepted climate change predictions in the range between the years 2030 and 2050, and water issues arising from natural disasters. In addition, it evaluated three different case scenarios.

Results show that the uncertainties surrounding climate change require new flexibility in meeting water supply goals, as well as complementary objectives that could be threatened by climate change. These additional objectives include in-stream flow augmentation, wetland creation or enhancement, coastal groundwater injection for saltwater intrusion barriers, fire suppression and control, agricultural irrigation, wastewater management, and groundwater replenishment. For all these aims, water reuse is a viable engineering and management technique.

The guide consists of three parts. Part I lays out a framework designed to make it easier for water resource managers to include climate change in both day-to-day and long-term decision-making; Part II presents an overview of the three case studies using the framework provided in Part I; and Part III provides a more rigorous technical discussion of specific issues and tools presented in Part I.

The purpose of *WRF-08-16: Implications of Future Water Supply Sources on Energy Demands* was to develop a projection tool for individual water utilities and groups of water utilities, as well as policy and decision makers, to quantify the impacts of future water supply portfolio changes on the energy demand. Based on the literature review, the project team developed an Excel based analytical tool. This was later evaluated against existing case studies.

Water managers face increasing challenges and constraints in providing reliable, high-quality water supplies. Rapid population growth, emerging contaminants, rising costs, and climate changes are only some of these challenges. Since multiple factors will influence the energy intensity of the water sector in the near future, a clear and consistent methodology is needed to evaluate the energy and greenhouse gas (GHG) implications of water management decisions. For this reason, the Water Energy Simulator (WESim) was created to provide a common framework in which the user can explore alternative scenarios.

In addition, certain challenges were identified as part of this project. Results show that a direct survey of water and wastewater utilities needs to be initiated to develop more robust water and energy related estimates. These surveys should be done every five years in order to capture technological improvements and changing water quality conditions. In addition, the report shows that the use of advanced treatment technologies is growing; however, these technologies are still relatively uncommon. As a result, energy requirements for these systems will not be accurately captured by direct surveys. Special effort will be needed to target treatment plants that employ advanced treatment technologies. At the same time, data on energy requirements for recycled water are also limited. The report recommend that detailed surveys be conducted to target recycled water producers and distributers across the nation. Such a survey should identify source and product water quality, the size of the facility, and the treatment methods employed. Energy requirements for distributing recycled water should also be included in the survey.

## Benefits to California

The state of California is on the path of reducing its energy demands and GHG emissions. The projects funded as part of this agreement promote the use of renewable energies, provide strategies to increase energy efficiency, establish criteria for the development of adequate infrastructure, and prepare for climate change.

# CHAPTER 1: Introduction

## 1.1 Background and Overview

California is faced with a major challenge to provide fresh water supplies for a growing population in times of climate uncertainty and high energy costs. To meet this challenge, municipalities are using recycled water to replace potable water supplies. Recycled water can replace fresh water in industry (e.g. cooling towers), agricultural and landscape irrigation, and groundwater recharge to name a few. Water reuse from municipal and other treatment systems is the fastest growing source of new water in California. However, before the wastewater can be reused, it must be treated to stringent health and quality standards. This treatment requires much greater energy than typical wastewater treatment. Generally, desalination requires even more energy than recycling water.

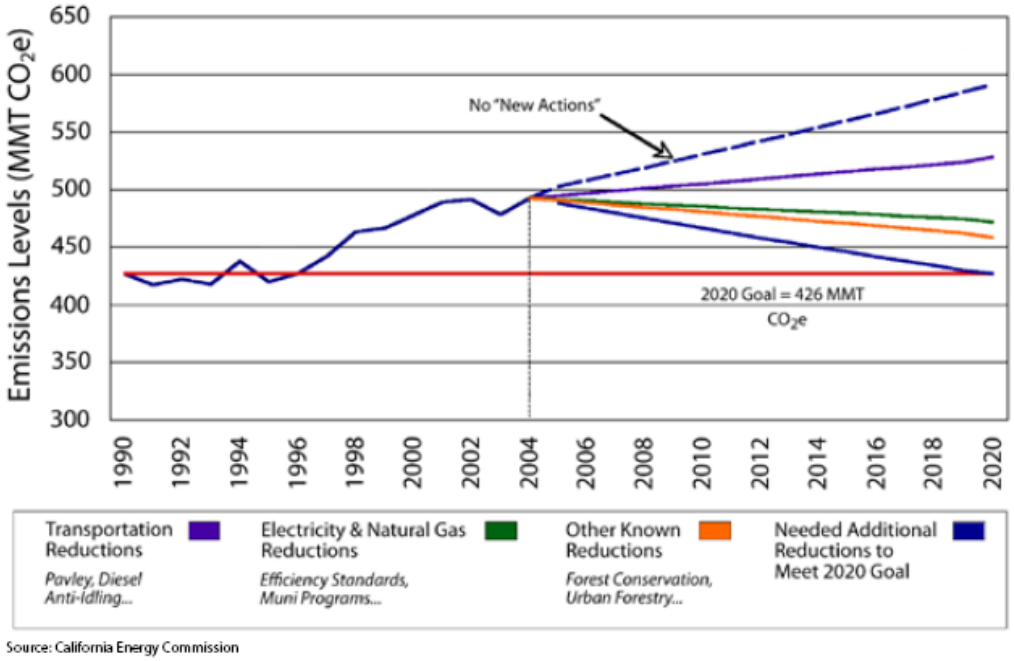
Like with freshwater supplies, California's energy demands are high. In May 2003, the Commission, the Public Utilities Commission (CPUC), and the Consumer Power and Conservation Financing Authority adopted the Energy Action Plan (EAP) I. The purpose of the document was to develop a coherent approach to meet California's current and energy needs.

In 2005, a new EAP was developed. The EAP II identified further actions necessary to meet California's future energy requirements. In 2008, the EAP II was updated. One of the most important aspects of the update was the recognition for reduce greenhouse gas (GHG) emissions. In 2006, the Global Warming Solutions Act of 2006, Assembly Bill 32, (Núñez, Chapter 488, Statutes of 2006) was signed (see Figure 1). The act sets an economy wide cap on California greenhouse gas emissions at 1990 levels by no later than 2020. This is an aggressive goal that represents approximately an 11 percent reduction from current emissions levels and nearly a 30 percent reduction from projected business-as-usual levels in 2020 (2008, Energy Action Plan).

