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Final Report: KCP&L Water-Energy Nexus Study

To
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From
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Re
KCP&L Water-Energy Nexus Study

Executive Summary

KCP&L commissioned AIQUEOUS to perform a study on the water-energy nexus as it relates to KCP&L's energy efficiency portfolio in Missouri. The objective of this project was to explore the energy efficiency potential associated with the water-energy nexus and identify specific opportunities for KCP&L to pursue that energy efficiency potential, whether through its Strategic Energy Management (SEM) program or its Standard and Custom commercial and industrial (C&I) rebate programs. This study focused on three market segments: water and wastewater treatment plants, commercial customers, and industrial customers.

To date, the energy savings associated with water-energy projects captured in KCP&L's recent program history account for a relatively small percentage of KCP&L's existing efficiency portfolio. The analysis of this report shows that the water-energy nexus has a cost-effective savings potential range of 61 to 165 GWh annually, demonstrating that it can positively contribute to KCP&L's portfolio goals. The bulk of this savings would be captured via KCP&L's Custom program, with the remaining savings to be captured in the Standard program. While there are savings opportunities in Strategic Energy Management (SEM), AIQUEOUS did not identify a savings estimate source for SEM savings in the water and wastewater sector.

Project Overview

As part of this study, the project team evaluated the water and energy consumption of three market segments: water and wastewater treatment plants, commercial customers, and industrial customers. Using these market characterizations as guides, the project team narrowed the focus of the study to the water and wastewater sectors and three segments of commercial sector (restaurants, schools, and colleges). Next, AIQUEOUS compiled a comprehensive list of water and energy efficiency measures available to these market segments. The project team then performed a cost-effectiveness analysis of these technologies to identify the most suitable measures for further analysis. After narrowing these measures down, the project team calculated water and energy savings estimates.

To supplement the savings potential analysis of water and energy efficiency measures and technologies, the project team also conducted three site visits from which to develop three case studies. The purpose of these case studies was to enhance the concreteness of the savings potential analysis and demonstrate the applicability of various water and energy efficiency measures.

In addition to these site visits, AIQUEOUS reviewed other utility program designs to gather insight on different approaches utilities have adopted to target these market segments. The project team also explored examples of energy and water utilities collaborating to co-promote water conservation measures that also provide energy savings. Based on the results of the quantitative analysis and the insight provided the evaluation of utility program designs, the project team concluded the report by offering specific program recommendations for incorporating water-energy efficiency measures into KCP&L's existing program designs and approaches.

Report Findings

Quantitative Analysis

Table ES-1 shows the estimated annual energy savings for water and wastewater treatment plants. Using a minimum and maximum potential range, water treatment plants can expect 12.5 to 35.3 percent energy savings from the implementation of applicable efficiency measures, while wastewater treatment plants can achieve even more, 30.1 to 66.8 percent.

Table 1. Total annual energy savings for water and wastewater treatment plants

Market	Minimum percent energy savings of total plants	Minimum total annual energy savings (GWh)	Maximum percent energy savings of total plants	Maximum total annual energy savings (GWh)
Total of all Water Treatment Plants	12.5%	14.9	35.3%	42.2
Total of all WWTPs	30.1%	22.2	66.8%	83.0

Tables ES-2 to ES-4 describe the total water and energy savings estimates for schools, restaurants, and colleges. For the purposes of this study, only commercial kitchen energy efficiency measures were considered in this study. For the water side, improvements for toilet, urinal, faucet and irrigation were taken into consideration.

Table 2. Total annual energy savings for restaurants

	Total annual energy savings (GWh)	Percent energy savings of total restaurant	Total annual water savings (Mgal)	Percent water savings of total restaurant
TOTAL MIN	15.1	2.6%	531.3	17.4%
TOTAL AVERAGE	20.2	3.5%	592.5	19.4%
TOTAL MAX	25.9	4.5%	660.7	21.6%

Table 3. Total annual energy savings for schools

	Total annual energy savings (GWh)	Percent energy savings of total school	Total annual water savings (Mgal)	Percent water savings of total school
TOTAL MIN	5.6	0.7%	269	25.8%
TOTAL AVERAGE	7.2	0.9%	272	26.0%
TOTAL MAX	8.8	1.0%	275	26.4%

Table 4. Total annual energy savings for colleges

	Total annual energy savings (GWh)	Percent energy savings of total college	Total annual water savings (Mgal)	Percent water savings of total college
TOTAL MIN	2.7	0.4%	229	25.8%
TOTAL AVERAGE	3.95	0.6%	231.09	26.0%
TOTAL MAX	5.2	0.8%	234	26.4%

Case Studies

To supplement these quantitative findings, the project team performed three site visits: XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX. These site visits provided a valuable opportunity to demonstrate the applicability of water and energy-related efficiency measures and establish a broader context for their implementation. Insights from these visits were incorporated into the study's final recommendations.

For the XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX, energy efficiency gains were possible via pump and motor optimization, as well as system design optimization. As these efficiency opportunities demonstrated, the XXXXXXX plant could easily benefit from a SEM cohort that focused exclusively on energy management in the water and wastewater sectors.

The site visit to XXXXXXXXXXX revealed opportunities to achieve energy savings via various water-related energy end uses, including cooling towers and commercial kitchen equipment. Specifically, the university campus could see improved efficiency from the reduction of scale buildup in the cooling tower systems.

Lastly, upon visiting the XXXXXXXXXXXXXXXXX, the project team learned that the organization was already actively engaged in water-related energy upgrades to its system operations. Their efforts included the conversion of older absorption type water chillers to centrifugal ones and the installation of VFDs and premium efficiency motors.

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Review of Utility Designs

In combination with a review of KCP&L's historic program participation, the project team performed a survey of utility program designs and approaches related to the water-energy nexus. According to this assessment, KCP&L's core water-related efficiency measures were faucet aerators, pre-rinse sprayers, pool pump VFDs, heat pump water heaters. Common measures offered by other utilities that were not included in KCP&L's Standard rebate program consisted of the following:

- Chilled water systems (air-cooled and water-cooled)
- Commercial dishwashers
- Commercial laundry or clothes washers
- Ice machines
- Steam cookers
- Variable frequency drives on pumps

Recommendations

AIQUEOUS recommends that KCP&L add measures to its Standard rebate program, more proactively identify and pursue Custom measures, and target water / wastewater facilities in its Municipal, School, and Hospital (MUSH) market segment in its SEM program, both to capture operations and maintenance savings and to identify projects for its Standard and Custom programs.

Specific measures identified in this study has having high energy efficiency potential to its Standard program, that are part of the prescriptive measure mix at other utilities, include:

- Commercial dishwashers
- Ice Machines
- Steam cookers
- Variable frequency drives on pumps

There are other measures that KCP&L should consider addition to its Standard program, based upon our review of energy efficiency potential in various building types as well as our comparison with other programs:

- Chilled water systems
- Commercial laundry or clothes washers
- Convection ovens (electric)
- Reach-in commercial refrigerators and freezers

For its Custom program, KCP&L can proactively target and pursue a wider range of custom measures, including chilled water systems, water treatment plant improvements, and wastewater treatment plant improvements. Those measures with high savings potential include:

Wastewater Treatment

- Aeration improvements
    - Intermittent aeration
    - Optical dissolved oxygen probe
    - Automated standard residence time / dissolved oxygen control system
- Blowers / diffusers
    - High-speed gearless blowers
    - Single-stage centrifugal blowers
    - Ultra-fine bubble diffusers
    - Rotary screw compressor

Water Treatment

- Pumps and motors
    - Pump system optimization controls
    - Advanced SCADA system
    - Water loss reduction

AIQUEOUS also recommends KCP&L collaborate with water utilities to promote these standard and custom rebates. Doing so may require assisting water utilities in forecasting the demand impacts of these measures, and building conservation savings into their cost of service and rate determinations. Communities experiencing significant growth are ideal targets for such a program, given the likely need to expand water system and / or storage capacity.

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Project Overview/Objectives

KCP&L retained AIQUEOUS to perform a study on the water-energy nexus as it relates to KCP&L's energy efficiency portfolio in Missouri. The purpose of this project was to identify opportunities for integrating water-energy savings into KCP&L's existing programs. These efforts explored the energy efficiency potential of the water-energy nexus in terms of direct savings (through the application of energy efficiency technologies) and indirect savings (through the embedded savings achieved by reductions in water use). The goal was to help KCP&L identify whether and how to adjust the scope and implementation of KCP&L's Standard Rebate Program, Custom Rebate Program, and Strategic Energy Management (SEM) program. As part of the SEM program, KCP&L offers energy education and technical assistance to encourage behavioral change and enhanced energy management across a diverse target market.

In support of these program objectives, KCP&L sought a more granular look at the water-energy nexus and the potential it holds for additional energy savings in the KCP&L Missouri territory. KCP&L hoped to demonstrate through these findings opportunities to expand the their programs' scope and participation to include the water-energy nexus. To drive this analysis, the project team chose the following market segments:

- Energy use in water and wastewater treatment and distribution, to be integrated into KCP&L's Municipal, School, and Hospital ("MUSH") cohort of its Strategic Energy Management ("SEM") program, which includes identifying project opportunities in their Standard and Custom programs; and

- Commercial and industrial water use, either as electrically-heated water or integrated electric and water impacts (e.g., onsite pumping, water-side economizers), to be integrated into the Industrial cohort of SEM or Custom or Standard program business rebates.

- Alternately, or in tandem, water-related measures could be added to KCP&L's Standard and Custom rebate offers.

The primary questions addressed in the scope of this project include:

1. What is the total volume of water use, water production, water distribution, and water treatment within KCP&L's service territory?
2. What is the electric energy use and demand associated with that water use, production, distribution, and treatment?
3. What technologies or strategies could drive energy efficiency improvements, both directly and through the reduction of water use, production, distribution, and treatment?
4. What technologies or strategies have interactive effects between water and electricity, and how could KCP&L approach these technologies or strategies?

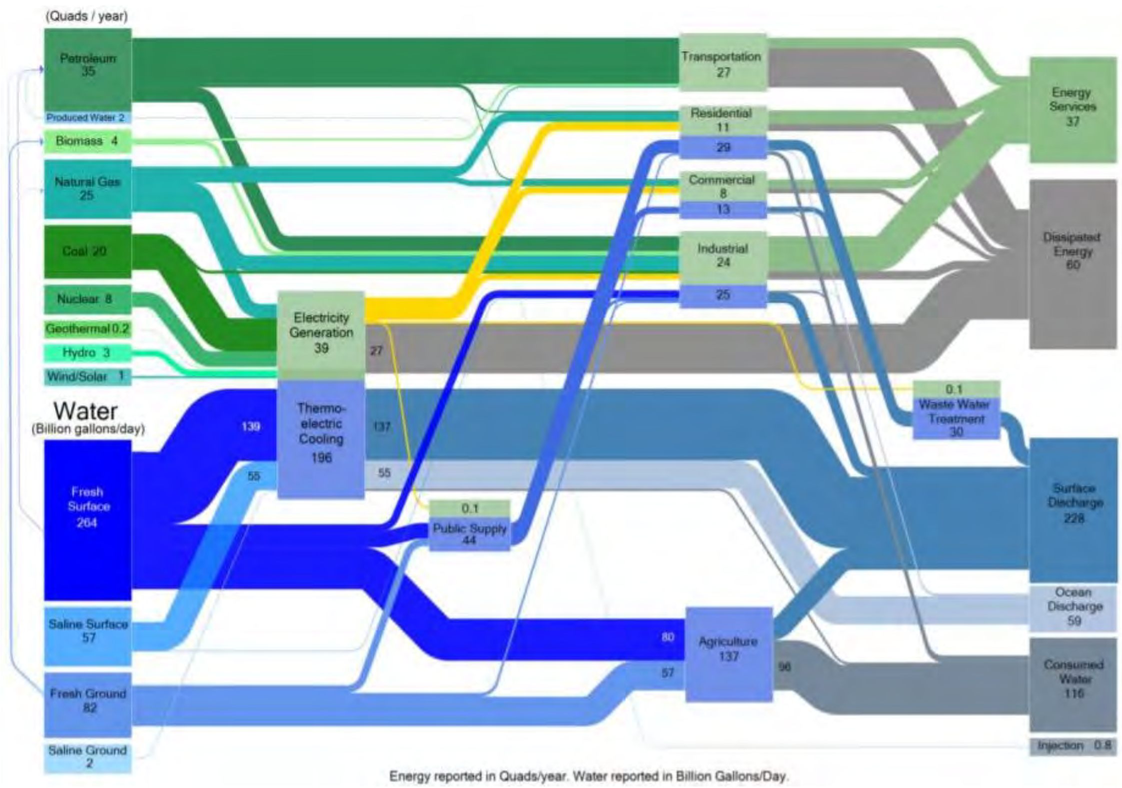
5. What has been the historical KCP&L program participation and customer engagement around the water-energy nexus?
6. What opportunities exist to jointly engage on the water-energy nexus with water utilities and other water authorities?

The following report presents findings on the current state of each market segment, common and emerging water-energy efficiency technologies and practices, and the water conservation and energy efficiency potential tied to these various measures. To supplement these quantitative results and provide broader context into the application of these strategies, the study also provides three case studies based on site visits to a water treatment facility, university, and hospital. The report concludes by offering recommendations to KCP&L on specific initiatives the utility can pursue to fold additional water-energy savings into its comprehensive energy efficiency portfolio.

Water-Energy Nexus

Before delving into the project's methodology and findings, it is important to first speak to the relevance of the water-energy nexus as it relates to KCP&L's energy efficiency objectives. The water-energy nexus refers to the interdependency between water and energy systems. In other words, the water required to produce energy and generate electricity, and alternatively, the energy required to convey, treat, and deliver water and wastewater. The diagram[1] below describes the complexities of this intrinsic relationship.

[1] U.S. Department of Energy, "The Water-Energy Nexus: Challenges and Opportunities," 2014.



Because of these connections, it is possible to capture energy savings by enhancing the efficiency of water and water-related energy end uses, and vice versa. These savings can be direct—i.e., energy savings from efficiency improvements to water and wastewater operations and equipment; or the energy and water savings associated with efficiency improvements to water-related energy end uses, such as HVAC systems, dishwashers, clothes washer, steam cookers, and icemakers. These savings can also be indirect—i.e., the embedded energy savings associated with more efficient water end uses, such as commercial kitchen pre-rinse sprayers or in-ground irrigation systems.

Traditional energy efficiency programs focus on the energy savings potential of energy end uses, but often overlook opportunities to create additional savings associated with the water-energy nexus. As part of its energy efficiency portfolio, KCP&L offers a limited number of water-related measures, including faucet aerators, pre-rinse sprayers, pool pump VFDs, and heat pump water heaters. Overall, however, the energy savings generated by these measures represents 1.82 percent of the utility's portfolio. To explore these opportunities, KCP&L commissioned AIQUEOUS to evaluate the energy efficiency potential of the water-energy nexus across KCP&L's Missouri territory.

Project Approach

The project team divided the water-energy nexus study into five parts. The first step was to determine the market size of each segment and quantify total energy and water consumption within each segment by end use and sector type. The second step was to compile a comprehensive list of water conservation and energy efficiency measures that could yield potential savings for the three target markets. The third step was to develop savings estimates for the technologies and practices identified as most cost-effective. The fourth step was to perform site visits to three KCP&L customers - a water treatment plant, a hospital, and a university – to use field conditions to qualify the results and recommendations.

Market Characterization

Water & Wastewater Treatment Plants

To determine the market size of water and wastewater treatment plants in the KCP&L territory along with their energy consumption by end use, the project team used state published data. The first step identified water and wastewater treatment plants within KCP&L's service boundary. To do this, the project team performed a spatial analysis using two separate datasets[2] obtained from the Missouri Spatial Data Information Service. Using the attribute data for wastewater treatment plants, the project team acquired average daily volume in million gallons per day. For the water treatment plants, the project team used the 2017 Census of Missouri Public Water Systems to identify average production levels in million gallons per day.

After identifying the number and size of facilities, the project team quantified total electric energy consumption by facility using estimates of energy usage intensities in kWh per million gallons produced. Data published by the Water Environment Research Foundation[3] provided a range of energy requirements for various wastewater treatment types. For water treatment plants, the project team acquired energy usage intensities from data published by the Water Research Foundation[4]. To conclude the analysis, the project team obtained end use estimates from various national studies and applied these to the total energy consumption of water and wastewater treatment plants.

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[2] 2015 National Pollutant Discharge Elimination System Outfalls and 2014 Public Water Supply Treatment Plants.

[3] J. S. George Crawford, "Energy Efficiency in Wastewater Treatment in North America: A Compendium of Best Practices and Case Studies of Novel Approaches," WERF, 2010.

[4] C. Arzbaecher et al, "Electricity Use and Management in the Municipal Water Supply and Wastewater Industries," Water Research Foundation, EPRI, 2013.

Commercial & Industrial

The project team obtained information on market size and energy consumption by segment/sector and end use from KCP&L's 2016 DSM Potential Study. The energy use data provided in this report formed the basis of the commercial and industrial market characterizations, and the project team used these data to estimate total building area by building type in the KCP&L service territory. Using these market segment sizes, the project team then applied water usage intensities (e.g., gallons per square foot for commercial and gallons per employee for industrial) to determine water consumption by segment and sector. These estimates of commercial water usage intensities were informed by several published reports focusing on usage patterns in various parts of the country[5] [6]. For the industrial sector, this information was obtained from nationwide[7] and California-based[8] assessments of industrial water use.

Next, the project team drew on national estimates of water end uses published by the EPA, which focused exclusively on the commercial and institutional sector, to disaggregate water consumption by end use. For industrial water end uses, the project team based their estimates on studies conducted in California[9] and New Mexico[10]. The availability of data on industrial water usage, however, was quite sparse given the wide variability in industrial types. Because of these data limitations, the project team was not able to develop water end use estimates for all industrial segments.

Measure identification & savings estimates

The first task was to conduct a literature review and provide a broad list of all energy efficiency technologies available for the target markets. Both cost and savings data were only available for a subset of the identified technologies. The project team used KCP&L's avoided cost data to create simple "pass/fail" cost-effectiveness rules, and screened out measures that fell outside of the cost-effectiveness thresholds. The final

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[5] A. Nuding et al, "Water Connection Charges: A Tool for Encouraging Water-Efficient Growth," Western Resource Advocates, Ceres, and UNC, 2015.
[6] 2012 Commercial Buildings Energy Consumption Survey: Water Consumption in Large Buildings Summary, EIA, 2012.
[7] J. Kiefer et al, "Methodology for Evaluating Water Use in the Commercial, Institutional, and Industrial Sectors," Water Research Foundation, 2015.
[8] P. Gleick et al, "Waste No, Want Not: The Potential for Urban Water Conservation in California," Pacific Institute, 2003.
[9] P. Gleick et al, "Waste No, Want Not: The Potential for Urban Water Conservation in California," Pacific Institute, 2003.
[10] "A Water Conservation Guide for Commercial, Institutional, and Industrial Users," New Mexico Office of the State Engineer, 1999.

part was to calculate the savings potential based on this list of effective measures and on the current energy consumption for each market.

For water and wastewater treatment plants, the project team used multiple sources to build the measure characterization table and can be found in Appendix 1. The majority of measure characterizations originate from the EPA[11] and EPRI[12] reports. Generally, the project team used percent savings, payback years and cost per yearly kWh saved from different sources to provide a range of values, representing the variability of each measure and its dependency on site-specific parameters. However, this range only characterizes a few data points, and should not be taken as absolute minimums or maximums for particular technologies.

For commercial kitchen, the project team exclusively used the ENERGY STAR® Commercial Kitchen Equipment Calculator (Excel based)[13], along with all of its default parameters.

Case Studies

In addition to these research components, the project also performed site visits and produced their findings as three case studies. For this task, AIQUEOUS visited the XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX The purpose of these studies was to enhance the "concreteness" of the study's quantitative analyses by comparing analyzed energy efficiency opportunities with specific on-site opportunities for these KCP&L customers.

Before visiting each site, the project team requested information related to the water and energy consumption at each location, including historic demands and billing data. This information provided preliminary insight into where certain efficiency strategies could be directed, and it also helped the project team identify specific buildings for the evaluation.

During the site visits, the project team performed a general walkthrough of the building to assess water and water-related energy end uses. Knowledgeable staff members at each location provided guidance throughout the building assessments and answered C

[11] J. S. George Crawford, "Energy Efficiency in Wastewater Treatment in North America: A Compendium of Best Practices and Case Studies of Novel Approaches," WERF, 2010.
[12] C. Arzbaecher et al, "Electricity Use and Management in the Municipal Water Supply and Wastewater Industries," Water Research Foundation, EPRI, 2013.
[13] https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/save-energy/purchase-energy-saving-products

questions as they arose. These individuals also provided follow-up information upon request of the project team.

Following the site visits, AIQUEUOUS prepared case studies summarizing the water and energy use at each location, the types of equipment inventoried, the savings potential associated with recommended efficiency measures, and relevant implications for the research project.

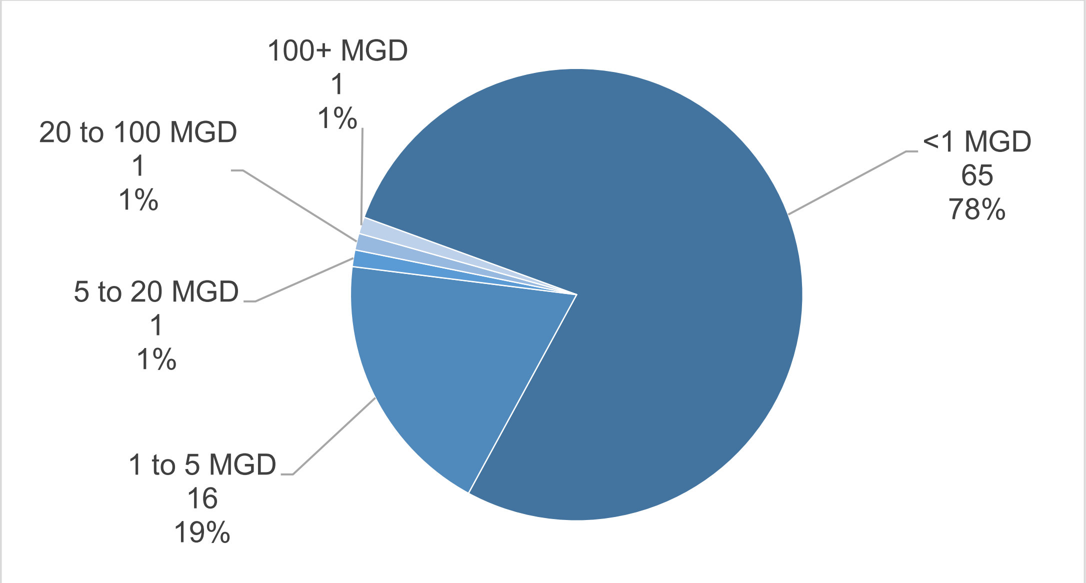
Market Characterization & End Use Estimates

Water Treatment Plants

Market Size

Figure 1 describes the number of water treatment plants by size category. In total, KCP&L provides electricity to 84 water treatment plants in the state of Missouri. A significant majority (78%) of these facilities produce less than one million gallons per day (MGD). These facilities are typically located in rural parts of the state, where on average they serve communities of approximately 2,000 people. Facilities generating 1 to 5 MGD of water represent the second largest category of water treatment plants (19%). On average, these facilities serve populations of 13,000. The three largest water treatment plants represent the smallest percentage (3.6%) of total facilities. These treatment plants serve the communities of Kansas City, Independence, and St. Joseph.

Figure 1. Number of water treatment plants by size category



Water Production

Figure 2 shows the total volume of water produced by water treatment plants according to size category. The largest treatment plant in KCP&L's service territory is in Kansas City and produces an average of 112 MGD, equaling 55% of overall production. Treatment plants sized 1 to 5 MGD produce the second largest share of the public water supply, 19% or 33.1 MGD. Working with the largest treatment plant, and creating a streamlined approach to the 16 1-5 MGD plants could yield significant savings for KCP&L.

Figure 2. Total water production by size category (MGD)

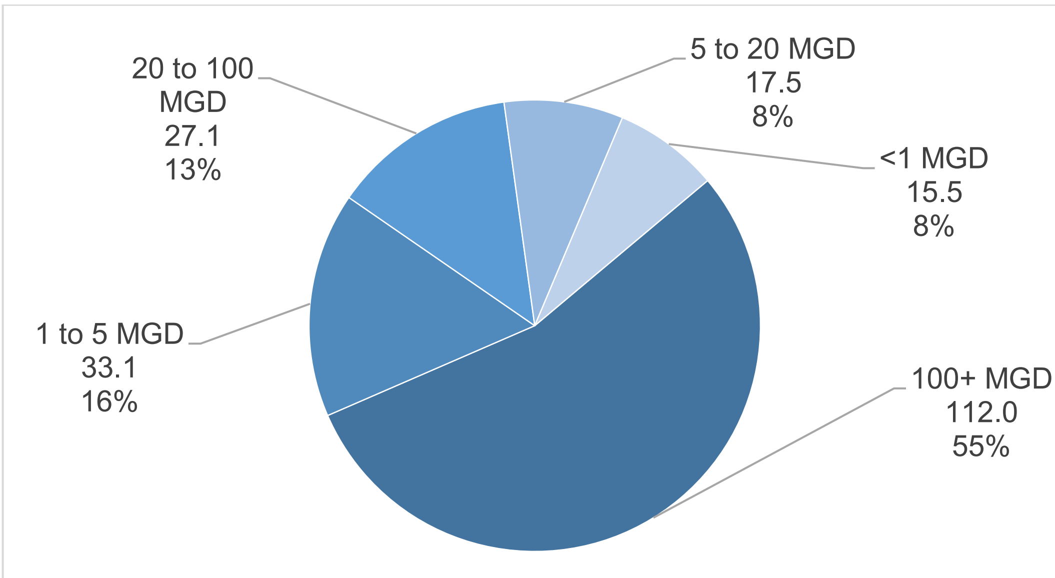
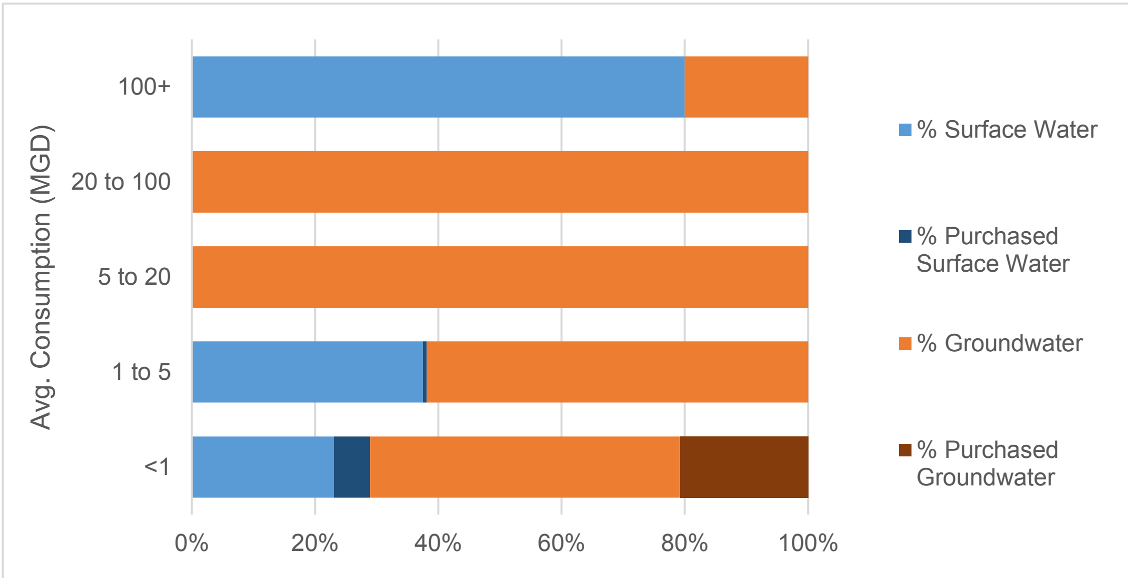


Figure 3 describes public water systems by size category and water source type. Overall, surface water and groundwater sources provide roughly equal shares of public water supply (52% and 48%, respectively). If the city of Kansas City were excluded, however, groundwater would represent 82% of the total water supply, of interest because groundwater sources are more energy-intensive than surface water sources. Amongst the smaller, rural communities, groundwater represents 65% of the public supply. For the cities of St. Joseph and Independence, groundwater is also the sole source of water.

Figure 3. Percentage of water source type by size category

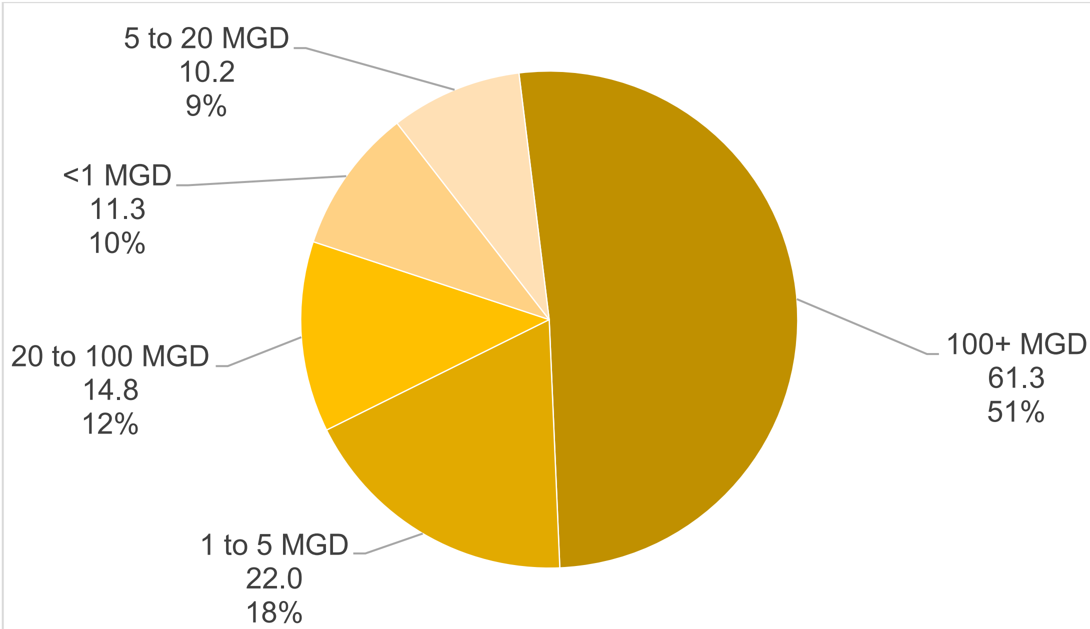


These water supply characteristics are important for understanding the embedded energy associated with water treatment and distribution in the KCP&L service territory. In general, surface water systems have lower embedded energy than groundwater systems. Though not captured as part of this analysis, the length (i.e., from the water source to the treatment plant) and pressure of the water distribution system also dictate the energy requirements for a water treatment plant.

Energy Use

The estimated annual energy consumption of all water treatment plants in the KCP&L territory is 119.6 GWh (see Appendix 2 for the methodology used to calculate energy usage). Figure 4 describes total energy consumption by size category.

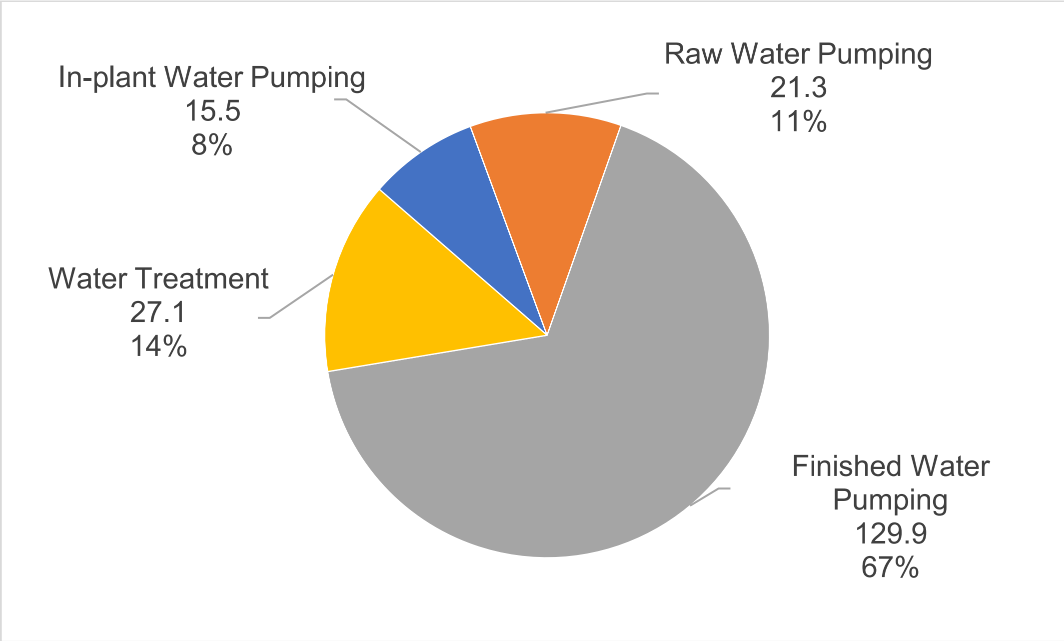
Figure 4. Total water treatment plant energy consumption by size category (GWh/year)



It is important to put this total energy use in context of various water treatment plant end uses. Figure 5 shows energy consumption by end use for a typical water treatment plant[14]. Typical end uses for a water treatment plant include raw water pumping, in-plant water pumping, water treatment, and finished water pumping. Pumping is by far the largest end-use, as it represents 86% of the total consumption.

[14] K. Kissock, "Energy-Efficient Waste Water Treatment," in *AEP 2017*, Ohio, May 17, 2017.