With a focus on GHG emission reduction, the EAP II targets the following areas:

- Energy Efficiency
- Demand Response
- Renewables
- Electricity Adequacy, Reliability and Infrastructure
- Electricity Market Structure
- Natural Gas Supply, Demand, and Infrastructure
- Transportation Fuels Supply, Demand, and Infrastructure
- Research, Development and Demonstration

**Figure 1: AB-32 Target Goals**




Source: California Energy Commission

## 1.2 Project Objectives and Approach

The California Energy Commission (Commission) and the WateReuse Research Foundation (Foundation) entered into a joint agreement (Agreement Number 500-07-038) to identify opportunities and support programs to reduce

- Electricity demand related to the water supply system during peak hours and
- Energy needed to operate water conveyance and treatment systems per the Energy Action Plan 2005.

Five projects were funded as part of this agreement (See Table 1). The U.S. Bureau of Reclamation was also a funding partner of these projects. The projects fall into one of these subject areas:

- Opportunities for new water sources in the energy industry
- Optimizing water reuse and desalination systems
- Using water reuse and desalination to prepare for climate change.

**Table 1: Five WateReuse Research Foundation Projects supported by the Commission**

| Project Number | Project Title | Principal Investigator, Affiliation |
|---|---|---|
| WRF-08-12 | Requirements and Opportunities for Water Reuse in Energy and Biofuels | Dave Richardson, RMC Water & Environment |
| WRF-08-13 | Renewable Energy, Peak Power Management, and Optimization of Advanced Treatment Technologies to Reduce Greenhouse Gases at Water Reuse, Desalination and Wastewater Membrane Treatment Plants. | Joe Jacangelo, MWH Global |
| WRF-08-14 | Evaluation and Optimization of Emerging and Existing Energy Recovery Devices for Desalination and Wastewater Membrane Treatment Plants | Robert Huehmer, CH2MHill |
| WRF-08-15 | Evaluating Long- and Short-Term Planning Under Climate Change Scenarios to Better Assess the Role of Water Reuse | Robert Raucher, Stratus Consulting |
| WRF-08-16 | Implications of Future Water Supply Sources on Energy Demands | Heather Cooley, Pacific Institute |

The five projects were part of the Foundation's Solicited Research Program. As described in detail in the Operating Plan (http://www.watereuse.org/sites/default/files/u8/Operating_Plan_2010.pdf), the Research Advisory Committee developed and Board of Directors approved the five projects. The Foundation Project Manager (PM) assembled expert technical members for the Project Advisory Committees (PAC) for each project. The PM and PAC further developed and refined the Request for Proposal (RFP), which was open for competitive bid. The Foundation and project PACs selected the top contractor proposal via the Foundation's evaluation criteria (http://www.watereuse.org/sites/default/files/images/Sample_Eval_Crit.pdf), resulting in 5 awards.

## 1.3 Report Organization

The report is organized such that this introduction is followed by the summaries of all projects (Chapter 2 to 4). The summaries have been developed from the final reports done by the awarded subcontractor as displayed in Table 1. Final reports will be available to the public in the WateReuse website http://www.watereuse.org/catalog/foundation-research-reports

# CHAPTER 2:
# Opportunities for New Water Sources in the Energy Industry

## 2.1 WRF-08-12: Requirements and Opportunities for Water Reuse in Energy and Biofuels

The purpose of project WRF-08-12 is to look for new opportunities for water reuse in the energy and biofuel industry. The intended audience for this report includes members of the recycled water industry interested in learning about new industrial and agricultural recycled water demands in these emerging fields, as well as people working in the energy industry. This project was conducted by Dave Richardson from RMC Water and Environment and Dave Smith from Merritt Smith Consulting.

### 2.1.1 Background

The high cost of electricity, increase in energy consumption and concerns over pollution and climate change has accelerated the process of finding new alternative energy. In parallel, governments, researchers and businesses are recognizing the strong relationship between energy and water. Power generation and fuel production require large quantities of water. As energy demands grow and water becomes scarcer, this interdependency becomes more influential in determining the appropriate steps needed to meet future demands for both energy and water.

With the movement toward new energy sources, planners must consider the impact to water resources and develop strategies for meeting the greater water demands associated with these. Recycled water exists as a valuable resource to replace traditional potable and surface waters that should be reserved for other beneficial uses. Therefore, the purpose of this project was to examine the potential opportunities for recycled water within the energy and biofuels industry, in order to promote recycled water use in the following energy sectors:

- **Power and Heat Production (PHP) –** Includes traditional, large-scale power generation (coal, natural gas, oil, nuclear), in addition to renewable energy-fueled power generation methods that use large amounts of water, such as concentrating solar power (CSP), and geothermal.
- **Biofuel Processing and Production (BFPP) –** Includes biofuel production industries, such as ethanol and biodiesel.
- **Bioenergy Processing and Production (BEPP) –** Includes the use of biomass as fuel for producing electricity. Methods include co-firing, pyrolysis, anaerobic digestion, among others.
- **Biomass Feedstock Production (BMFP) –** Includes the production of any biologically-based material that can be used as feedstock for biofuels or directly as fuel for making energy. Biomass includes agricultural crops, residues, woody wastes, and municipal wastes, among others.

### 2.1.2 Objectives and Approach

The objectives of the study include the following:

1. Identify and quantify potential recycled water markets and demands in each of the four energy sectors.
2. Characterize the water quality requirements for these water demands, and suggested treatment methods to meet those requirements.
3. Compile issues and barriers that may hinder the use of recycled water.
4. Develop strategies to enhance the use of recycled water in the four energy sectors.
5. Create a decision support tool to guide recycled water users and suppliers to meet the potential demands identified in this study for recycled water.

The project team performed a literature review and conducted a survey to industry experts in the four energy sectors. The survey was conducted to expand on information found in the literature, and to direct the project team to additional relevant information. The project team compiled and analyzed data from each industry to determine quantification demands and potential supply, water quality requirements, cost, and define factors that influence selection of recycled water. To provide more guidance to users looking to expand their use of recycled water in the four energy sectors, the project team created a decision support tool. This tool is a web-based (http://dev.wrime.com/waterreuse/login.php), interactive interface that incorporates geographic data so that the user can perform a screening-level analysis to determine whether recycled water is appropriate for their individual project.