Figure 5. Water treatment plant energy consumption by end use (GWh)



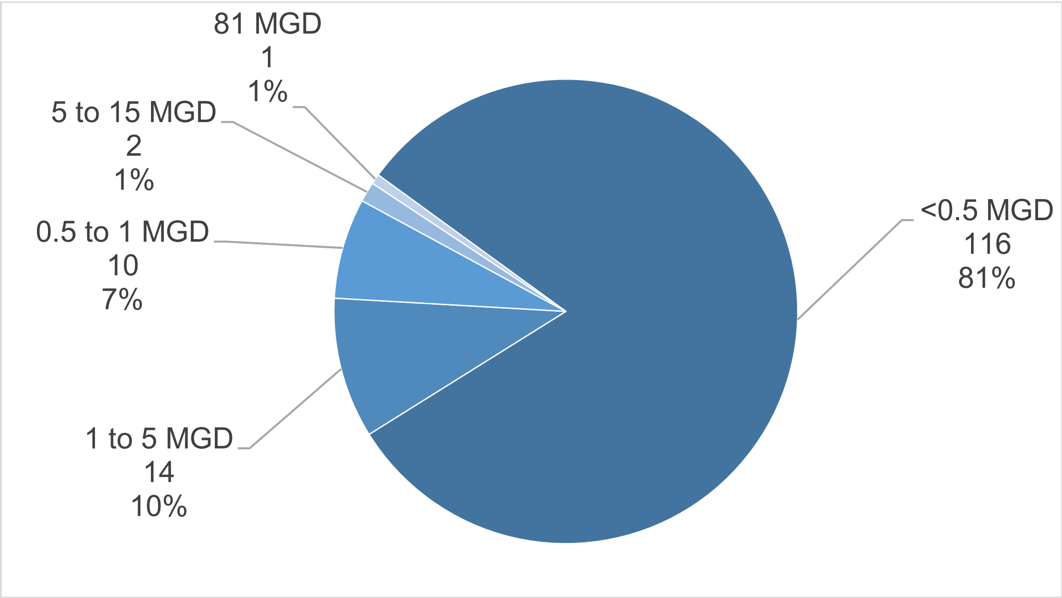
With pumping providing 86% of total energy use, energy efficiency measures associated with pumping – notably high efficiency motors, VFDs, and pump system optimization – have the greatest potential to provide energy savings in KCP&L programs for water treatment facilities.

Wastewater Treatment Plants

Market Size

Figure 6 describes the number of wastewater treatment plants by size category. In total, KCP&L provides electricity to 143 wastewater treatment plants in the state of Missouri. A significant majority (81% or 116 in total) of these facilities treat less than 0.5 MG of wastewater per day. Facilities treating 1 to 5 MGD of wastewater represent the second largest category of wastewater treatment plants (10% or 14 in total), followed by plants sized 0.5 to 1 MGD (7% or 10 in total). The three largest wastewater treatment plants represent the smallest percentage (2.1%) of total facilities. All three of these facilities are in the Kansas City area.

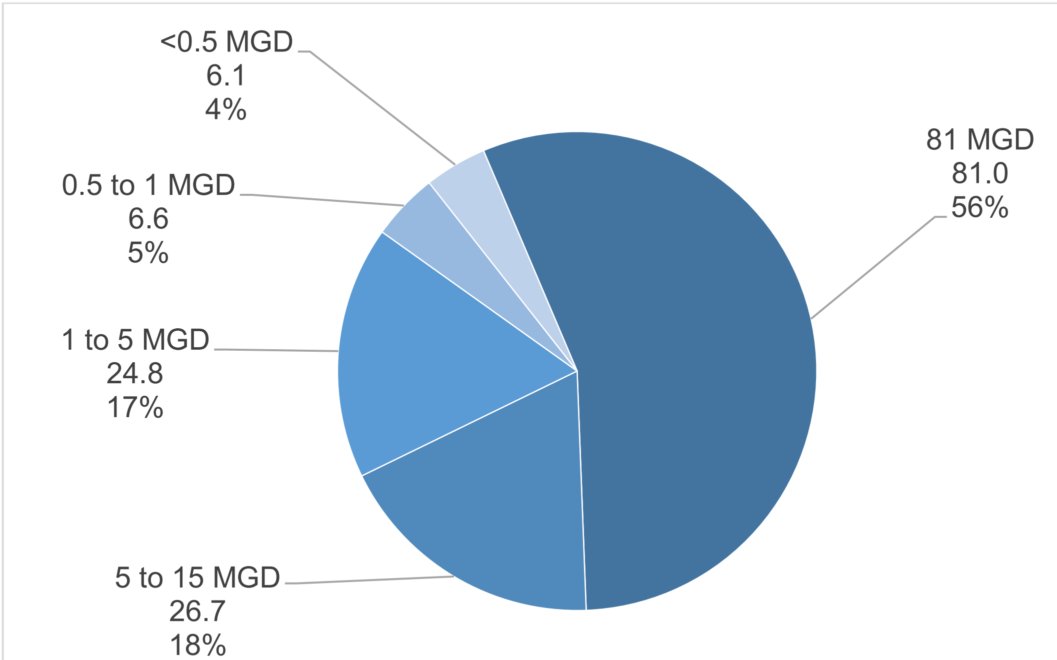
Figure 6. Number of wastewater treatment plants by size category



Wastewater Production

Figure 7 shows the total volume of wastewater treated by facility according to size category. The three wastewater treatment plants in Kansas City alone treat 77%, or 107.7 MGD, of the total wastewater produced. Alternatively, the 116 facilities sized 0.5 MGD or less treat a combined volume of 6.1 MGD, or 4% of total wastewater produced.

Figure 7. Total volume wastewater treated by size category (MGD)



Energy Use

Figure 8 shows an estimated range of energy consumption by facility size. On average, wastewater treatment plants in KCP&L territory consume 73.8 to 124.1 GWh annually (see Appendix 3 for the methodology used to calculate energy usage).

Figure 8. Wastewater treatment plant energy consumption by size category (GWh/year)

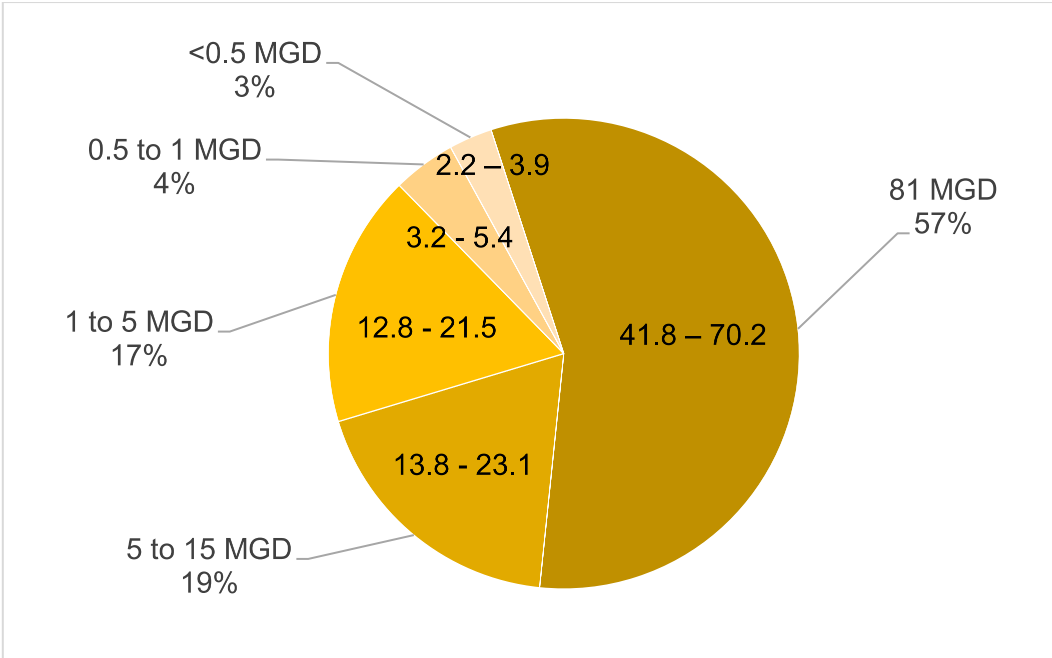
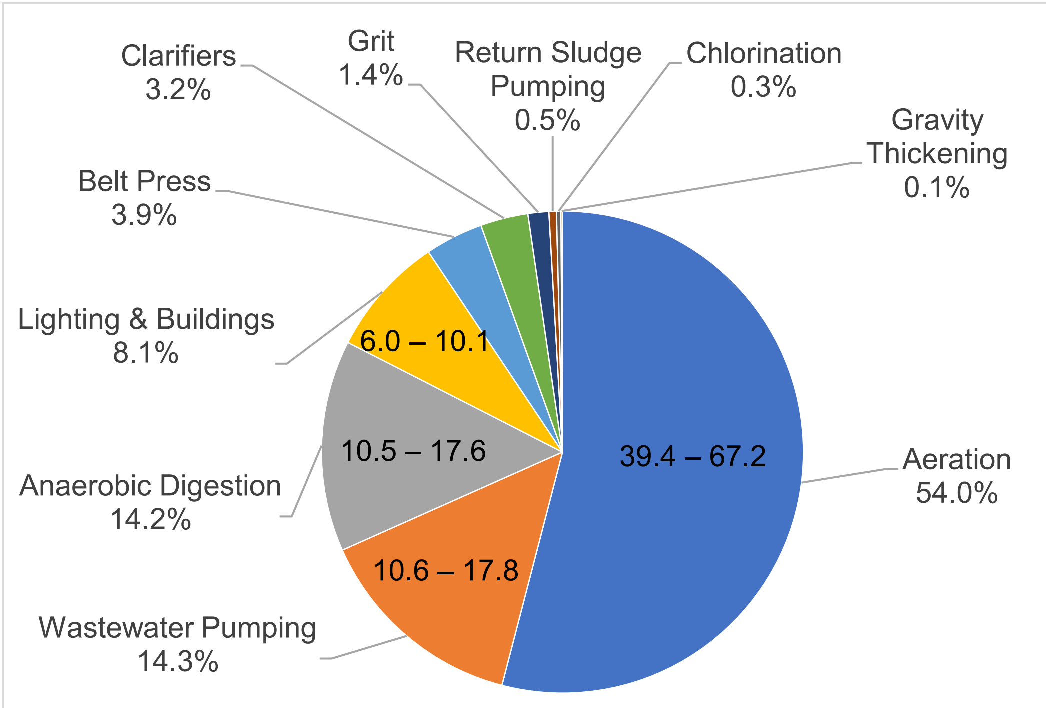


Figure 9 shows the energy consumption end use disaggregation for a typical wastewater treatment plant with activated sludge[15]. Aeration is the main energy intensive end-use with more than half of the total energy consumption.

[15] Derived from data from the Water Environment Energy Conservation Task Force Energy Conservation in Wastewater Treatment.

Figure 9. Wastewater treatment plant energy consumption by end use (GWh)



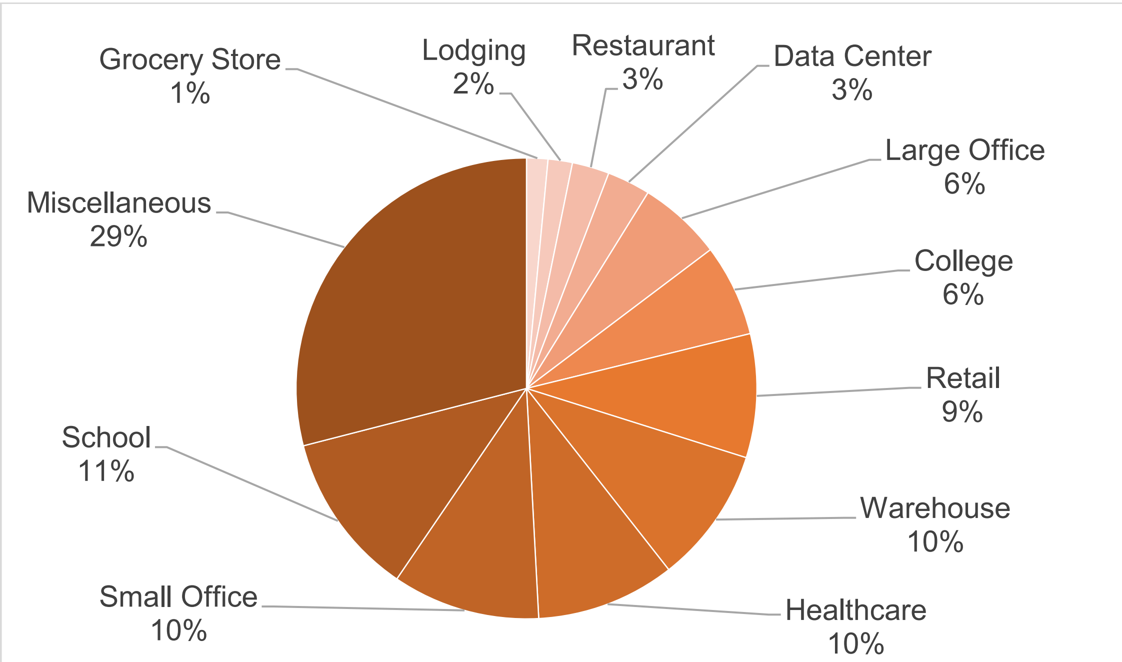
With aeration and pumping providing the majority (68%) of energy use, technologies such as VFDs, fine-bubble diffusers, high efficiency motors, and fan and pump system optimization controls are all effective energy efficiency measures. Additionally, new processes that do not rely upon aeration are evolving in the wastewater market, and are worth considering for custom program measures.

Commercial

Market Size

The second sector considered by this report is the commercial building sector. Figure 10 shows the size of the commercial sector by segment according to total square footage, based on KCP&L's 2016 DSM Study. The five largest identified segments in KCP&L's service territory are schools, small offices, health care, warehouse, and retail.

Figure 10. Commercial sector size by segment (based on total square footage)



Water Use

Figure 11 describes total water consumption by commercial segment. The five largest identified segments by water use in KCP&L's service territory are restaurant, health care, retail, data centers (for cooling), and schools and colleges. Although restaurants make up only 3% of the commercial market, this segment uses 16% of total water used in this sector.

Figure 11. Commercial water consumption by segment

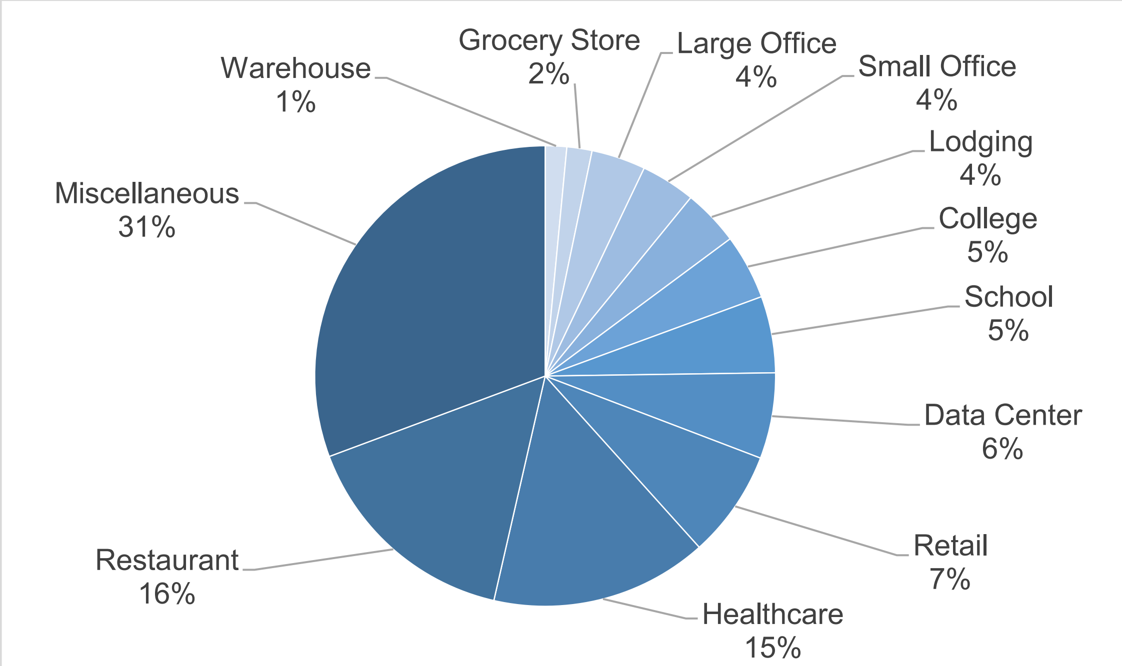
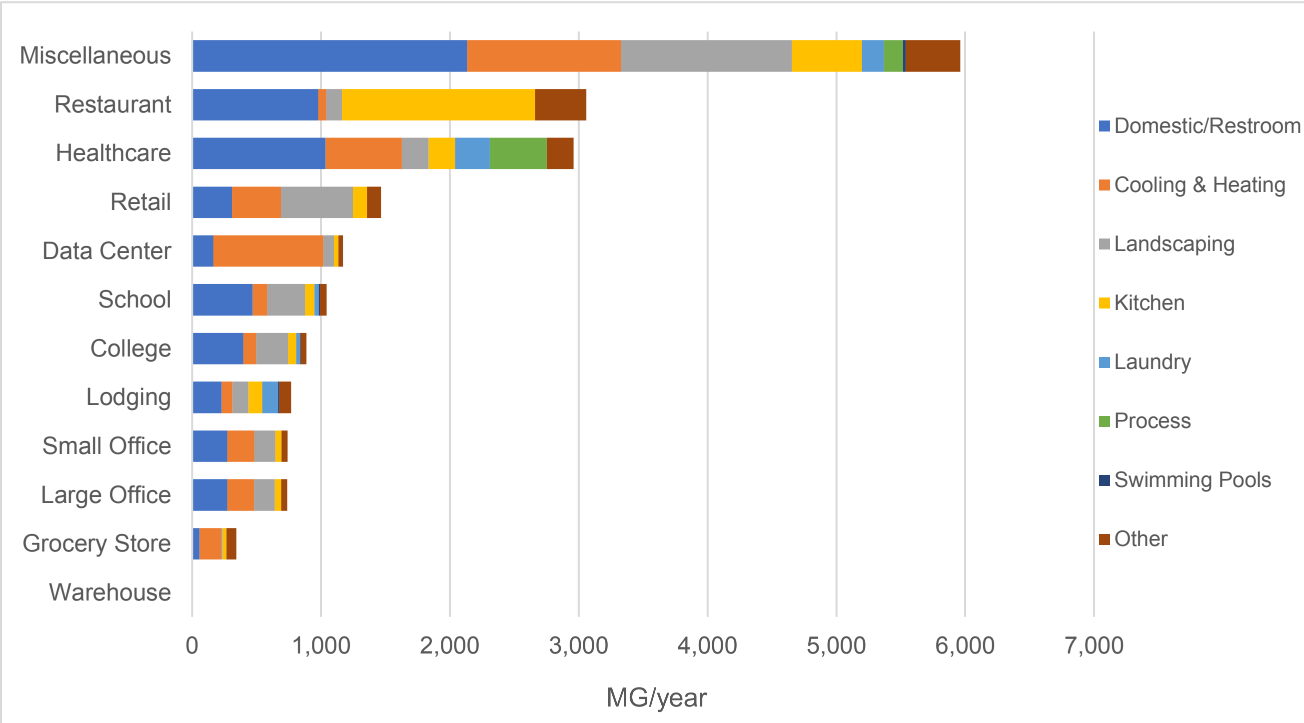


Figure 12 describes the commercial sector's water consumption by segment and end use. Water end intensities vary significantly by building type. For instance, the domestic/restroom end use represents 45% of water consumption in the college/school segment, translating to a water use intensity of 7 to 11 gallons per square foot. While a slightly smaller percentage of restaurant water use also goes towards the domestic/restroom end use (32%), this equates to 66 gallons per square foot. Similarly, while landscaping represents 16% of water use by the lodging sector— which is a lower percentage than colleges and schools (28%) and retail (38%)—the lodging segment uses 13 gallons per square foot for landscaping purposes, the highest of all segments.