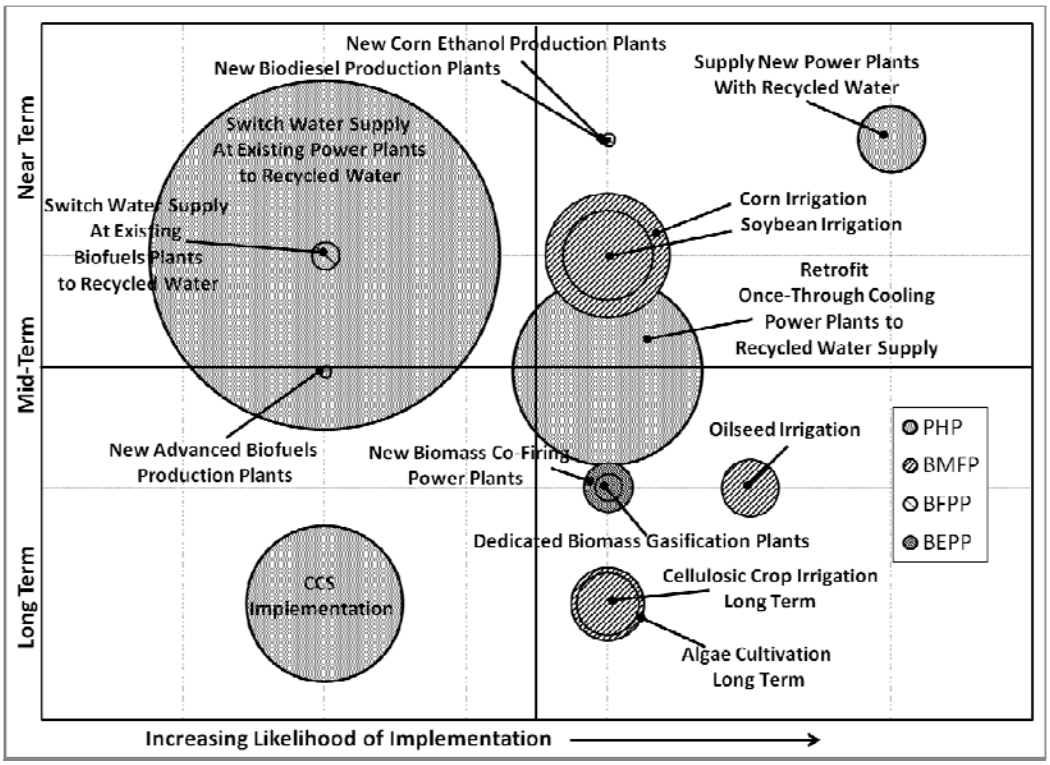
### 2.1.3 Results and Recommendations

The results of the study identified many potential recycled water demands in the four energy sectors. However, results show that PHP has the largest potential. This sector includes thermoelectric power generation, an established industry which requires large volumes of water for cooling and boiler feed. Existing thermoelectric power plants are less likely to switch their supply to recycled water, but power generation is expected to increase steadily for the foreseeable future, requiring new power plants that could potentially use recycled water. Additionally, many existing power plants are scheduled to be retired as they reach their useful lives, requiring replacement. Figure 1 illustrates an estimate of the potential magnitude of the demands identified in this study, with estimates of the time frame of implementation and the relative likelihood that these types of demands will be met with recycled water.

BMFP follows PHP as the next largest set of demands. This result is expected, as the power industry and agricultural irrigation have the largest fresh water demands in the US. Within PHP, carbon capture & sequestration (CCS) also has a substantial potential for water demands, as it would require additional power capacity be added to the grid. Biofuels production has a much smaller water demand relative to these other demands on an industry-wide basis, however, there is likely to still be opportunities for recycled water use because new plants are expected to be built as biofuels use expands. New facilities are the best opportunities for

recycled water implementation projects because facilities can be designed specifically for recycled water.

**Figure 2: Relative Opportunities for Recycled Water in the Four Energy Sectors**




Source: WateReuse Research Foundation report WRF-08-12, in press

Results showed that the final water quality of the effluent is dependent on the final end-user. Requirements can vary from project to project and can be driven by particular constituents. Typical tertiary-treated recycled water can be utilized as is for cooling tower make-up water. Boiler feed, slurry water for ethanol production, and other process water used in the four energy sectors typically require higher treatment in the form of membrane filtration, reverse osmosis (RO), or some other type of demineralization or desalination treatment. Irrigation water quality requirements vary according to the specific crop, but general guidelines suggest that the constituents that drive suitability of a recycled water supply with irrigation include salinity, chloride, sodium, and boron, although other constituents can also limit the use of recycled water, including metals. In addition, recycled water can sometimes provide an additional nutrient benefit if nitrogen has not been removed from the water during wastewater treatment

The issues and barriers associated with implementation of recycled water projects in the four energy sectors are generally in line with typical requirements in any recycled water implementation project, although there are specific considerations needed. Therefore, water

suppliers and potential users need to develop strategies to overcome these challenges. These issues and barriers include:

- Cost and Supply Availability Considerations : The cost of recycled water must be minimized and reliability needs to be emphasized to make it attractive to potential users
- Lack of knowledge recycled water suppliers and potential users have of each other: Water suppliers should outreach to potential users to promote recycled water use
- Market Uncertainty: Many of the technologies and products have not yet been established commercially, or for those that have, will grow depending on uncertain factors, such as government incentives. However, the fact that these industries are so new allows for great opportunities.
- Regulatory issues in states without established regulations: Projects must meet regulations for recycled water treatment and permitting, environmental documentation, water rights, and discharge.
- Institutional Issues and Arrangements: The water supplier and user need to establish a water agreement delineating responsibilities for operations and maintenance, reliability, water quality requirements, regulatory reporting and other requirements, rates, and term of the agreement.

A guideline report and a decision support tool were developed as result of this project to bridge the gap between the recycled water industry and those in the four energy sectors evaluated. The intent is to provide a planning level screening tool to provide both quantitative and qualitative guidance to water supplier or potential user. The tool is a web-based interface that utilizes Google Maps code to display information about potential users, including power plant locations, existing and proposed biofuels production facilities, resource information, and wastewater treatment facility locations (i.e., sources of recycled water supply). In addition, the tool will provide guidance on suggested level of treatment, conveyance facilities, potential demands, water quality requirements, and other project considerations including cost, which may influence the decision to use recycled water.

Increase collaboration and outreach need to be considered early in project development to enhance the use of recycled water in the energy and biofuels industries. In addition, it is recommended for planners to:

- Target projects where user is close to the supplier.
- Target new facilities.
- Partner with regulators.
- Use existing experience as guidance for future projects.
- Establish an agreement between the water supplier and user.

# CHAPTER 3:
# Optimizing Water Reuse and Desalination Systems

## 3.1 WRF-08-13: Renewable Energy Technologies and Energy Efficiency Strategies: Guidebook for Water Desalination and Reuse Systems to Optimize Energy Use and Reduce Green House Gas Emissions

The goal of WRF-08-13 was to produce an easy to use guidance document to provide utilities and water treatment practitioners with strategies for energy minimization and renewable energy utilization. This project was conducted by Dr. Joe Jacangelo of MWH Global.

### 3.1.1 Background

Desalination and reuse treatment processes are energy intensive. Therefore, energy consumption is of particular concern due to the rising cost of electricity and source of green house gas (GHG) emissions. Minimizing energy use and integrating renewable energy sources (RES) in desalination and advanced water treatment (recycling/reuse) processes has become a critical component of an effective water management portfolio.

While equipment costs have been decreasing as a result of technological advancements, the cost of energy continues to escalate. For example, due to significant reductions in membrane equipment and material costs over the last 20 years, energy consumption is now the second largest fraction of unit water cost in RO applications. Improving energy efficiency of desalination and water reuse processes requires that a comprehensive understanding of the energy consumption by the different equipment is developed. Key to improving the energy efficiency of desalination and water reuse processes is to understand the important characteristics such as determining the primary energy consuming equipment, water quality and operating parameters that are influencing energy consumption.

Until recently, conventional fossil fuel based power plants have been utilized as the primary source for supplying energy to desalination and water reuse plants. However, the use of fossil fuels for generating power has spurred environmental concerns, specifically with GHG emissions. Thus, there are a large number of energy minimization approaches and renewable energy alternatives being developed, investigated and implemented around the globe for desalination and water reuse applications.

### 3.1.2 Objectives and Approach

The objectives of this study were:

- To develop a comprehensive knowledge base for utilities in the United States, with the most updated developments in energy minimization and renewable energy techniques, and
- To prepare an easy-to-understand guidebook based on the relevant practical lessons learned by global researchers, organizations and utilities. The guidebook delineates analytical and quantitative guidelines on technologies to reduce energy use, overall

facility costs, and GHG emissions from advanced wastewater treatment (AWT) processes used in water reuse and desalination.

The project consisted of three major phases: I) literature review, II) utility case studies and III) guidebook development. During Phase I of the project, a thorough literature review consisting of energy minimization strategies and renewable energy implementation for desalination and water reuse facilities was undertaken. During Phase II of the project, desalination and water reuse utilities with conventional and renewable energy resource utilization were surveyed. Information pertaining to the challenges and lessons learned in the process, energy minimization approaches, and renewable energy implementation was obtained. During Phase III of the project, information gathered from the literature review and utility survey was used to prepare this guidebook on energy minimization and renewable energy implementation strategies.

### 3.1.3 Results and Recommendations

Energy usage at desalination and advanced wastewater treatment facilities can impact a utility in several areas of operation. Reducing energy consumption can lead to both reduced energy costs and reduced GHG emissions.

A combination of several strategies needs to be considered to reduce energy consumption. These strategies include improved system design, utilization of high efficiency pumping, implementation of energy recovery devices, and non-process related conservation. All the energy minimization strategies and technologies are well developed and proven. For example, for seawater and brackish water desalination, energy minimization is achieved by proper system design, efficient pumping, utilization of energy recovery devices, selection of membranes and efficient utilization of non-process components. For AWT technologies, maximum energy efficiency is obtained through system design/process modification and efficient pumping. For AWT technologies involving membranes (Microfiltration/ Ultrafiltration, Membrane Bioreactor), proper selection of membrane also reduces energy. Utilization of newer HVAC and lighting systems can reduce building energy use by 10-40%.

Utilization of renewable energy technologies depends on the geography, technology, means of handling variability, and solving economic scale up and permitting issues. Technologies such as solar photovoltaic, wind turbines, geothermal energy, and biogas cogeneration are well developed but are still expensive to implement without the availability of funding, grants, and incentives. Return on investment is a key criteria and decision maker for implementation of renewable energy technologies at the utility-scale.

A well thought out energy minimization plan and renewable energy utilization will reduce energy costs, positively impact the environment and show a strong commitment to environmental stewardship and conservation of natural resources. Development of an energy core team that understands energy usage of the utility will be key to implementing these strategies. Implementation of energy efficiency programs should be performed with an energy audit to access baseline energy consumption. Energy minimization approaches need to be considered during the initial design phase of the project.

As result of this project, an easy-to-use guidebook was developed for water utilities and practitioners. The guidebook is best utilized during the concept development and design phase of a project, but the guidelines can also be implemented during routine process operations and maintenance periods. The guidebook can be utilized for a new treatment facility design, upgrades and retrofits to existing treatment facilities to improve energy efficiency. Also included is a resource section at the end of every chapter with information on tools available for design and implementation, resource guides, technology updates and vendor information.

This guidebook was developed to answer the following questions:

- What are the steps and methods to reduce energy consumption for various membrane-based desalination and advanced water treatment processes?
- What are the resources and tools available in pursuing energy efficiency at a treatment facility and in renewable energy resource implementation?
- What are the steps required for utilizing renewable energy resources?
- What are the challenges involved during implementation of renewable energy technologies?

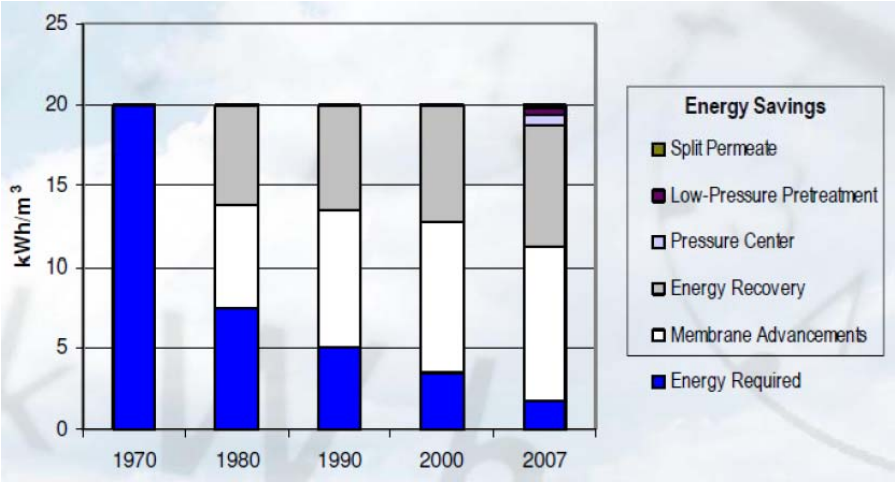
## 3.2 WRF-08-14: Evaluation and Optimization of Emerging and Existing Energy Recovery Devices for Desalination and Wastewater Membrane Treatment Plants

The purpose of WRF-08-14 was to develop an Excel-based tool that permits utilities, engineers, and plant operating staff to determine whether an ERD is appropriate (i.e., cost effective) for a RO application and, if so, to select the most appropriate ERD for the specific application. The principal investigator for this team was Robert Huehmer from CH2M HILL.