Figure 12. Commercial water consumption by segment and end use (MG/year)

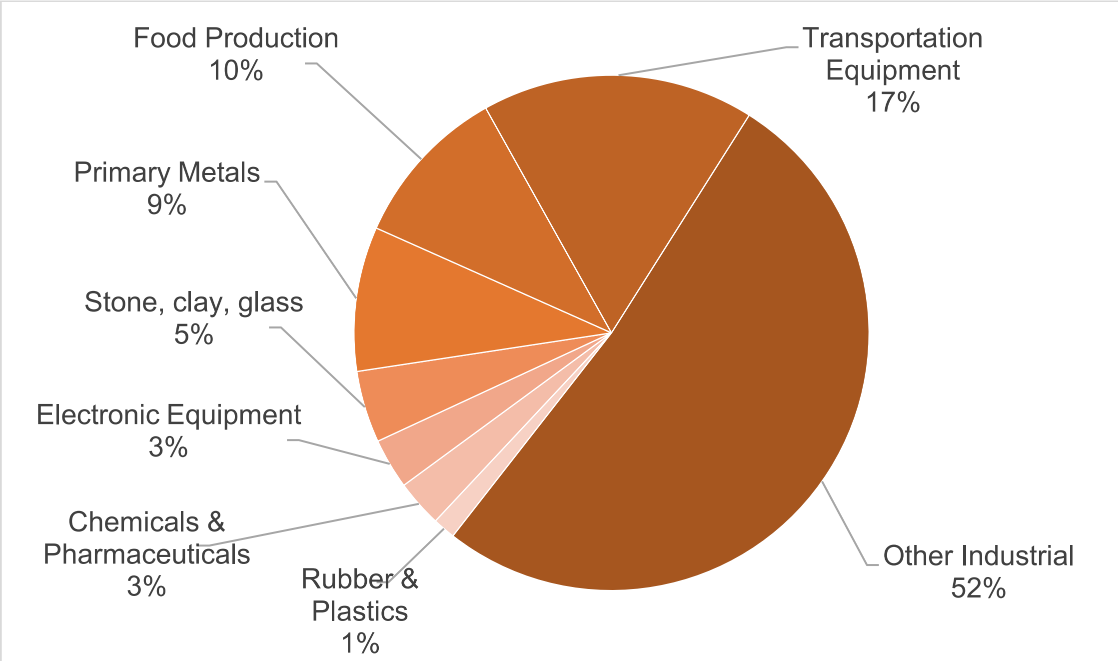


Industrial

Market Size

Figure 13 shows the size of the industrial sector by segment based on number of employees, as estimated in the 2016 DSM Potential Study. Of the identified industrial segments, the largest share of employment is comprised by transportation equipment, followed by food production, primary metals, and stone, clay and glass. These four segments account for 41 percent of employment.

Figure 13. Industrial sector size by segment (based on number of employees)



Water Use

Using the employment information and industrial water use data, the project team developed estimates of water use by industry segment. Figure 14 describes total industrial water consumption by segment. Again, the other industrial segment accounts for the largest water user category. Primary metals and transportation equipment remain among the highest segments for water use, with electronic equipment and food production rounding out the “Top 4.”

Figure 14. Industrial water consumption by segment

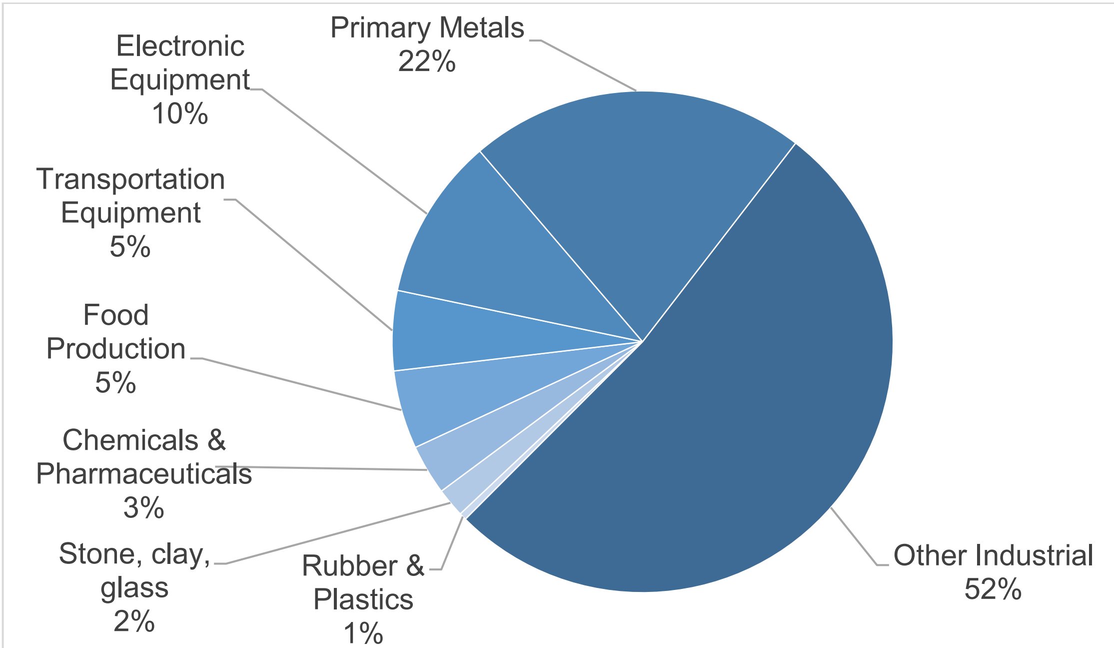
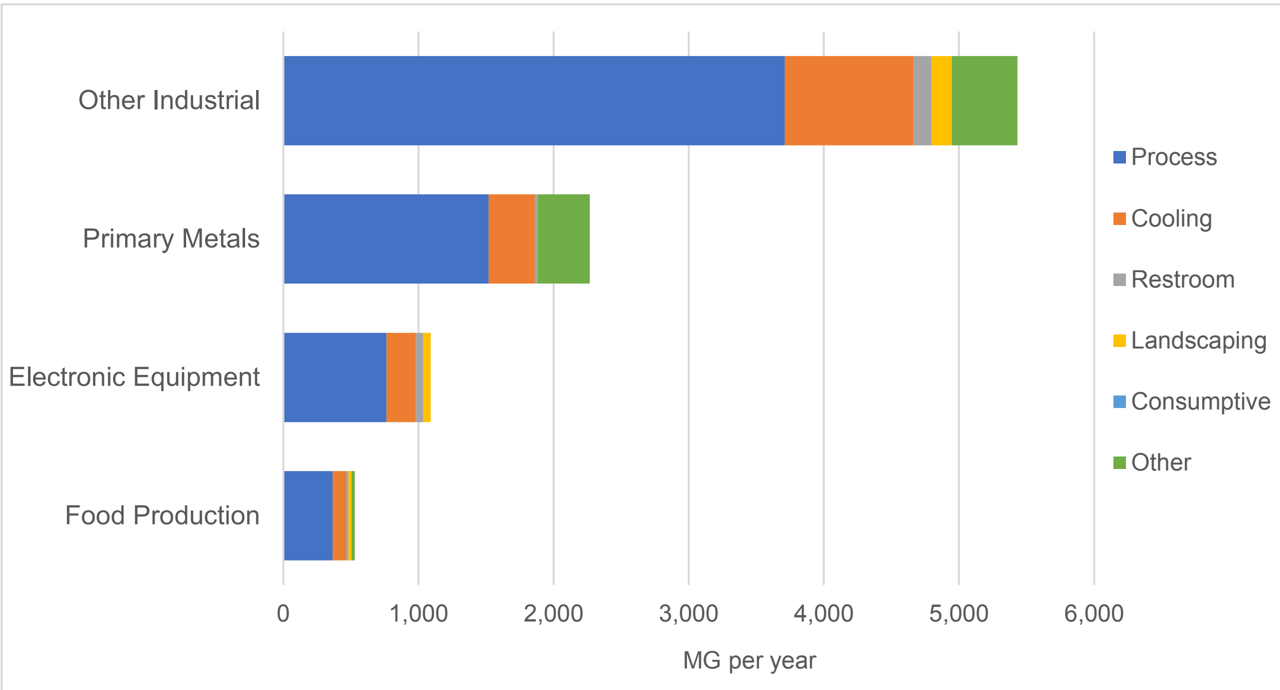


Figure 15 highlights industrial water consumption by segment and end use. Due to the wide variety of industrial types and end uses, limited data was available to estimate these water end uses. Estimates could only be obtained for food production, electronic equipment, primary metals, and other industrial types. In all of these segments, water used for processing purposes accounts for the largest share of total consumption.

Figure 15. Industrial water consumption by segment and end use (MG/year)



Measure Identification and Savings Estimates

Measure Characterization

Separated energy and water efficiency measures

AIQUEOUS compiled a list of water and energy program measures related to water treatment plants, wastewater treatment plants, commercial kitchens, indoor plumbing fixtures, and outdoor irrigation. For each measure, the project team developed a brief description of the new technology and of the baseline technology. Depending on available secondary sources, the project team added the measure useful life, percent savings, cost per kWh saved and simple payback period. The project team then applied measure savings against the appropriate total consumption or end use consumption data by market segment. For example, end-uses for wastewater treatment plants include “Design and control of aeration systems”, “Treatment processes”, and “Pump / motor.” Depending on the data source, the project team listed measure savings as a percent savings for the whole plant, or a percent savings of the end-use only. The project team also identified mutually exclusive measures to avoid double-counting savings when accounting for all possible measures. The table of all measures is shown in Appendix 1.

Water and energy-related measures

AIQUEOUS also looked at strategies that have interactive effects between water and electricity. The main technology which allows this interaction is cooling towers.

Cooling towers reject unwanted heat from a chilled water system, and can use either water or air to do this. Even if water-cooled towers use more water than air-cooled ones, they are generally more energy efficient. Consequently, there is a trade-off between water and energy consumption based on the technology used. Recently, the emergence of hybrid cooling towers using both air and water, depending on exterior conditions, can be an efficient way to optimize the consumption of water and energy[16]. The measure table for cooling towers can be found in Appendix 1/Table AP-4.

Cost-Effectiveness

AIQUEOUS' research generated only high-level information on the levelized cost of the identified energy efficiency measures. In some cases, measure life or cost information were missing. To create a simple screening, AIQUEOUS used KCP&L's avoided costs to determine a cost-effective 10-year measure, with a flat load shape. This screening determined that the cost per kWh saved should not exceed $0.40 per annual kWh to be cost-effective for KCP&L. Thus, the project team classified measures into four categories:

- No cost information available
- Cost / annual kWh saved < $0.40
- Wide range of cost / annual kWh saved below and above $0.40
- Cost / annual kWh saved > $0.40

No cost information available

The measures falling in the first category were typically relatively new technologies which haven't been monitored in a non-theoretical environment or which haven't even been tested in full-scale yet. The project team listed these measures for information purposes and to make KCP&L aware of all possible measures but weren't considered for further analysis given the lack of data.

Cost-effective measures

The measures in the second category (i.e. which have a cost per annual kWh saved lower than $0.40) are commercially available technologies which have undergone

[16] J. S. George Crawford, "Energy Efficiency in Wastewater Treatment in North America: A Compendium of Best Practices and Case Studies of Novel Approaches," WERF, 2010.

previous case studies analysis and which have a high cost-effectiveness. The project team included these measures in the savings estimate.

Marginally cost-effective measures

The measures in the third category are commercially available technologies which have undergone previous case studies analysis but which highly depend on the project. For example, the implementation of variable frequency drives on pumps at a water treatment plant can be met with a wide range of success. The cost-effectiveness for this measure ranged from $0.26 to $1.02 per annual kWh saved based on different case studies. The project team included these measures in the energy savings analysis, but KCP&L should be aware that some measures might not be cost-effective depending on the specific project, and that a more in-depth investigation would be necessary.

Non-cost-effective measures

The measures in the last category (i.e. which have a consistent cost per annual kWh saved higher than $0.40) are typically measures which would be good options at the time of replacement, but not as retrofits due to their low cost-effectiveness. Thus, these measures were not considered for further analysis.

Savings Calculations

Current energy consumption within the KCP&L territory

The list of all water systems and wastewater treatment plants located in the KCP&L territory with their relative average daily flows can be found in Appendix 2/Table AP-5 and Appendix 3/Table AP-6. There are 143 wastewater treatment plants and 84 water systems in the KCP&L territory. The total annual energy consumption of all water systems facilities was estimated at 120 million kWh and for wastewater treatment plants between 74 million kWh and 124 million kWh.

The current yearly energy consumption of all restaurants, schools and colleges in the KCP&L territory are 576 GWh, 842 GWh, and 646 GWh respectively.

Savings potential

For all measures, when not directly found in literature, the percent savings of the whole plant was calculated as follows:

$$\%\, savings\ of\ whole\ plant = \%\ savings\ of\ end\ use * \%\, energy\ consumption\ of\ end\ use \quad (1)$$

The measure-level potential energy savings is defined as follows:

$$C_{pot}(\%) = \frac{Total\ conservation\ potential}{Total\ current\ comsumption} \qquad (2)$$

For most scenarios where one efficient measure replaces one inefficient measure, the conservation potential is equal to:

$$C_{pot}(\%) = \frac{(1-p) * \%_{Savings} * A}{(1 - p * \%_{Savings})} \qquad (3)$$

Where:

- $C_{\text{pot}}(\%)$ = Efficiency potential savings in percent of the total current consumption
- p = Penetration factor = Percent cases where the efficient measure has already been implemented
- $\%_{Savings}$ = Percent savings achieved by the efficient measure compared to the inefficient one
- A = Applicability factor = Percent cases where the efficient measure can be implemented in lieu of the inefficient one.

In the case where there are multiple inefficient measures (for example, toilets with 3.5 and 5 gpf), which are replaced by one efficient one (for example, toilet with 1.6 gpf), then the conservation potential is as follows:

$$C_{pot}(\%) = \frac{\sum_{i=1}^{N}\left(\frac{A_i * p_i * \%_{Savings,i}}{1 - \%_{Savings,i}}\right)}{p + \sum_{i=1}^{N}\left(\frac{p_i}{1 - \%_{Savings,i}}\right)} \qquad (4)$$

Where:

- $C_{\text{pot}}(\%)$ = Efficiency potential savings in percent of the total current consumption
- p = Percent cases where the efficient measure has already been implemented
- p_i = Percent cases where the inefficient measure i is in place
- N = total number of different inefficient measures (≥1)
- $\%_{Savings,i}$ = Percent savings achieved with the efficient measure compared to the inefficient measure i
- A_i = Applicability factor = Percent cases where the efficient measure can be implemented in lieu of the inefficient measure i.

The full derivation of equations (3) and (4) can be found in Appendix 4. The penetration factor and applicability factor were assumed to be 10% and 90% respectively unless noted otherwise, but information on these factors was very scarce. Often, the percent savings were given as a range instead of a precise value so a minimum and a maximum value was calculated for the total annual energy savings. The full detailed tables of these savings are displayed in Appendix 5. Table 1 below shows the total economic potential for all plants when all compatible measures are taken into consideration. The total percent savings for water systems ranged from 12.5% to 35.3% of the total energy consumption, and for wastewater treatment plants, it ranged from 30.1% to 66.8%.

This difference in cost-effective savings potential between water and wastewater facilities can be partly explained by the fact that measures concerning pumps and motors are fairly common (their penetration factor reaches 50%)[17]. Since for water systems pumping energy is responsible for 86% of the total consumption, that means that efficiency options have already been addressed for 43% of total sector consumption. Wastewater treatment plants involve multiple processes with lower penetration rates, making the energy efficiency potential higher.

Table 5. Total annual cost-effective energy savings for water and wastewater treatment plants

Market	Minimum percent energy savings of total plants	Minimum total annual energy savings (GWh)	Maximum percent energy savings of total plants	Maximum total annual energy savings (GWh)
Total of all Water Treatment Plants	12.5%	14.9	35.3%	42.2
Total of all WWTPs	30.1%	22.2	66.8%	83.0

For restaurants, schools and colleges, the project team only considered commercial kitchen[18] energy efficiency measures. Regarding embedded energy savings associated with water treatment and distribution, the project team also took into consideration toilet, urinal, faucet and irrigation conservation measures. The total embedded energy associated with water savings is 3466 kWh per million gallons. This number includes both water and wastewater treatment energy savings and the calculation of this value can be found in appendix 3. The Tables 2 to 4 show the total energy and water savings for restaurants, schools and colleges, respectively. The detailed tables of these savings are displayed in Appendix 5.

[17] SBW Consulting, "Municipal Water Treatment Plant Energy Baseline Study," 2006.
[18] All measures for commercial kitchens were taken from the Energy Star: Commercial kitchen equipment calculator.

Table 6. Total annual cost-effective energy savings for restaurants

	Total annual energy savings (GWh)	Percent energy savings of total restaurant	Total annual water savings (Mgal)	Percent water savings of total restaurant
TOTAL MIN	16.9	2.9%	531	17.4%
TOTAL AVERAGE	22.3	3.9%	592	19.4%
TOTAL MAX	28.2	4.9%	661	21.6%

Table 7. Total annual energy savings for schools

	Total annual energy savings (GWh)	Percent energy savings of total restaurant	Total annual water savings (Mgal)	Percent water savings of total restaurant
TOTAL MIN	6.6	0.8%	269	25.8%
TOTAL AVERAGE	8.1	1.0%	272	26.0%
TOTAL MAX	9.8	1.2%	275	26.4%

Table 8. Total annual energy savings for colleges

	Total annual energy savings (GWh)	Percent energy savings of total restaurant	Total annual water savings (Mgal)	Percent water savings of total restaurant
TOTAL MIN	3.5	0.5%	229	25.8%
TOTAL AVERAGE	4.7	0.7%	231	26.0%
TOTAL MAX	6.0	0.9%	234	26.4%

All assumptions regarding how the final values were obtained can be found in Appendix 5.

Case Studies

The project team conducted three case studies in three different sectors within the KCP&L region (i.e. water treatment plant, college and hospital). The goal of these site visits were threefold. The project team wanted to make sure that the measures studied and identified were relevant, not only in theory, but also in the field. Secondly, even if three visits is not a statistically significant sample number, it provided the project team a better idea of the kinds of equipment used by these facilities. Last, it helped the team understand whether water-related energy efficiency measures had been considered and implemented.

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KCP&L Program Participation History

To assess the proportion of savings potential that KCP&L has captured in its prior program years, AIQUEOUS reviewed KCP&L's program history for custom and prescriptive measures in its Commercial and Industrial (C&I) program. KCP&L provided AIQUEOUS with a data set from the past year.

Figure 32 presents the annual energy savings captured in the water sector – those C&I customers associated with the treatment and delivery of water. A total of nine projects accounted for just over 1,300,000 kWh in annual energy savings, with lighting contributing 95 percent of those savings. These energy savings represent 1.1 to 3.4 percent of the energy savings potential identified in this study for the water sector.

Figure 32**. Energy Savings from Water Sector Projects in KCP&L's Commercial** & Industrial Program (kWh)

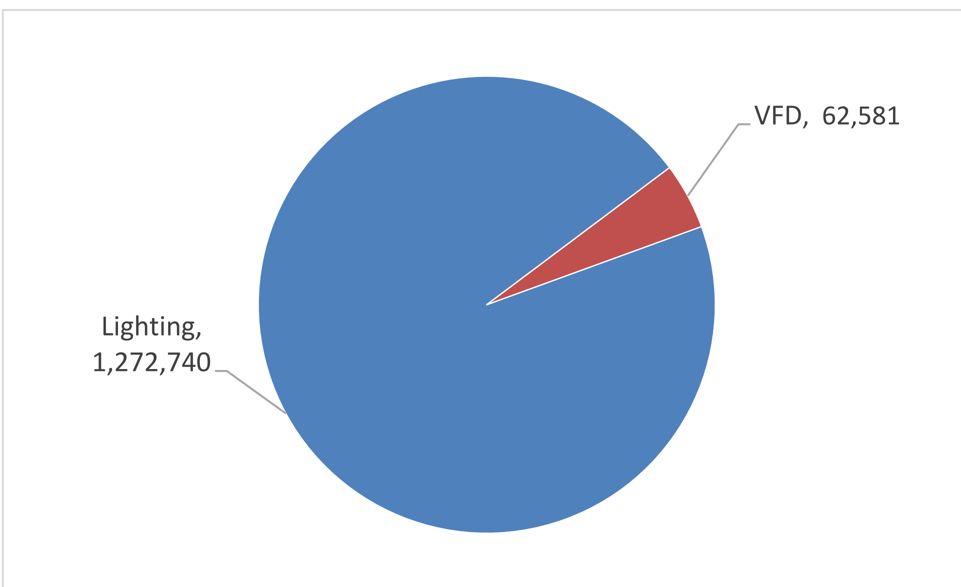


Figure 33 presents the annual energy savings captured via "standard" or prescriptive measures in the C&I program associated with pumps, commercial kitchens, and water-source heat pumps. Total energy savings were just over 500,000 kWh per year, and VFDs accounted for the bulk (91 percent) of measure savings.

Figure 33. Energy Savings from Water-Related Prescriptive Measures in **KCP&L's Commercial & Industrial Program (kWh)**

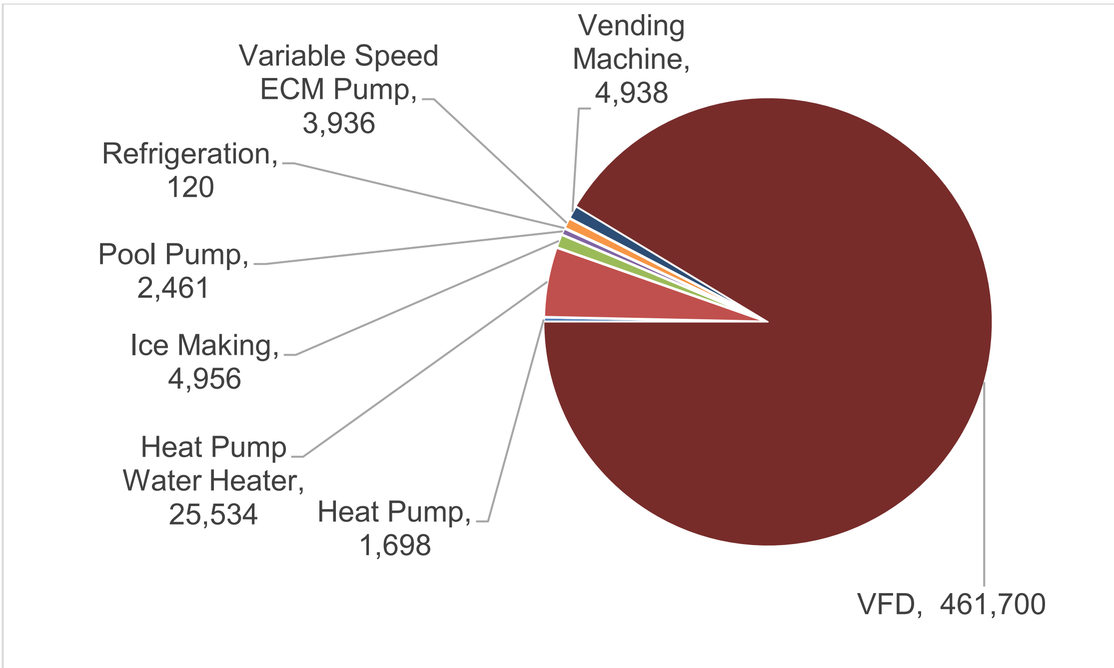
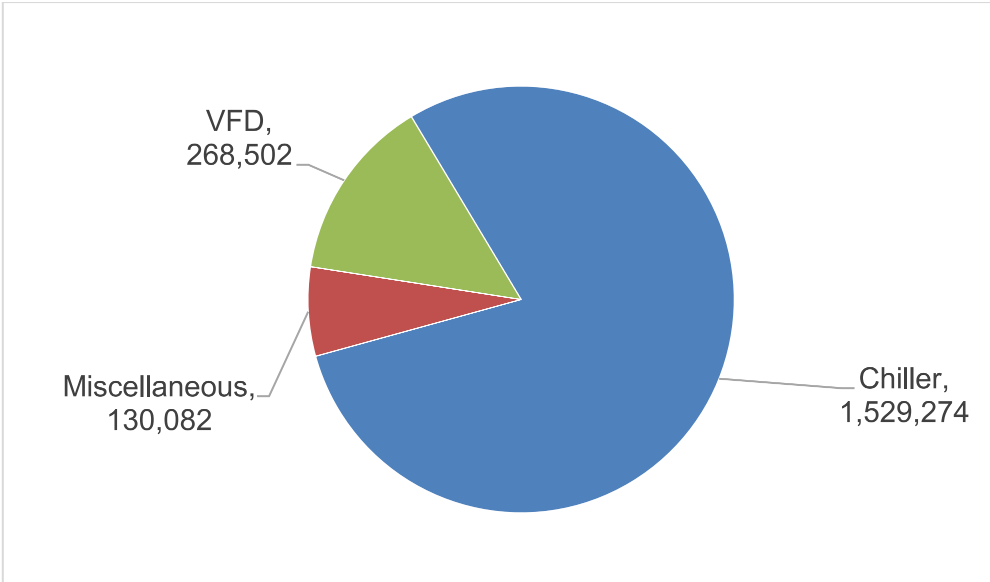


Figure 34 presents the annual energy savings captured from custom measures in KCP&L's C&I program associated with pumps or chilled water plants. Total energy savings were nearly 2,000,000 kWh per year, and one chilled water plant project accounted for the bulk (79 percent) of measure savings.

Figure 34. Energy Savings from Water-**Related Custom Measures in KCP&L's** Commercial & Industrial Program (kWh)



Combining the savings for water-related measures yields about 2,500,000 kWh in annual energy savings, which is approximately 1 to 4 percent of the energy saving potential identified in this study.

Overall, this review of KCP&L program history indicates a significant amount of remaining energy efficiency potential in the water sector and in water-related measures.

Water-Energy Nexus Program Examples

In addition to reviewing program history, AIQUEOUS compared KCP&L's water-related program offerings to those of other utilities. Table 7 highlights a comparison of KCP&L's "standard" incentives on water-related measures, with those offered by other utilities.

Table 11. Comparison of Utilities Offering Water-Related Incentives

Water-Related Standard Measure	KCP&L (MO)	Alliant (IA)	Ameren (OR)	Avista (OR)	Con Edison (NY)	Duke Energy (NC)	Eff. Vermont (VT)	PG&E (CA)	Pepco (MD)	SDG&E (CA)
Chiller Pipe Insulation		X								
Chillers - air cooled		X			X	X			X	
Chillers - water-cooled centrifugal		X			X	X			X	
Chillers - water-cooled reciprocating		X			X	X			X	
Chiller tune-up		X								
Clothes washer		X							X	
Commercial geothermal heat pump		X								
Commercial dishwasher		X		X		X		X	X	
Commercial laundry				X				X	X	X
Drain water heat transfer system		X								
Drains, no-loss							X			
Faucet Aerator - Bathroom	X			X	X	X				
Faucet Aerator - Kitchen	X			X	X	X				
Heat pumps - water source				X			X			X
Ice Machine				X		X	X	X	X	X
Irrigation, centrifugal booster pump								X		
Irrigation system, drip								X		X
Irrigation system, low pressure		X								
Irrigation system, submersible pump								X		
Irrigation system, turbine pump								X		
Irrigation system, well pump VFD								X		
Livestock waterer		X								

Water-Related Standard Measure	KCP&L (MO)	Alliant (IA)	Ameren (OR)	Avista (OR)	Con Edison (NY)	Duke Energy (NC)	Eff. Vermont (VT)	PG&E (CA)	Pepco (MD)	SDG&E (CA)
Motors, premium efficiency					X					
Ozone laundry system								X		X
Plate coolers for agricultural use							X		X	
Pre-rinse sprayer	X	X			X	X			X	
Pumps, high-performance circulator							X			
Showerhead				X						
Showerwand				X						
Spa or hot tub cover		X								
Steam cooker		X	X	X		X	X	X	X	X
Steam traps		X								X
Swimming pool cover		X								X
Swimming pool heat pump water heater			X					X		
Swimming pool pump timer			X							
Swimming pool pump VFD	X		X				X			
VFDs		X					X		X	X
Water cooler									X	
Water heater - heat pump	X	X	X				X	X	X	
Water heater - instantaneous				X						X
Water heater - thermostat setback					X					

Water-Related Standard Measure	KCP&L (MO)	Alliant (IA)	Ameren (OR)	Avista (OR)	Con Edison (NY)	Duke Energy (NC)	Eff. Vermont (VT)	PG&E (CA)	Pepco (MD)	SDG&E (CA)
Chiller Pipe Insulation		X								
Chillers - air cooled		X			X	X			X	
Chillers - water-cooled centrifugal		X			X	X			X	
Chillers - water-cooled reciprocating		X			X	X			X	
Chiller tuneup		X								
Clothes washer		X							X	
Commercial geothermal heat pump		X								
Commercial dishwasher		X		X		X		X	X	
Commercial laundry				X				X	X	X
Drain water heat transfer system		X								
Drains, no-loss							X			
Faucet Aerator - Bathroom	X			X	X	X				
Faucet Aerator - Kitchen	X			X	X	X				
Heat pumps - water source				X			X			X
Ice Machine				X		X	X	X	X	X
Irrigation, centrifugal booster pump								X		
Irrigation system, drip								X		X
Irrigation system, low pressure		X								
Irrigation system, submersible pump								X		
Irrigation system, turbine pump								X		
Irrigation system, well pump VFD								X		
Livestock waterer		X								
Motors, premium efficiency					X					

Ozone laundry system								X		X
Plate coolers for agricultural use							X		X	
Pre-rinse sprayer	X	X			X	X			X	
Pumps, high-performance circulator							X			
Showerhead				X						
Showerwand				X						
Spa or hot tub cover		X								
Steam cooker		X	X	X		X	X	X	X	X
Steam traps		X								X
Swimming pool cover		X								X
Swimming pool heat pump water heater			X					X		
Swimming pool pump timer			X							
Swimming pool pump VFD	X		X				X			
VFDs		X					X		X	X
Water cooler									X	
Water heater - heat pump	X	X	X				X	X	X	
Water heater - instantaneous				X						X
Water heater - thermostat setback					X					

KCP&L's core water-related measures with standard rebates consist of the following:

- Faucet aerators
- Pre-rinse sprayers
- Pool pump VFDs
- Heat pump water heaters

AIQUEOUS reviewed standard or prescriptive rebates offered by nine other utilities (see Table 7). The following measures were offered by four or more utilities and are not currently included in KCP&L's standard rebate program:

- Chilled water systems (air-cooled and water-cooled)
- Commercial dishwashers
- Commercial laundry or clothes washers
- Ice machines
- Steam cookers
- Variable frequency drives on pumps

An evaluation of program participation history for each of these measures was outside of AIQUEOUS' scope of work. It is probable that these measures account for a relatively small percentage of program participation at these other utilities, much as the above list of measures accounts for a relatively small percentage of savings for KCP&L's portfolio.

Key Recommendations

The purpose of this study was to demonstrate the energy efficiency potential associated with the water-energy nexus and identify specific opportunities for KCP&L to pursue that energy efficiency potential, whether through its Strategic Energy Management (SEM) program or its standard and custom commercial and industrial (C&I) rebate programs. To date, the energy savings associated with water-energy projects captured in KCP&L's recent program history account for 1.8 percent of KCP&L's existing efficiency portfolio. Results from this analysis reveal a range pf cost-effective savings potential of 61 to 165 GWh annually, demonstrating several key areas where KCP&L can advance its portfolio objectives. The strategies and measures recommended by AIQUEOUS focus on three types of savings opportunities: water/wastewater treatment plants, water-related energy efficiency, and the embedded energy of water production and delivery. These recommendations take into account prior program history, the applicability of efficiency measures within KCP&L's customer base, and the cost-effectiveness of efficiency outcomes. Opportunities for KCP&L to collaborate with water utilities to promote these efficiency measures is also discussed.

Standard & Custom Rebate Program Changes

For the water-energy nexus, KCP&L's Standard program offers four core water-related measures: faucet aerators, pre-rinse sprayers, pool pump VFDs, and heat pump water heaters. Water sector customers have also benefited from standard rebates (lighting and VFDs). In total, these standard measures reflect just 0.5 percent of KCP&L's portfolio savings. Alternatively, the Custom program, focusing on VFDs, chillers, and lighting yielded 1.3 percent of total savings. The cost-effective energy efficiency potential identified in this study ranges from 16 to 44 times greater than was captured in the Standard and Custom programs data set provided to AIQUEOUS.