### 3.2.1 Background

Desalinated seawater has been identified as a viable alternative water source; however, high energy consumption has been a major barrier to desalination. Energy consumption in RO processes is influenced by a number of factors, including the osmotic pressure of the feed water, the water mass transfer characteristics of the membrane, system recovery, and pressure drop across the element (from feed to concentrate). In beginning stages of seawater desalination, RO was limited to locations where fresh water supplies were either absent or very limited. Over time, through steady improvements in the permeability (water mass transfer) of the RO membrane in combination with the development of improved energy recovery devices (ERDs), energy consumption of seawater RO systems has been reduced significantly. Figure 3 presents energy consumption and the impact of technology minimization from 1970 to 2007.

**Figure 3: Technology Contribution (including ERD) for Energy Minimization in RO Plants**




Source: WateReuse Research Foundation report WRF-08-14, in press

ERDs utilized in RO applications convert residual hydraulic energy into mechanical energy that is re-applied either to the RO feed (for seawater applications) or to an inter-stage feed (for brackish or wastewater applications) to reduce the energy input to the RO system. Two general classifications of ERDs are commercially available and utilized in the desalination industry: centrifugal devices and isobaric devices. Centrifugal devices can further be classified into direct-coupled devices and turbocharger devices. Table 2 outlines commercial energy recovery devices that are available on the market.

**Table 2: Commercially Available Energy Recovery Devices**

| Manufacturer | Device Type | Trade Name | Capacity Range ($m^3$/d) per device* |
|---|---|---|---|
| Flowserve/Calder | Centrifugal | Pelton Wheel | 360 to 24,000 |
| PEI (division of ERI) | Centrifugal | Turbocharger | 136 to 65,500 |
| FEDCO | Centrifugal | Turbocharger | 360 to 84,000 |
| Danfoss | Isobaric | iSAVE | 504 to 960 |
| Energy Recovery Inc. | Isobaric | PX | 109 to 1,640 |
| Flowserve/Calder | Isobaric | DWEER | 2,400 to 8,450 |
| Aqualyng | Isobaric | Recuperator | Proprietary |
| Spectra Watermakers | Isobaric | Clark Pump | <10 |
| Spectra Watermakers | Isobaric | Pearson Pump | 24 – 40 |
| KSB | Isobaric | SalTec | Up to 20,000 |

*Note that most ERD are easily operated in parallel for larger capacities.
Source: WateReuse Research Foundation report WRF-08-14, in press

### 3.2.2 Objective and Approach

The objectives of this project were to:

- Perform a literature review and manufacturer assessment of ERDs.
- Evaluate all the information collected from the literature review and present a comparative discussion of each of the ERD technologies relative to their applicability and effectiveness.
- Develop an Excel-based tool capable of conducting reverse osmosis projections, comparative energy calculations, cost estimates, and ERD evaluation.
- Compare the results of the model with respect to five case studies.

The project consisted of three major phases. As part of Phase 1, a literature review and manufacturer assessment was conducted on ERDs and their use in the desalination of brackish water, seawater, and wastewater. This literature review incorporated published material from peer-reviewed journal articles, conference presentations and proceedings, patents, technical reports, user reviews, feasibility analyses, media reports, and information on vendor websites and brochures. Based on the conclusion from the literature review, an Excel-based ERD decision making tool was developed as part of Phase 2 to evaluate current and emerging ERDs based on their performance, applicability and life cycle costs. The model will allow the user to select the best ERD application. As part of Phase 3, five case studies were compared to the tool. Information on these case studies is provided in Table 3.

**Table 3: WRF-08-14 Case studies**

| Facility | Source Water | Type of ERD |
|---|---|---|
| Eastern Municipal Water District | Brackish groundwater desalter | Turbocharger |
| Bonita Springs Utilities, BWRO Facility | Brackish water desalter | Turbocharger |
| Luggage Point Advanced Water Treatment Plant | Three-stage RO with microfiltered effluent | Turbocharger (*between stages two and three)* |
| Tampa Bay Water, Desalination Plan | Ocean water treated with two-pass RO | Pelton wheel |
| Perth Seawater Desalination Plant | Ocean water treated with two-pass RO | ERI PX Isobaric |

### 3.2.3 Results and Recommendations

A review of the current desalination literature and tools conducted by the authors indicate that no existing model available on the market is capable of conducting RO projections, comparative

energy calculations, and providing cost estimates. To fill a need in the desalination community, an Excel based computer tool was developed. The tool provides the following functionality: RO mass balance, RO projections, incorporation of ERDs, calculation of power consumption, and estimation of capital and electrical operating costs.

To develop the model, the project team evaluated all commercially available ERDs; these technologies were compared with respect to their capacity, reliability, flexibility, adaptability, potential for modifications, and other related relevant factors. Devices where adequate cost or performance data were not provided by the manufacturer or were not readily available from the literature were not included. The ERDs that ranked highest in efficiency, performance, and track record in the marketplace were included in the model. These include:

- Turbochargers
  - FEDCO HPB™
  - ERI Low Pressure Turbocharger (LPT)™, High Pressure Turbocharger (HALO)™, and Hydraulic Turbocharger (HTC)™
- Flowserve/Calder Pelton Wheels
- Isobaric Devices
  - ERI PX™
  - Flowserve/Calder DWEER™

The main objective of the tool is to allow users decide on whether including an ERD in an RO system is economically worthwhile. Results show that if the payback period is less than the projected equipment life, then ERD inclusion will save money over the duration of the equipment life. In the case an ERD is worthwhile, selection should be based on the present worth of equipment cost and energy, not on payback period or ERD efficiency. The tool returns both present worth project costs and payback period estimates. However, to determine the payback period of the ERD, the NPV power cost is used; this calculation compares future power costs against the initial capital cost.

One of the main aspects that need to be assessed during ERD selection process is concentrate backpressure. Backpressure applied to the concentrate discharge stream of the ERD will have an adverse impact on the energy recovered by a turbocharger or a Pelton Wheel. In the case of a turbocharger, the higher the concentrate backpressure, the less energy that can be recovered. In a Pelton Wheel, the concentrate exit flows freely at atmospheric pressure from the device. Therefore, a pump will be required if the water needs to be repressurized for disposal; not included as part of the ERD. In comparison, isobaric systems can handle substantial amounts of concentrate backpressure with little effect on energy recovery.

The results from the literature review show that most surface water RO (SWRO) trains are single stage, operate at recoveries in the range of 40% to 50%, and can have concentrate pressures as high as 960 psig. These characteristics are ideally suited to the isobaric ERDs. At these high concentrate flows and pressures, the energy recovered through the ERD results in a

rapid payback period. Any additional capital costs involved with incorporation of the ERD are minor compared with the significant energy savings available at these high pressures. In general, there is a significant amount of energy available in the concentrate stream of a SWRO system, and ERDs, particularly the isobaric type, are ideally suited to capture and reuse this energy within the RO system, greatly reducing the system's energy consumption compared to one not using an ERD.

Wastewater and brackish water RO systems are designed with multi-stage trains. Therefore, turbocharger use is favored (for inter-stage boost) despite reduced energy recovery efficiency compared to that achieved by an isobaric device.

Evaluation of the existing RO operations is required when a plant is considered for an ERD retrofit. At a minimum, the high-pressure feed pump operation would need to be evaluated because a change in the pump's operating point (or range) may reduce the pump's hydraulic efficiency and counteract the energy savings benefit provided by ERD use. Depending on the mode of operation, the selected ERD will determine whether additional improvements are required at feed pumping. In the case of an isobaric ERD, if the RO train capacity is unchanged, the required capacity of the high-pressure RO feed pump will be decreased by the introduction of an isobaric ERD. With turbochargers, if the RO train is single stage and the ERD is placed in series with the high-pressure feed pump, this will reduce the required discharge pressure of the pump. Since Pelton Wheels are directly coupled to the high-pressure pump and motor shaft, a motor replacement, at a minimum, will be required.

The results of the tool were successfully compared to the data provided for each case study. The results are presented below:

- Case Study #1: Eastern Municipal Water District, Perris I BWRO Facility: The tool's prediction of feed and ERD boost pressure are within 5% of the actual April 2012 operational numbers.
- Case Study #2: Bonita Springs Utilities, BWRO Facility: The tool confirms the engineer's estimate that the turbocharger is the best choice for the retrofit despite the fact that the isobaric ERD's have a substantially higher efficiency.
- Case Study #3: Luggage Point Advanced Water Treatment Plant, Water Reuse RO comparison between the actual operating data and the tool indicate that the predicted membrane feed pressure and turbocharger boost pressures are accurate within 5 and 7 %, respectively.
- Case Study #4: Tampa Bay Water, Desalination Plant. The tool was within 2 percent of the kilowatt (kW) value reported.
- Case Study #5: Perth Seawater Desalination Plant, Kwinana Beach, Australia - The tool confirms that the isobaric type ERD is the best choice.

An annual review and update to the model is recommended. As evident in the literature review, the ERD market is expanding and evolving. As new technologies are brought to market

and proven to be effective, the model should be updated to incorporate these technologies in order to remain relevant and of value to the WateReuse Research Foundation membership.

# CHAPTER 4:
# Using Water Reuse and Desalination to Prepare for Climate Change

## 4.1 WRF-08-15: Evaluating Long- and Short-Term Planning Under Climate Change Scenarios to Better Assess the Role of Water Reuse

The purpose of this project was to develop a practical guidance document to plan for climate change and the role of water reuse as a climate preparation tool given its climate independent nature. The guide is targeted to utility managers. The Principal Investigator was Mr. Robert Raucher from Stratus Consulting.

### 4.1.1 Background

Water resource managers and planners face considerable challenges in planning for the future, even under the best of circumstances. Many of a utility's key planning decisions concern expensive, long-lived investments in water resources, treatment facilities, distribution and collection networks, and other costly infrastructure. Many of these decisions need to be made in the near term, despite uncertainties about future supply, projected demand, regulatory changes, technological advancements, and other parameters that may significantly impact the value of the investments over the course of their useful asset lives.

When the potential impacts associated with climate change are added to the list of planning uncertainties, utility managers can find themselves overwhelmed. Climate change is an extensive subject full of unknowns and probabilities. Planning ahead for dire changes in climate or other environmental changes due to extreme weather events will allow preparation time required to increase the number of viable alternatives in such situations.

It is expected that climate change-related uncertainties and challenges will create expanded needs and opportunities for water reuse, since it is typically envisioned as a means of supplementing potable water supplies. The uncertainties surrounding climate change, however, demand a new flexibility in meeting water supply objectives, as well as complementary objectives that could be threatened by climate change. These additional objectives include in-stream flow augmentation, wetland creation or enhancement, coastal groundwater injection for saltwater intrusion barriers, fire suppression and control, agricultural irrigation, wastewater management, and groundwater replenishment. For all these objectives, water reuse is a viable engineering and management technique.

### 4.1.2 Objective and Approach

The objectives of this project are to develop an approach to plan for climate change events that takes into account historical weather patterns, predictions from established climate change models, and current experience in responding to natural disasters to assist utilities the when, where, and how of including climate change in their decision making and how to include a reclaimed water program as a best climate preparation tool given its climate-independent nature.

The project consisted of three phases. In phase I, the project team conducted a thorough review of historical weather patterns, accepted climate change predictions in the range between the years 2030 and 2050, and water issues arising from natural disasters such as earthquake, flooding, widespread fire, drought, heat waves, prolonged cold spells, excessive snow or rain, or other events of similar impact. The project team also reviewed current regional models which follow various climate scenarios. In phase 2, the project evaluated different case scenarios (see Figure 4). The results of the case scenarios were used in phase 3 to develop the guideline.

**Figure 4: Critical Planning Issues Faced by the Case Study Utilities**

**Inland Empire Utilities Agency**

As a water supply wholesaler and regional wastewater utility, IEUA is faced with unique issues. The biggest is how to ensure that a highly regulated, overused, heavily salted aquifer can continue to meet the growing population needs of southern California without increased use of imported waters. In addition, it must do this with a myriad other players having input.

**Miami-Dade Water and Sewer Department**

The most critical climate issues faced by MDWASD relate to sea level rise (SLR) and balancing aquifer storage with seasonal stormwater and flood management. The potential impacts of these events are severe. During periods of excessive rainfall or in anticipation of major rainstorms or hurricane landfall, water levels in canals and the water table in the Biscayne aquifer are lowered to increase stormwater storage capacity. The key issue in stormwater and flood management is how to manage these aquifer water levels. It is important to strike a balance between the need to keep the aquifer's stormwater capacity available during wet periods and the need to store freshwater for higher demand during potentially drier seasons. New regulations, which ban ocean outfalls and preserve groundwater flows to the Everglades, are also creating planning complications.