To capture additional savings, AIQUEOUS recommends that KCP&L incorporate additional measures into its Standard program, and take a more targeted approach in its SEM program (see below) to identify more projects for the Custom programs. For its Standard program, KCP&L can offer a more comprehensive list of water-related measures, including ENERGY STAR commercial dishwashers and icemakers. These two water-related measures produce both water and energy savings and can be co-promoted by both KCP&L and local water utilities.

KCP&L should also add measures identified in this study has having high energy efficiency potential to its Standard program, that are part of the prescriptive measure mix at other utilities, including:

- Commercial dishwashers
- Ice Machines
- Steam cookers
- Variable frequency drives on pumps

There are other measures that KCP&L should consider addition to its Standard program, based upon our review of energy efficiency potential in various building types as well as our comparison with other programs:

- Chilled water systems
- Commercial laundry or clothes washers
- Convection ovens (electric)
- Reach-in commercial refrigerators and freezers

For its Custom program, KCP&L can proactively target and pursue a wider range of custom measures, including chilled water systems, water treatment plant improvements, and wastewater treatment plant improvements. Those measures with high savings potential include:

Wastewater Treatment

- Aeration improvements
  - Intermittent aeration
  - Optical dissolved oxygen probe
  - Automated standard residence time / dissolved oxygen control system
- Blowers / diffusers
  - High-speed gearless blowers
  - Single-stage centrifugal blowers
  - Ultra-fine bubble diffusers
  - Rotary screw compressor

Water Treatment

- Pumps and motors
  - Pump system optimization controls
  - Advanced SCADA system
  - Water loss reduction

Target SEM Program to Water / Wastewater Sector

KCP&L's SEM program captures energy savings through operations and maintenance improvements at participating facilities, and it also recommends capital projects to be pursued in the Standard and Custom programs. The SEM program participation history indicates limited engagement with the water sector, which could also account for the relatively limited number of projects submitted to the Standard and Custom program.

There is considerable cost-effective energy efficiency potential in the water sector. For water treatment plants, these energy savings can range from 15 to 42 GWh, while for wastewater treatment plants, savings can be as much as 22 to 83 GWh. Because AIQUEOUS could not find a measure characterization for O&M savings specifically, these estimates do not include potential O&M savings to be captured directly in the SEM program.

Given this efficiency potential and the water sector's minimal past involvement in KCP&L's SEM program, AIQUEOUS recommends that KCP&L expand its SEM program to target water and wastewater utilities within its MUSH cohort. As a starting point, AIQUEOUS suggests that KCP&L work with the largest treatment plant (City of Kansas City, MO) and create a streamlined approach to the 16 1-5 MGD plants to yield these efficiency savings.

Because many of the water and wastewater treatment plants in KCP&L's Missouri territory are relatively small and serve more rural communities, they often lack the resources and staff necessary pursue to broad efficiency initiatives. General lack of awareness is also a common barrier to incorporating energy management into their system-wide operations. Creating a SEM cohort dedicated to these customers would, therefore, prove extremely beneficial to promoting persistent energy savings within this sector.

Opportunities to Collaborate with Water Utilities

There are numerous examples across the United States of energy and water utilities co-promoting water conservation measures that also provide energy savings. High efficiency showerheads and faucet aerators, ENERGY STAR clothes and dish washers, and ENERGY STAR commercial kitchen equipment all generate water and energy savings. Examples of utilities co-promoting these products include Pacific Gas & Electric and Bay Area Water Agencies, SoCalGas and Los Angeles Department of Water and Power, and most recently Suez Water New York and Orange & Rockland Counties. Co-promotion can include the combining of rebates, as well as unified messaging promoted by both utilities in overlapping service territories[24].

To evaluate such opportunities for KCP&L, AIQUEOUS first reviewed its waterrebates.com database for water conservation programs offered in Missouri. One example we found was at City Utilities in Springfield, Missouri, which is a combined water and energy utility. City Utilities offers a residential and commercial rebate for high efficiency toilets. The second example is Missouri American Water, which as a result of its most recent rate case, had set aside a budget for a water conservation program and had been asked to coordinate program delivery with energy efficiency programs. The project's first call with Missouri American Water resulted in a "next step" to try to integrate high efficiency fixtures into KCP&L's residential audit program.

The primary barriers to the implementation of a water conservation in a "water-rich" state such as Missouri are the financial impacts of decreasing consumption and revenue, as well as the lack of drivers for water conservation such as water scarcity or unreliability. This does not mean that water conservation cannot play a role in the cost-effectiveness of water utility operations—growth in water utility territories can be highly localized, resulting in water supply challenges in specific pressure zones, and peak water demand can be a serious issue for many utilities.

Based upon AIQUEOUS' experience in New York State, utilities must be able to address the financial impacts of water conservation to be able to pursue it as a demand-side strategy. The New York Public Service Commission recently allowed Suez Water New York to earn a shareholder incentive for the delivery of water conservation program savings[25]. A similar structure to MEEIA could incentivize investor-owned water utilities to pursue water conservation as an "integrated resource." Additionally, water utilities could

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[24] Water-Energy Synergies: Coordinating Efficiency Programs in California, Pacific Institute, 2013; AIQUEOUS SWNY Report, 2016.

[25] State of New York Public Service Commission, "Order Establishing Rate Plan," Case 16-W-0130, 2017. http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={ECCAD35D-B853-47EA-B97E-5F6BB1020CFC}

benefit from case studies such as Westminster, Colorado, where conservation has resulted in lower water rates over time, and in the creation of tariff structures that maintain revenue levels while promoting water conservation.

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Appendices

Appendix 1: Measure characterization tables

Water Treatment Plant

Table AP-1 shows the different energy efficiency measures associated with water treatment plants. The superscript numbers point to the source number.

Table 12. Measure characterization table for water treatment plants

Applicable End Use	Measure name	Measure description	Baseline Description	Life (yr)	Total % savings	% savings of the end-use	cost / yearly kWh saved	Payback years	Source 1	Source 2	Source 3
Pump / motor	high efficiency pump/motor system	high efficiency pump/motor system	pump/motor system with low efficiency	10 - 15 [3]	1.3% - 7.6% [2]	10 % - 30% [3]	$0.11 - $1.28 [1,2,3]	0.7 - 8.2 [2]	http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001019360	https://www.epa.gov/sites/production/files/2016-01/documents/nrwa-energy-audits-for-small-utilities-8-4-14.pdf	http://www.waterrf.org/PublicReportLibrary/4454.pdf TRM MEEIA cycle 2
	Pump modification	adjusting effluent pumping, inline flow meters in collection/distribution systems, and pump controls	Non-optimized pump	10 - 15 [3]	0.5% - 7.2% [2]	15% - 30% [3]	$0 - $1.369 [2]	0 - 10.7 [2]			https://focusonenergy.com/sites/default/files/info-center-article/WW-Best-Practices_web.pdf TRM MEEIA cycle 2
	Variable frequency drive	Varies the speed of a pump to match the flow conditions. Controls the speed of a motor by varying the frequency of the power delivered to the motor.	Pump with standard drive	10 [3]	0.4% - 4.2% [2]	10 % - 20% [1,3]	$0.26 - $1.02 [2]	2.4 - 12 [2]			http://www.waterrf.org/PublicReportLibrary/4454.pdf TRM MEEIA cycle 2

Distribution	Pipeline optimization	Reduce power required to overcome friction of a pumping system by selecting appropriate check valves, optimizing pipe diameter, optimizing flow rate	non-optimized pipeline			5% - 20%					
	Advanced SCADA systems	This advanced control system can be applied to raw water pumping, treatment and distribution. Reduce pumping and treatment energy consumption. Increase quality and reliability. Decrease operation and maintenance costs.	No SCADA system	10 [2]	10% - 20%					TRM MEEIA cycle 2	
	Automatic meter reading (AMR) /Acoustic leak detection integration	Monitors consumption of water and detects leaks in pipeline	No AMR	10 [2]		5% - 15% (of water supply energy)				TRM MEEIA cycle 2	
Treatment processes	Advanced membranes	Separate particulate matter with a size higher than the size of the membrane	Standard membrane filtration			15% - 25%					
	Advanced Ozonation	Reduce energy consumption of ozone generators by half. Decrease need for water transport pumping through use of local water sources. Reduce operation costs.	Standard ozone generators			10% - 20%				http://www.spartanwatertreatment.com/	

	Advanced UV (low-pressure high-output (LPHO))	The short UV wavelength radiation physically penetrates the cell wall of microorganisms and has a germicidal effect.	Standard UV (low-pressure (LP) and medium-pressure (MP))	0.9 - 1.4		10% - 30%				http://www.trojanuv.com/products/wastewater/trojanuv3000plus	
	Photo catalytic oxidation	can utilize visible light as the driving force for the production of hydroxyl radicals (the disinfecting agent)	Standard oxidation								
	Advanced reverse osmosis	Greatly reduce baseline energy consumption for desalination through optimizing components and energy recovery. Reduce operating costs.	Desalination (seawater or brackish water) without RO			50.00%					
	Capacitive deionization	Use about half the energy of the best case RO system. Lower operating costs than RO. Develop new water sources.	Best case RO system			50.00%					
	Membrane distillation	Capable of utilizing solar thermal energy and/or waste heat for water purification needs	Standard desalination treatment (seawater or brackish water)								
HVAC	Optimized and efficient system	Replace the existing system with a rightsized, more efficient system, replace the compressor, replace older, inefficient motors with high-	Old inefficient systems	15 [2]					Laura Defense, Take a Systems approach to Energy management, AWWA, 2016.	TRM MEEIA cycle 2	

		efficiency motors, improve insulatio, add electronic control systems and temperature sensors									
Electric demand management	Electric demand management	monitoring total energy use/demand with installation of electrical metering, maximizing off-peak operations	No electric demand management		0.7% - 7.3%			0 - 1	https://www.epa.gov/sites/production/files/2016-01/documents/nrwa-energy-audits-for-small-utilities-8-4-14.pdf		
Lighting	Efficient lighting fixtures (LED) with sensors	Efficient lighting fixtures (LED) with sensors	Inefficient lighting fixtures (CFL, incandescent)	12 [2]	0.5% - 2.9%		$0.14 - $1.26 [1,3]	1.5 - 11.2 [1,3]		TRM MEEIA cycle 2	https://iac.university/assessment/MA0763

Wastewater Treatment Plant

Table AP-2 shows the energy efficiency measures for wastewater treatment plants. The superscript numbers point to the source number. Values written in blue represent savings in therms for natural gas.

Table 13. Measure characterization table for wastewater treatment plants

Applicable End Use	Measure name	Measure description	Baseline Description	Life (yr)	Total % savings	% savings of the end-use	cost / yearly kWh saved*	Payback years	Source 1	Source 2	Source 3
Design and control of aeration systems	Intermittent Aeration	Reduces number of hours that an aeration system operates or the aeration system capacity.	Continuous aeration	10 [3]		22.5% - 38%	$0.130	<1	EPA, Evaluation of energy conservation measures for wastewater	https://nepis.epa.gov/Exe/ZyPDF.cgi/P1008SBM.PDF?Dockey=P1008SBM.PDF	TRM MEEIA cycle 2

	Dual Impeller Aerator (mechanical mixing)	Includes a lower impeller near the bottom of the basin floor to augment the surface impeller which provides additional mixing energy near the floor of the basin	Single impeller aerator						treatment facilities, 2010.		
	Optical DO probe	Measure changes in light emitted by a luminescent or fluorescent chemical and relates the rates of change in the emission to the DO concentration in solution.	Membrane DO probe			14% - 40%				http://www.vernier.com/products/sensors/dissolved-oxygen-probes/odo-bta/	
	Most Open Valve (MOV) control	Ensures the control butterfly valve serving the zone with the highest oxygen demand is essentially full open.	Standard aeration control system	10 [3]	11.6% [1]		$0.16 [1]	1.5 [1]			TRM MEEIA cycle 2
	Integrated air flow control	Eliminates the pressure control loop in automatic DO control systems which can cause instability in the operation of the blowers and control valves.	Pressure control loop in automatic DO control system	10 [3]	12% [1]						TRM MEEIA cycle 2
	Automated SRT (standard residence time) /DO (dissolved oxygen) Control System	Optimize the DO and SRT levels with an algorithm based on activated sludge modeling, plant historical data, and statistical process control	No DO control system	10 [3]	10%-33% [1]	20% - 50% [2]	$ 0.086 - $0.44 [1]	2.4 - 5 [1]		https://focusonenergy.com/sites/default/files/info-center-article/WW-Best-Practices_web.pdf	TRM MEEIA cycle 2 http://www.dvrpc.org/EnergyClimate/WSTP/pdf/ElectricUseReport.pdf

	Respirometry for aeration control	Measures oxygen uptake rate by a biological treatment culture. Direct measure of biomass needs, can predict oxygen requirements for WW as it enters the basin.	monitoring and control based on DO concentrations	10 [3]							TRM MEEIA cycle 2
	Critical oxygen point control	Accurately knowing the critical oxygen point for the active biomass allows the optimal DO setpoint to be determined	monitoring and control based on DO concentrations	10 [3]						http://www.strathkelvin.com/wastewater/applications.asp	TRM MEEIA cycle 2
	Off-gas monitoring and control	Determines in-process oxygen transfer efficiency (OTE) based on a gas-phase mass balance	conventional feedback-based DO control systems	10 [3]		>20% [2]				Trillo, I., T. Jenkinds, D. Redmon, T. Hilgart, and J. Trillo. 2004. Implementation of Feedforward Aeration Control Using On-Line Offgas Analysis: The Grafton WWTP Experience. Presented at WEFTEC 2004. New Orleans, LA.	TRM MEEIA cycle 2
	Online monitoring and control of nitrification using nicotinamide adenine dinucleotide (NADH) (Symbio® process)	Determine changes in biological demands. Based on the results, airflow to the basin is controlled to promote simultaneous nitrification-denitrification (SNdN) of wastewater	nitrifying plants without this control technology	10 [3]	25%-30% [2]					http://www.eimcowatertechnologies.com/muniusa/index.php?option=com_content&view=article&id=72&Itemid=146	TRM MEEIA cycle 2
	Bioprocess Intelligent	On-line process simulation program optimizing the	Standard biological nitrogen								

	Optimization System (BIOS)	operation of a biological nitrogen removal process.	removal process								
Blower and Diffuser Technology for Aeration Systems	Aeration control / improvements	Smaller blower installation, operation changes, better control with meter installation	Big blowers, not optimized, no control	10 [3]	1.6% - 26.9% [2]	30% - 70% [3]	$0.44 - $1.22 [1,2]	4.7 - 13.3 [2]		https://www.epa.gov/sites/production/files/2016-01/documents/nrwa-energy-audits-for-small-utilities-8-4-14.pdf	https://focusonenergy.com/sites/default/files/info-center-article/WW-Best-Practices_web.pdf TRM MEEIA cycle 2
	High-speed gearless (Turbo) blowers. (Air bearing or magnetic bearing)	Design to operate at at higher speed (upwards of 40,000 revolutions per minute [rpm]). Is friction free	Conventional multi-stage centrifugal or positive displacement blowers	10		10%-20% but can be up to 50%	$0.14 - $0.4	1.6 - 14			
	Single-stage centrifugal blowers with inlet guide vanes and variable diffuser vanes	Pre-rotate the intake air before it enters the high speed blower impellers. This reduces flow efficiently. Improves control of the output air volume	conventional single-stage or multi-stage centrifugal blowers	10 [1]	13%	28% - 49% [1]	$0.358	14 [3]		Greene, M. and D. Ramer. 2007. Innovative Process Modifications Resolve Consent Order and Initiate a Sustainability Program. Presented at WEFTEC 2007. San Diego, CA. WEF.	http://brownfields-toolbox.org/download/office_of_water/2011%20Addendum%20Emerging%20Technologies%20For%20Wastewater%20Treatment%20&%20In-Plant%20Wet%20Weather%20Management.PDF

	Ultra-fine bubble diffusers. (Traditional ceramic and elastomeric membrane)	Increased oxygen transfer rates afforded by the high surface area of the fine bubbles (0.2-1mm). More resistant to fouling	mechanical or coarse bubble diffusers	20 [1]		30%-60% [1,2]	$0.34 - $1.48 [2]	3.7 - 16.4 [2]		Lawrence J. Pakenas, Energy Efficiency in municipal Wastewater Treatment Plants Technology assessment, New York State Energy Research and Development Authority	http://www.dvrpc.org/EnergyClimate/WSTP/pdf/ElectricUseReport.pdf
	Ultra-fine bubble diffusers. (Strip homogeneous thermoplastic membrane)	Less prone to tearing. Also, the smaller strips allow tapering of the diffuser placement to match oxygen demand across the basin.	Ultra-fine bubble diffusers. (Traditional ceramic and elastomeric membrane)	20		10%-20%					
	Polyurethane or silicone membrane materials	More resistant, less susceptible to biological fouling	ethylene propylenediene rubber (EPDM) membrane material							Wagner M, von Hoessle R. 2004. Biological Coating of EPDM-membranes of Fine Bubble Diffusers. Water Science and Technology. 2004; 50(7):79-85.	
	In place gas cleaning: Sanitaire® by ITT Water and Wastewater	clean ceramic fine bubble diffusers without interruption of process or tank dewatering. Injects anhydrous HCl gas into the process air stream. removes biological foulants by decreasing the pH	Standard periodic pressure washing or acid cleaning for ceramic diffusers							http://www.sanitaire.com/3117913.asp	