**City of Phoenix Water Services Department**

PWSD is currently working to address future water supply reliability within the context of climate change and other uncertainties. Key decisions and investments PWSD is making and/or faces in the near term include developing a new drought and shortage management plan and planning for the development of additional long-term supply sources. In terms of both drought and supply planning, the city's core focus is adequacy and affordability of "shortage insurance" to maintain lifestyles and the economy.

### 4.1.3 Results and Recommendations

As a result of this project, a guidance document was developed to show utility managers where to access information and how to use that information appropriately. The guideline is the result of the case study evaluation.

Results show that water reuse is typically envisioned as a means of supplementing potable water supplies. The uncertainties surrounding climate change, however, demand a new flexibility in meeting water supply objectives, as well as complementary objectives that could be threatened by climate change. These additional objectives include in-stream flow augmentation, wetland creation or enhancement, coastal groundwater injection for saltwater intrusion barriers, fire suppression and control, agricultural irrigation, wastewater management, and groundwater replenishment. For all these objectives, water reuse is a viable engineering and management technique.

The guide consists of three parts. Part I lays out a framework designed to make it easy for water resource managers to include climate change in both day-to-day and long-term decision-making; Part II presents an overview of the three case studies using the framework provided in Part I; and Part III provides a more rigorous technical discussion of specific issues and tools presented in Part I.

Part I, climate change planning framework, begins with overview of the basic climate change information necessary to address the issue. This includes a short primer on climate science, an overview of the important climate players, and a description, with links for more detailed information, of the most likely changes in temperature and precipitation for each region of the United States (see Figure 4) results show that the elements that need to be included/identified when climate change is included in the planning are identified below:

- Temperature and precipitation- Identify the most likely changes in precipitation and temperature for a utility location
- Impacts and implications-Identify the direct impacts/implications of the identified changes in temperature and precipitation
- Risks and vulnerabilities - Assess/identify the risks and vulnerabilities associated with the identified direct impacts of climate change
- Adaptation/preparation - Prepare for highly likely and high consequence risks and vulnerabilities by identifying adaptation strategies—including reuse
- Coordination and communication- Identify other important players; establish agreements for sharing risks and maximizing flexibility

**Figure 5: Summary of Highly Likely Changes in Climate by Region during the Next Century**

**Changes in the Mountain West**

- Warmer and shorter winter seasons
- Warmer and potentially drier summer seasons
- More intense rainfall events

**Changes in the Southwest**

- Warmer and probably drier overall
- More extreme droughts
- More extreme heat waves
- More intense rainfall events
- Vegetation changes

**Changes in the humid East, Southeast (except coastal areas), and Midwest**

- Warmer overall
- Possible increases in annual precipitation
- More intense rainfall events

**Changes in coastal regions**

- Rising sea levels
- Warmer overall
- More intense rainfall events
- More intense storm events
- More extreme heat waves
- More dry spells and extreme droughts

The second element of the planning framework provides tools for turning the most likely potential changes in temperature and precipitation at a region level into potential impacts. These tools include a series of flow charts and tables that identify how specific combinations of changes in temperature and precipitation (e.g., warmer and shorter winters) may impact a utility.

The third element provides several straightforward techniques for characterizing the probable impacts of climate change to identify the specific implications of climate change that are likely to be of significant concern for a utility. To follow the warmer and shorter winter example, if a utility has a sole source groundwater supply and that supply is already near capacity, then the potential reduction in recharge that is due to climate change may represent a tipping point.

The fourth element of the climate planning framework discusses strategies for adapting and preparing for climate changes. This section of the final report provides both ideas for building overall utility resilience (e.g., identifying no-regrets options and developing flexibility) and examples of specific adaptations. This section also discusses the significant role that reuse can play in preparing for climate change, including supplementing potable supplies, instream flow augmentation, aquifer recharge augmentation, coastal groundwater injection for saltwater

barriers, wetlands creation or enhancement, fire suppression and control, and agricultural and other outdoor irrigation needs.

The purpose of Part II was to provide examples and to illustrate the practicality of the planning framework. Because each of the three case study utilities faces both distinct climate challenges and a distinct political climate, the case studies provide a wide range of examples of how the developed framework can be used to include climate in utility planning, and the potential role of reuse.

Part III includes a technical presentation of climate science and global climate models, global climate model downscaling, high-probability climate changes, tools for identifying climate change impacts on utilities, tools for identifying potential risks and vulnerabilities, sea-level rise, and an overview of common questions and misperceptions.

The document provides potential changes in climate in utility planning, as well as to illustrate the significant role of reclaimed water in preparing for these changes. This does not mean that the document will provide straightforward answers. Changes in temperatures and precipitation, increasing incidences and magnitudes of extremes events, and the exact implications of these changes are unknown.

## 4.2 WRF-08-16: Implications of Future Water Supply Sources on Energy Demands

The purpose of this project was to develop a projection in energy demand changes resulting from shifts in future water supply sources, population increases, and increased water conservation efforts by quantifying the impacts on energy requirements associated with these three parameters. The tool is targeted to individual water utilities and groups of water utilities, as well as policy and decision makers. This project was lead by Heather Cooley from the Pacific Institute and Robert Wilkinson from the University of California at Santa Barbara.

### 4.2.1 Background

Water provision and use require energy in all phases, from extraction to treatment to delivery to use, and finally to the treatment and discharge of wastewater. However, many factors will influence the energy intensity of the water sector in the future.

Continued population growth will make meeting water demands increasingly difficult over the coming years. Between 2000 and 2030, the U.S. population is projected to increase by 30%, with much of this growth concentrated in water-scarce regions in the Southwest and Florida.

Climate change will further exacerbate these problems. Climate change is causing significant changes in water resources and coastal ocean conditions, ultimately affecting the supply of, and demand for, water resources. Concerns about climate change are also prompting local, state, and federal agencies to identify the most effective and efficient ways of reducing energy use and greenhouse gas emissions. Some agencies are voluntarily setting emissions reduction targets in response to growing concern about the potential impacts of climate change on water resources.

To meet future needs, water managers are considering a range of water supply options, from traditional surface and groundwater sources to alternatives such as recycled water, water conservation and efficiency, stormwater capture, brackish and impaired groundwater desalination, and seawater desalination. The energy intensity of these supply options, however, varies widely. More energy intensive options include seawater desalination and interbasin transfers, whereas recycled water and conjunctive use are often less energy intensive. Energy intensity estimates are highly site specific, highlighting the need for water managers to be able to quantify and assess the energy impacts of supply sources available in their region.

Furthermore, new water treatment techniques have additional possible implications for energy demand. Stricter water quality regulations and emerging contaminants are forcing agencies to install advanced treatment options such as ultraviolet radiation, ozone disinfection, and reverse osmosis. The differences between energy use by traditional and new treatment techniques can be significant.

At the same time, water managers are faced with rising energy costs. The water sector can work to meet these targets through a variety of means, including implementing water conservation and efficiency measures; optimizing the efficiency of existing systems; and increasing renewable energy generation with wastewater biogas or wind and solar power. Additionally, the water sector can develop less energy-intensive local sources, such as recycled water.

### 4.2.2 Objectives and Approach

The objective of this project was to develop a tool that provides a common framework to quantify the impacts of future water supply portfolio changes on the energy demand. This project puts into perspective, with respect to energy use, the net environmental benefits and drawbacks of alternative water sources, and how to connect these sources with tomorrow's energy requirements.

The project was developed in three different phases: 1) preparation of literature review, 2) development of an Excel based analytical tool that allows users to evaluate the energy and greenhouse gas implications of population growth, the impact of climate change, the development of alternative water and energy sources, and water treatment improvements resulting from stricter water-quality guidelines and emerging contaminants, and 3) evaluation of the tool based on existing case studies. The literature review was conducted to gather data on attempted future projections involving the role of non-traditional water sources. The Excel-based tool was designed to provide a common framework by allowing the user to input actual operating data for water and energy use. To demonstrate the capabilities of the pool, the tool evaluated two different case studies.

### 4.2.3 Results and Recommendations

Since multiple factors will influence the energy intensity of the water sector in the near future, a clear and consistent methodology is needed to evaluate the energy and greenhouse gas implications of water management decisions. For this reason, the Water Energy Simulator (WESim) was created as part of this project. WESim is an easy-to-use analytical tool that allows the user to evaluate the energy and greenhouse gas implications of population growth, the

impacts of climate change, the development of alternative water and energy sources, needed water treatment improvements resulting from emerging contaminants and stricter water quality guidelines and changes in energy sources. The model has been designed to allow the user to input actual operating data for water and energy use, as this will allow an analysis that better reflects operating conditions.

It is important to understand that WESim does not provide "the answer." Rather, it is a tool that creates a common framework in which the user can explore alternative scenarios. For example, the user can compare the energy and greenhouse gas implications of using recycled water and of seawater desalination. Alternatively, it can explore the implications of installing ozone disinfection at a water treatment facility or biogas recovery at a wastewater treatment facility. The user can also evaluate ways to offset the energy use and greenhouse gas emissions associated with energy-intensive water sources through the installation of renewable energy technologies or investments in conservation and efficiency.

Defaults for the energy requirements of various components of the water and wastewater system have also been provided. However, one of the key findings of this effort is that adequate data on the energy requirements for water systems are lacking.

In addition, energy requirements for the water and wastewater sector are still largely unknown. In recent years, numerous case studies have been undertaken to try to better quantify the energy requirements. However, these case studies are done in ways that are not directly comparable. For example, some studies lump all of the water and wastewater facilities together and report a single energy-intensity estimate. Others report energy intensity by category, e.g., treatment or distribution. Some studies report the treatment technologies employed, e.g., activated sludge, whereas others simply report the level of treatment, e.g., secondary or tertiary. The case studies also indicate that there is tremendous variability among water and wastewater systems. Often, the source of the variability is not analyzed.

The results of this project show that a direct survey of water and wastewater utilities should be initiated to develop more robust estimates. These surveys should be done every five years in order to capture technological improvements and changing water quality conditions.

In addition, the use of advanced treatment technologies is growing; however, these technologies are still relatively uncommon. As a result, energy requirements for these systems will not be captured well by direct surveys. Special effort will be needed to target treatment plants that employ advanced treatment technologies.

Data on energy requirements for recycled water are also limited. We recommend that detailed surveys be conducted to target recycled water producers and distributers across the nation. Such a survey should identify source and product water quality, the size of the facility, and the treatment methods employed. Energy requirements for distributing recycled water should also be included in the survey.

# CHAPTER 5:
# Benefits to California

This research provides water and wastewater utilities in California access to new research and information that will help them improve energy efficiency and reduce energy consumption. The research provides an opportunity to evaluate energy consumption at their facilities, optimize existing processes and operations, and evaluate new technologies. Therefore, reduction of electrical consumption and GHG emissions will help achieve the goal of AB-32.

As part of this project, a guideline was developed to bridge the gap between the water reuse and energy and biofuel industries. This will promote the expansion of renewable energy in the state of California, as required by EAP II, one of California's goals to make 33% of the power delivered renewable. In addition, the guidelines provide information on water quality and quantity demands required by the energy sectors evaluated in the event that recycled water in used. This is critical since adequate infrastructure is required.

California's ability to slow the rate of growth of greenhouse gas emissions will largely depend on the success of its energy efficiency and renewable energy programs (2003, CEC). Energy efficiency is considered the most important tool for addressing GHG emissions. As part of this agreement, a guideline was developed to implement strategies in desalination and reuse membrane plants to reduce energy by installing utilization of high efficiency pumping, implementation of energy recovery devices, and non-process related conservation. The guidelines also provide strategies to implement renewable energy technologies for a variety of geographies representative of California's diverse terrain. In addition a tool was developed to evaluate whether an ERD is appropriate (i.e., cost effective) for a RO application, and if so what type.

Climate change has been recognized by the state of California as a major issue. Given climate uncertainty and the population growth in California, a practical guidance document to plan for climate change and the role of water reuse as a climate preparation tool was developed. In addition, a tool was developed to evaluate the energy and greenhouse gas implications of water management decisions.

# APPENDIX A: WRF-08-12
# Requirements and Opportunities for Water Reuse in Energy and Biofuels

# APPENDIX B: WRF-08-13
# Renewable Energy, Peak Power Management, and Optimization of Advanced Treatment Technologies to Reduce Greenhouse Gases at Water Reuse, Desalination and Wastewater Membrane Treatment Plants

# APPENDIX C: WRF-08-14
# Evaluation and Optimization of Emerging and Existing Energy Recovery Devices for Desalination and Wastewater Membrane Treatment Plants

# APPENDIX D: WRF-08-15
# Evaluating Long- and Short- Term Planning Under Climate Change Scenarios to Better Assess the Role of Water Reuse

# APPENDIX E: WRF-08-16
# Implications of Future Water Supply Sources on Energy Demands