	Monitoring device for diffuser cleaning	Predicts cleaning when diffused air systems require it. Measures oxygen transfer efficiency	Standard periodic pressure washing or acid cleaning			15% [2]				Larson, Lory. 2009. A Digital Control System for Optimal Oxygen Transfer Efficiency. California Energy Commission, PIER Industrial / Agricultural / Water End-Use Energy Efficiency program. Report CEC-500-2009-076 http://www.energy.ca.gov/2009publications/CEC-500-2009-076/CEC-500-2009-076.PDF	
	Rotary screw compressor	Rotary screw compressor	rotary lobe blower			27.5% - 50% [2,3]				http://www.efficiencyblowers.com/efficiencyblowersus/ http://www.rootsblower.com/ https://info.aerzenusa.com.	http://www.waterworld.com/articles/wwi/print/volume-28/issue-3/editorial-focus/aeration-systems/wastewater-aeration-low-pressure-screw.html
Selected Treatment Processes	Pretreatment	Removes suspended solids from wastewater and allows a plant to reach the same level of treatment at a lower UV dose	No pretreatment								
	Low-pressure high-output lamps for UV disinfection	Used mercury amalgam so they can operate at higher internal lamp pressures. It reduces	low-pressure low-intensity lamps	1.37		70%-80%					

		lamp requirements (quantity) and energy requirements									
	Mechanical and chemical cleaning of UV lamps	Prevent algal growth mineral deposits, and other materials that can foul the lamp sleeve and subsequently decrease UV intensity and disinfection efficiency	Poor UV lamp maintenance							Leong, L.Y.C., J. Kuo, and C Tang. 2008. Disinfection of Wastewater Effluent—Comparison of Alternative Technologies. Water Environment Research Foundation (WERF), Alexandria, VA.	
	Membrane bioreactor (MBR) air scour alternatives. GE 10/30 Eco-aeration	Membrane is scoured for 10 seconds on, 30 second off during non-peak flow conditions.	MBR aeration with periodic chemical cleaning			50% [2]				Ginzburg, B., J. Peeters, and J. Pawloski. 2008. On-line Fouling Control for Energy Reduction in Membrane Bioreactors. Presented at Membrane Technology 2008. Atlanta, GA. WEF.	
	Hyperbolic mixers	The stirrer is equipped with transport ribs that cause acceleration of the wastewater in a radial direction to promote complete mixing	Traditional submersible mixers			63% [2]	$0.20 [2]	1 - 5 [1]		Gidugu, S., S. Oton, and K. Ramalingam. 2010. Thorough Mixing Versus Energy Consumption. New England Water Environment Association Journal, Spring 2010.	

	Pulsed Large Bubble Mixing (e.g., Biomx)	Reduces energy required for anoxic or anaerobic zone mixing by firing short bursts of compressed air into the zone. The large air bubbles minimize oxygen transfer and maintain anoxic or anaerobic conditions	Submersible propeller mixers (mechanical)			45%-60% [2]	$0.130	<1		(Randall and Randall 2010). http://www.enviro-mix.com/biomx.php http://www.enviro-mix.com/documents/FWayneHillEnergySuccessStory2009-091001.pdf	
	Vertical linear motion mixer	Prevents solids deposition and minimizes scum and foam formation. Mixes digester contents by moving a thin steel disk in an up and down motion to create axial and lateral agitation.	Recirculation pumps or conventional propeller-type mixers			50 to 90% [2,3]				http://www.enersavemixers.com/	WERF, Energy Efficiency in Wastewater Treatment in North America: A Compendium of Best Practices and Case Studies of Novel Approaches, 2010.
Solids Processing	Flue Gas Recirculation systems with waste heat recovery	Takes the exhaust flow from the top hearth of the furnace and re-injects it into the one of the lower hearths. Allows the furnace to be run at a lower temperature (or without an exhaust gas afterburner), optimizing fuel consumption and eliminating ash slagging	Multiple heat furnace		76%		$14.06	11.3			
	Cogeneration	Generates electricity and recoverable heat onsite	Anaerobic digesters without								

		using methane off-gas from anaerobic digesters.	cogeneration technology								
	Thermal drying. Direct (convection) or indirect (conduction)	It is is the use of heat to evaporate residual water from sludge. Reduces the mass and volume of dewatered solids and results in a product with a high nutrient and organic content that can be used as a low-grade fertilizer. Energy provided by solar panels	Conventional dryers			95% [2]				WEF and ASCE. 2010. Design of Municipal Wastewater Treatment Plants – WEF Manual of Practice 8 and ASCE Manuals and Reports on Engineering Practice No. 76, 5th Ed. Water Environment Federation, Alexandria, VA, and American Society of Civil Engineers Environment & Water Resources Institute, Reston, Va.	
	Optimized motor	Replace old inefficient motor with new more efficient ones	Old inefficient motor	10 - 15 [2]	4% - 8% [1]					TRM MEEIA cycle 2	
Pump / motor	Optimized pumping system	Replace inefficient pumps with more efficient ones or optimize sizing or replace large capacities pumps with smaller capacities pumps	Standard pumping system	10 - 15 [2]		10% - 44% [1]	$0.381	<1	EPA, Evaluation of energy conservation measures for wastewater treatment facilities, 2010.	TRM MEEIA cycle 2	
	Variable Frequency Drive (VFD)	Varies the speed of a pump to match the flow conditions. Controls the speed of a motor by varying the frequency of the power delivered to the motor.	Standard drives	10 [3]	13% [1]	up to 50% [2]	$0.14 - $0.68 [2]	1.5 - 4.6 [2]		http://aceee.org/files/proceedings/2009/data/papers/6_83.pdf http://www.energy.ca.gov/process/pubs/vfds.pdf	TRM MEEIA cycle 2

HVAC	Optimized and efficient system	Replace the existing system with a rightsized, more efficient system, replace the compressor, replace older, inefficient motors with high-efficiency motors, improve insulation, add electronic control systems and temperature sensors	Old inefficient systems	15 [2]					Laura Defense, Take a Systems approach to Energy management, AWWA, 2016.	TRM MEEIA cycle 2	
Electric demand management	Electric demand management	monitoring total energy use/demand with installation of electrical metering, maximizing off-peak operations	No electric demand management		0.7% - 7.3%			0 - 1	https://www.epa.gov/sites/production/files/2016-01/documents/nrwa-energy-audits-for-small-utilities-8-4-14.pdf		
Lighting	Efficient lighting fixtures (LED) with sensors	Efficient lighting fixtures (LED) with sensors	Inefficient lighting fixtures (CFL, incandescent)	12 [2]	0.5% - 2.9%		$0.09 - $1.26 [1,3]	1.3 - 11.2 [1,3]		TRM MEEIA cycle 2	https://iac.university/assessment/LE0410

Commercial kitchen, restroom and landscaping

Table 14. Measure characterization table for commercial kitchen, restroom, and landscaping

Applicable End Use	Applicable technology	Measure name	Measure description	Baseline Description	% savings for Electricity	% savings for Gas	% savings for Water	Simple payback period for additional initial cost (years)	Additional cost / yearly kWh saved	Life (yr)	Source 1	Source 2
Commercial kitchen	Dishwasher	Low temperature under counter	Energy Star model	Standard model	23%	-	31%		$0.02	10	Energy Star:	http://pacinst.org/app/uploads

		Low temperature stationary single tank door			41%	-	44%	immediate	$0.00	15	Commercial kitchen equipment calculator	/2013/02/appendix_d3.pdf
		Low temperature single tank conveyor			32%	-	40%	immediate	$0.00	20		
		Low temperature Multi Tank Conveyor			38%	-	48%	0.4	$0.05	20		
		High temperature Under Counter			26%	-	21%	0.4	$0.04	10		
		High temperature Stationary Single Tank Door			30%	-	31%	0.6	$0.06	15		
		High temperature Single Tank Conveyor			20%	-	20%	2	$0.22	20		
		High temperature Multi Tank Conveyor			38%	-	44%	0.3	$0.04	20		
		High temperature Pot, Pan, and Utensil			16%	-	17%	4.3	$0.52	10		
	Freezer	Solid door			38%	-	-	immediate	$0.00	12		
		Glass door			44%	-	-	immediate	$0.00	12		
	Fryer	Electric Standard			5%	-	-	2.4	$0.22	12		
		Electric Large Vat			14%	-	-	immediate	$0.00	12		
		Natural gas Standard			-	32%	-	immediate	-	12		
		Natural gas Large Vat			-	28%	-	2.9	-	12		
	Griddle	Electric			12%	-	-	immediate	$0.00	12		
		Natural gas			-	11%	-	3	-	12		
	Hot food holding cabinet	Hot food holding cabinet			53%	-	-	immediate	$0.00	12		

	Ice Machine	Batch, Ice Making Head			11%	-	16%	immediate	$0.00	8		http://pacinst.org/app/uploads/2013/02/appendix_d3.pdf
		Batch, Remote Condensing Unit			7%	-	10%	immediate	$0.00	8		
		Batch, Self-Contained Unit			8%	-	35%	immediate	$0.00	8		
		Continuous, Ice Making Head			14%	-	-	immediate	$0.00	8		
		Continuous, Remote Condensing Unit			11%	-	-	immediate	$0.00	8		
		Continuous, Self Contained Unit			6%	-	-	immediate	$0.00	8		
	Oven	Convection, electric, full size			16%	-	-	immediate	$0.00	12		
		Convection, electric, half size			3%	-	-	immediate	$0.00	12		
		Convection, Natural Gas			-	16%	-	immediate	-	12		
		Combination, Electric			35%	-	-	immediate	$0.00	12		
		Combination, Natural Gas			-	28%	-	immediate	-	12		
	Refrigerator	Solid door			40%	-	-	immediate	$0.00	12		
		Glass door			32%	-	-	immediate	$0.00	12		
	Steam cooker	Electric			57%	-	93%	0.3	$0.06	12		
		Natural gas			-	53%	93%	0.4	-	12		
	Pre-Rinse spray valve	Pre-Rinse spray valve	WaterSense model		-	20%	20%	immediate	-	5		http://pacinst.org/app/uploads/2013/02/appendix_d3.pdf
Restroom	Toilet	Ultra-low flush toilet	Ultra-low flow toilet 1.6 gpf	Toilet 3.5 gpf			54%				http://pacinst.org/app/uploads/2013/02/appe	
				Toilet 5 gpf			68%					

	Urinal	Ultra-low flush urinal	Ultra-low flush urinal 1 gpf	Conventional urinal 1.5 gpf			33%				ndix_d3.pdf	
	Faucet	Faucet aerator	Faucet 1gpm	Faucet 2 gpm			50%				http://pacinst.org/app/uploads/2013/02/appendix_c3.pdf	
Landscaping	Landscaping	Water sensing for turf	Water sensing for turf	Conventional watering			43%				http://pacinst.org/app/uploads/2013/02/appendix_d3.pdf	http://www.pacinst.org/app/uploads/2013/02/waste_not_want_not_full_report3.pdf

Cooling Towers

Table 15. Measure characterization table for commercial kitchen, restroom, and landscaping

Measure name	Measure description	Baseline Description	Life (yr)	Total % savings (water)	Total % savings (energy)	Cost / yearly kWh saved	cost / yearly gallons saved	Payback years	Assumptions	Source 1
Conductivity or flow based controller	Maximize the cycles of concentration which decreases the amount of makeup water (ex: 3.5 to 4.9 cycles)	350 ton evaporative (or open) cooling tower	10			$4.223	$0.042	4.9	$8.12 / kgal 1.1% rate increase annually	Cooling Tower Water Savings 2013 California Building Energy Efficiency Standard
flow meter on the make-up water line	Allows the operator to know how much water the tower is using and facilitates the identification of excessive water use due to leaks	350 ton evaporative (or open) cooling tower	15							

overflow alarm	The failure of the makeup water line control can result in uncontrolled dilution and no activation of chemical feed, putting the system at risk for scale. An overflow alarm prevents these losses from going undetected	350 ton evaporative (or open) cooling tower	15							
efficient drift eliminators	Minimizes losses due to drift, which is liquid water that is blown or splashed out of the tower during normal operations	350 ton evaporative (or open) cooling tower	9							
Pre-treatment	Softeners will reduce scaling and demineralization or reverse osmosis will remove TDS ==> that increases the number of cycles (from 3.5 to 8)	Water cooling tower with 3 cycles	10	7% - 26%						The ripple effect, Reducing water use in cooling towers and evaporative condensers, 2011.
Increasing chilled water temperature by 1 ºF	Increasing chilled water temperature by 1 ºF	Standard Water-cooled system	20		0.6%-2.5%					
Reducing the condenser water from 2ºF to 15ºF	Reducing the condenser water from 2ºF to 15ºF (i.e. condenser water between 70ºF and 83ºF)	Standard 500 tons Water-cooled system with a condenser water at 85ºF	20		5% - 21%	$0.05 - $0.22		<1 - 2	8 months operation ; 2500 equivalent full load hr / year ; $0.08/kWh ; $10/kW	Michael D. Pugh, Benefits of water-cooled systems vs air-cooled systems, CTI
Reducing condenser pressure by 10 psi	Reducing condenser pressure by 10 psi	Standard Water-cooled system	20		6%					

400 ton water-cooled centrifugal chiller; 4 cycles	400 ton water-cooled centrifugal chiller; 4 cycles	400 ton air-cooled chiller	20	-100%	36.73%	$1.27	-$0.029	1.3	6 months operation ; 1800 equivalent full load hr/year ; $0.06/kWh ; $12/kW ; $3/kgal	
500 ton water cooled, centrifugal chiller with a variable speed drive	500 ton water cooled, centrifugal chiller with a variable speed drive	500 ton air cooled rotary screw water chiller	17	-100%	46%	$0.44	-$0.062	1.3	$0.103/kWh $13.44/kW $2.90/kgal supply $5.31/kgal sewage	BAC comparison of heat rejection methods
Hybrid adiabatic 350 ton cooling tower	Hybrid adiabatic 350 ton cooling tower	Traditional 350 ton water cooling tower		66%	negative impacts					http://www.nimbus.cool/Resources

Appendix 2: Water systems in the KCP&L territory

Figure AP-1 shows typical energy intensity use (kWh/MG) for different ranges of water treatment plant flow rates[26].

Figure 35. Energy use intensity for water treatment plants

Average Daily Flow Range (MGD)	Energy Use Intensity (kWh/MG)	Water Main length (miles)	Distribution Pressure (psia)	Source Water Distribution		
				Ground Water	Surface Water	Purchased Water
< 3	2,000	126	67	32%	41%	27%
3-5	1,400	138	69	31%	32%	36%
5-20	1,600	346	72	28%	39%	33%
20-600	1,500	2,700	62	7%	68%	25%

Data source: Lawrence Berkeley National Laboratories, "Market Profiles Used in Energy Star's Portfolio Manager for Water and Wastewater Utilities", unpublished data from October 2012.

Table 16. Water systems average daily flow and estimated energy consumption

PWS NAME	Community Water System Name	Avg Daily Consumption MGD	Avg Energy use kWh / yr
	MO1010001	1.10	803,000
	MO1010024	0.01	5,110
	MO1010046	0.02	12,410
	MO1024031	0.09	63,510
	MO1010068	0.35	255,500
	MO1010084	0.05	35,770
	MO2010091	0.02	12,410
	MO1010117	0.05	32,850
	MO1010118	0.68	495,670
	MO2010140	0.60	438,000
	MO1024111	0.48	351,860
	MO2010162	1.30	949 000
	MO1010173	0.01	6,570
	MO1010182	0.01	9,490

[26] C. Arzbaecher et al, "Electricity Use and Management in the Municipal Water Supply and Wastewater Industries," Water Research Foundation, EPRI, 2013.

	MO1010184	0.60	438,000
	MO1010191	0.13	96,360
	MO1010225	0.05	35,040
	MO1010265	0.04	29,200
	MO1010299	0.29	209,510
	MO1010301	0.10	73,000
	MO1010307	2.40	1,752,000
	MO2010308	0.17	121,910
	MO1010346	0.05	33,580
	MO1024241	0.03	21,900
	MO1010349	1.25	912,500
	MO1024247	0.70	511,000
	MO1010358	0.07	54,354
	MO1021117	0.20	146,000
	MO1010177	1.00	730,000
	MO1010363	0.91	665,760
	MO1010371	0.25	182,500
	MO1010378	0.04	27,740
	MO1010399	27.10	14,837,250
	MO1010406	0.04	32,120
	MO1024310	0.32	231,410
	MO1024311	0.24	172,280
	MO1010415	112.00	61,320,000
	MO2010420	0.05	38,690
	MO1010425	0.07	51,100
	MO1010880	0.08	58,400
	MO5010446	0.50	365,000
	MO1010460	0.05	32,850
	MO1010464	0.50	365,000
	MO5010465	0.08	57,670
	MO1010466	2.70	1,971,000
	MO2024353	0.10	73,000
	MO2024355	0.11	77,380
	MO1010489	0.02	16,060
	MO2010502	2.66	1,938,880
	MO1010508	1.70	1,241,000
	MO2010109	0.84	613,200
	MO1010625	2.20	1,606,000

	MO1010714	17.50	10,220,000
	MO1010833	2.40	1,752,000
	MO1010548	0.17	124,100
	MO5010562	0.87	635,100
	MO2010578	0.06	40,880
	MO1010580	3.10	1,584,100
	MO1010599	0.50	365,000
	MO1010605	0.16	113,150
	MO1024478	0.78	567,940
	MO2010664	0.14	100,010
	MO1010673	0.03	20,440
	MO1024511	1.35	986,960
	MO1010682	0.18	131,400
	MO1010685	0.78	565,750
	MO1010696	0.26	191,990
	MO1010757	0.02	16,790
	MO2010722	0.20	146,000
	MO1010724	0.50	365,000
	MO5010725	0.08	56,210
	MO3010728	3.50	1,788,500
	MO1010739	0.02	14,600
	MO1010744	0.06	43,361
	MO2010745	0.35	254,040
	MO1010748	1.30	949,000
	MO1010786	0.23	164,250
	MO2010796	1.72	1,254,140
	MO1071079	3.40	1,737,400
	MO1010921	0.07	53,290
	MO5010828	0.02	14,600
	MO1010839	0.05	39,420
	MO1010851	0.38	277,400
	MO1079501	0.60	438,000
	TOTAL:	205.14	119,620,615

The embedded energy associated with water treatment was obtained by dividing the total energy consumption by the total volume of water treated. Water treatment plants in the KCP&L territory use on average 1598 kWh per million gallons of water.

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Appendix 3: Wastewater treatment plants in the KCP&L territory

Figure AP-2 represents typical ranges of energy intensity use (kWh/MG) for the five main types of wastewater treatment[27]. For each type, the minimum and maximum kWh/MG was deduced from the figure below.

Figure 36. Energy intensity use for wastewater treatment plants

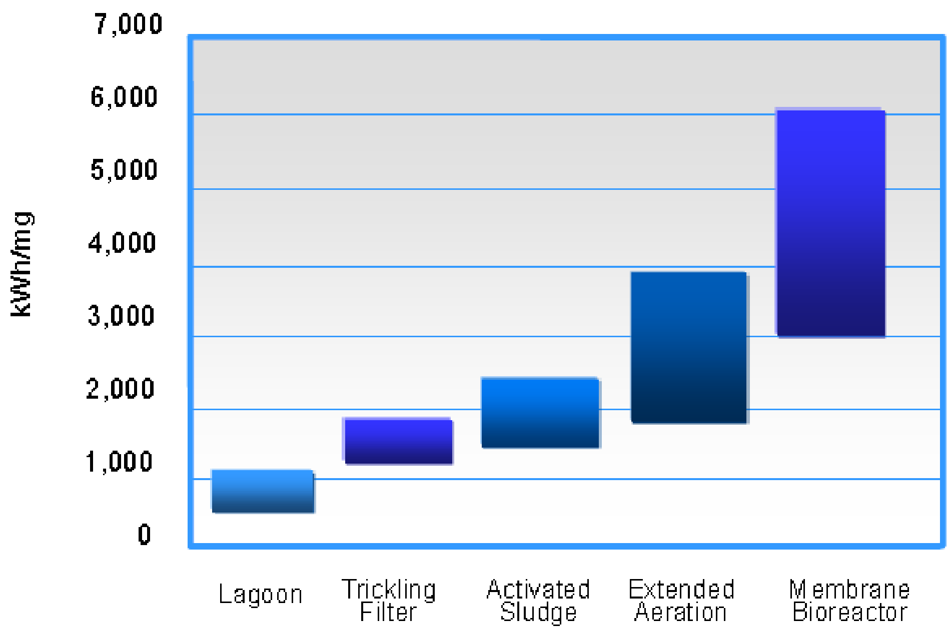

Table AP-6 shows the list of all wastewater treatment facilities in the KCP&L region with the estimated range of energy consumption. The treatment types “mechanical plant” and “land application” were both considered to fall under the category “activated sludge”. For each facility, the average flow and the type of treatment plant were known. The project team calculated the minimum and maximum energy requirements (in kWh/yr) given the energy intensity values from Figure AP-2.

[27] J. S. George Crawford, "Energy Efficiency in Wastewater Treatment in North America: A Compendium of Best Practices and Case Studies of Novel Approaches," WERF, 2010.

Table 17.

Facility Name	Treatment Type	Average Flow (MG/day)	Min Energy Usage (kWh /yr)	Max Energy Usage (kWh /yr)
	Mechanical Plant	81.00	41,834,475	70,216,875
	Mechanical Plant	14.30	7,385,593	12,396,313
	Mechanical Plant	12.40	6,404,290	10,749,250
	Mechanical Plant	4.30	2,220,843	3,727,563
	Mechanical Plant	2.62	1,353,165	2,271,213
	Mechanical Plant	1.84	950,314	1,595,050
	Mechanical Plant	1.80	929,655	1,560,375
	Land Application	1.75	903,831	1,517,031
	Mechanical Plant	1.70	878,008	1,473,688
	Mechanical Plant	1.57	810,866	1,360,994
	Mechanical Plant	1.50	774,713	1,300,313
	Mechanical Plant	1.40	723,065	1,213,625
	Mechanical Plant	1.40	723,065	1,213,625
	Mechanical Plant	1.38	713,768	1,198,021
	Mechanical Plant	1.38	712,736	1,196,288
	Mechanical Plant	1.15	593,946	996,906
	Mechanical Plant	1.05	542,299	910,219
	Mechanical Plant	0.79	408,015	684,831
	Mechanical Plant	0.76	392,521	658,825

	Mechanical Plant	0.71	366,697	615,481
	Mechanical Plant	0.69	356,368	598,144
	Lagoon	0.65	118,808	264,941
	Mechanical Plant	0.65	335,709	563,469
	Mechanical Plant	0.60	309,885	520,125
	Mechanical Plant	0.60	309,885	520,125
	Mechanical Plant	0.58	299,556	502,788
	Mechanical Plant	0.57	292,841	491,518
	Mechanical Plant	0.45	232,414	390,094
	Mechanical Plant	0.36	184,382	309,474
	Trickling Filter	0.35	153,300	231,866
	Mechanical Plant	0.31	157,525	264,397
	Land Application	0.29	149,778	251,394
	Lagoon	0.20	36,500	81,395
	Mechanical Plant	0.19	96,064	161,239
	Mechanical Plant	0.19	95,806	160,805
	Lagoon	0.17	31,025	69,186
	Lagoon	0.15	27,375	61,046
	Mechanical Plant	0.15	77,471	130,031
	Lagoon	0.14	26,057	58,107
	Mechanical Plant	0.13	69,208	116,161
	Mechanical Plant	0.12	59,395	99,691
	Lagoon	0.12	20,988	46,802
	Lagoon	0.10	18,442	41,125

	Mechanical Plant	0.10	49,582	83,220
	Mechanical Plant	0.09	47,516	79,753
	Mechanical Plant	0.09	46,483	78,019
	Land Application	0.09	45,450	76,285
	Land Application	0.09	43,900	73,684
	Lagoon	0.08	15,148	33,779
	Lagoon	0.08	15,148	33,779
	Lagoon	0.08	14,053	31,337
	Lagoon	0.07	13,505	30,116
	Land Application	0.07	36,153	60,681
	Lagoon	0.07	12,275	27,373
	Lagoon	0.07	12,009	26,779
	Lagoon	0.06	10,950	24,419
	Lagoon	0.06	10,768	24,012
	Lagoon	0.06	10,403	23,198
	Lagoon	0.05	9,800	21,855
	Lagoon	0.05	9,490	21,163
	Lagoon	0.05	9,125	20,349
	Lagoon	0.05	8,760	19,535
	Sand/Rock Filter	0.05	20,148	30,474
	Mechanical Plant	0.05	23,241	39,009
	Lagoon	0.05	8,213	18,314
	Lagoon	0.04	7,665	17,093
	Lagoon	0.04	7,483	16,686
	Lagoon	0.04	7,373	16,442
	Lagoon	0.04	6,935	15,465
	Lagoon	0.04	6,734	15,017
	Lagoon	0.04	6,570	14,651

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	Lagoon	0.04	6,388	14,244
	Lagoon	0.04	6,388	14,244
	Lagoon	0.03	6,205	13,837
	Mechanical Plant	0.03	17,560	29,474
	Lagoon	0.03	6,205	13,837
	Lagoon	0.03	6,205	13,837
	Lagoon	0.03	6,023	13,430
	Lagoon	0.03	5,658	12,616
	Lagoon	0.03	5,475	12,209
	Lagoon	0.03	5,475	12,209
	Lagoon	0.03	5,110	11,395
	Mechanical Plant	0.03	14,441	24,238
	Lagoon	0.03	4,964	11,070
	Lagoon	0.03	4,745	10,581
	Land Application	0.02	12,395	20,805
	Lagoon	0.02	4,234	9,442
	Trickling Filter	0.02	10,074	15,237
	Lagoon	0.02	4,015	8,953
	Lagoon	0.02	3,979	8,872
	Lagoon	0.02	3,951	8,811
	Lagoon	0.02	3,833	8,546
	Lagoon	0.02	3,650	8,140
	Lagoon	0.02	3,303	7,366
	Lagoon	0.02	3,285	7,326
	Lagoon	0.02	3,285	7,326
	Lagoon	0.02	3,194	7,122
	Lagoon	0.02	3,103	6,919
	Lagoon	0.02	2,920	6,512
	Lagoon	0.02	2,738	6,105
	Lagoon	0.02	2,738	6,105
	Lagoon	0.01	2,592	5,779

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	Land Application	0.01	7,231	12,136
	Lagoon	0.01	2,555	5,698
	Lagoon	0.01	2,190	4,884
	Lagoon	0.01	2,154	4,802
	Sand/Rock Filter	0.01	4,906	7,420
	Lagoon	0.01	2,008	4,477
	Lagoon	0.01	2,008	4,477
	Lagoon	0.01	1,825	4,070
	Lagoon	0.01	1,825	4,070
	Lagoon	0.01	1,661	3,703
	Mechanical Plant	0.01	4,648	7,802
	Lagoon	0.01	1,606	3,581
	Lagoon	0.01	1,570	3,500
	Sand/Rock Filter	0.01	3,548	5,366
	Lagoon	0.01	1,460	3,256
	Lagoon	0.01	1,387	3,093
	Lagoon	0.01	1,299	2,898
	Lagoon	0.00	912	2,034
	Sand/Rock Filter	0.00	1,971	2,981
	Sand/Rock Filter	0.00	1,577	2,385
	Land Application	0.00	1,616	2,712
	Lagoon	0.00	566	1,262
	Land Application	0.00	1,601	2,687
	Sand/Rock Filter	0.00	1,314	1,987
	Mechanical Plant	0.00	1,394	2,341
	Sand/Rock Filter	0.00	1,095	1,656

	Mechanical Plant	0.00	1,291	2,167
	Mechanical Plant	0.00	1,033	1,734
	Lagoon	0.00	0	0
	Land Application	0.00	0	0
	Land Application	0.00	0	0
	Land Application	0.00	0	0
	Land Application	0.00	0	0
	Lagoon	0.00	0	0
	Lagoon	0.00	0	0
	Land Application	0.00	0	0
	Lagoon	0.00	0	0
	Mechanical Plant	0.00	0	0
	Mechanical Plant	0.00	0	0
	Mechanical Plant	0.00	0	0
	Lagoon	0.00	0	0
	TOTAL:	145	73,827,893	124,228,655

Similarly to the water treatment plants, the embedded energy associated with wastewater treatment was calculated. Taking an average of the minimum and maximum values we obtained an energy consumption of 1868 kWh per millions gallons of treated wastewater.

The total embedded energy associated with both water and wastewater treatment is 3466 kWh per million gallons.

Appendix 4: Efficiency potential derivation

Only one inefficient measure

$$C_{pot}(\%) = \frac{Total\ conservation\ potential}{Total\ current\ comsumption}$$

$$C_{pot}(\%) = \frac{(1-p) * \%_{Savings} * A}{(1 - p * \%_{Savings})}$$

Where:

- $C_{\text{pot}}(\%)$ = Conservation potential savings in percent of the total current consumption
- p = Penetration factor = Percent cases where the efficient measure has already been implemented
- $\%_{Savings}$ = Percent savings achieved by the efficient measure compared to the inefficient one
- A = Applicability factor = Percent cases where the efficient measure can be implemented in lieu of the inefficient one.

Proof:

Let assume that two technologies can be applied for a same end use, one efficient, one inefficient. We have:

$$V_{tot} = V_{eff} + V_{inef}$$

Where:

- V_{tot} is the current total amount of water used by the end use
- V_{eff} is the total amount of water used by the efficient measure for that end use
- V_{inef} is the total amount of water used by the inefficient measure for that end use

$$V_{tot} = v_{eff} * N_{eff} + v_{inef} * N_{inef}$$
$$V_{tot} = v_{inef} * \left(1 - \%_{Savings}\right) * N_{eff} + v_{inef} * N_{inef}$$

Where:

- v_{eff} is the amount of water used by the efficient measure (applied once) for that end use

- v_{inef} is the amount of water used by the inefficient measure (applied once) for that end use
- N_{eff} is the total number of times the efficient measure is used for that end use
- N_{inef} is the total number times the inefficient measure is used for that end use
- $\%_{Savings}$ is the percent savings achieved by the efficient measure compared to the inefficient measure
- So we have $v_{eff} = v_{inef} * (1 - \%_{Savings})$

Let's introduce the penetration factor p:

$$p = \frac{N_{eff}}{N_{tot}}$$

Where:

- p = Percent cases where the new measure has already been implemented
- N_{tot} is the total number of times that a measure is used for that end use ($N_{tot} = N_{eff} + N_{inef}$)

So:

$$V_{tot} = \left[(1 - \%_{Savings}) * p + (1 - p)\right] * v_{inef} * N_{tot}$$

$$V_{tot} = (1 - p * \%_{Savings}) * v_{inef} * N_{tot}$$

Let's now calculate the minimum possible amount water used by this end use by replacing all the inefficient measures by the efficient one. We thus have:

$$V_{min} = v_{eff} * N_{tot}$$

$$V_{min} = v_{inef} * (1 - \%_{Savings}) * N_{tot}$$

Where:

- V_{min} is the minimum total amount of water that can be used for that end use

The conservation potential savings V_{pot} is the amount of water that can be saved by replacing all the inefficient measures by the efficient one. We thus have:

$$V_{pot} = V_{tot} - V_{min}$$

$$V_{pot} = (1 - p * \%_{Savings}) * v_{inef} * N_{tot} - v_{inef} * (1 - \%_{Savings}) * N_{tot}$$

$$V_{pot} = (1-p) * \%_{Savings} * v_{inef} * N_{tot}$$

The percent conservation potential savings $C_{\text{pot}}(\%)$ is the amount of water that can be saved by replacing all the inefficient measures by the efficient one divided by the current use in percent. We thus have:

$$C_{pot}(\%) = \frac{V_{pot}}{V_{tot}}$$

$$C_{pot}(\%) = \frac{(1-p) * \%_{Savings} * v_{inef} * N_{tot}}{\left(1-p * \%_{Savings}\right) * v_{inef} * N_{tot}}$$

$$C_{pot}(\%) = \frac{(1-p) * \%_{Savings}}{\left(1-p * \%_{Savings}\right)}$$

If now we consider that we cannot replace all the inefficient measures by efficient ones but only a fraction of them we have:

$$C_{pot}(\%) = \frac{(1-p) * A * \%_{Savings}}{\left(1-p * \%_{Savings}\right)}$$

Where:

- A = Applicability factor = Percent cases where the efficient measure can be implemented in lieu of the inefficient one

Multiple inefficient measures

$$C_{pot}(\%) = \frac{\sum_{i=1}^{N}\left(\frac{A_i * p_i * \%_{Savings,i}}{1-\%_{Savings,i}}\right)}{p + \sum_{i=1}^{N}\left(\frac{p_i}{1-\%_{Savings,i}}\right)}$$

Where:

- $C_{\text{pot}}(\%)$ = Conservation potential savings in percent of the total current consumption
- p = Percent cases where the efficient measure has already been implemented
- p_i = Percent cases where the inefficient measure i is in place

- N = total number of different inefficient measures (≥1)
- $\%_{Savings,i}$ = Percent savings achieved with the efficient measure compared to the inefficient measure i
- A_i = Applicability factor = Percent cases where the efficient measure can be implemented in lieu of the inefficient measure i.

Proof:

Let assume that three technologies can be applied for a same end use, one efficient and two inefficient. We will use the same nomenclature than for the proof above. The subscript 1 and 2 will be used for the inefficient measure #1 and the inefficient measure #2 respectively. We have:

$$V_{tot} = V_{eff} + V_{inef,1} + V_{inef,2}$$
$$V_{tot} = v_{eff} * N_{eff} + v_{inef,1} * N_{inef,1} + v_{inef,2} * N_{inef,2}$$

Where:

$$v_{eff} = (1 - \%_{Savings,1}) * v_{inef,1} = \left(1 - \%_{Savings,2}\right) * \ v_{inef,2}$$

Thus:

$$V_{tot} = (1 - \%_{Savings,1}) * v_{inef,1} * N_{eff} + v_{inef,1} * N_{inef,1} + \frac{\left(1 - \%_{Savings,1}\right)}{\left(1 - \%_{Savings,2}\right)} * \ v_{inef,1} * N_{inef,2}$$

And because:

$$N_{tot} = N_{eff} + N_{inef,1} + N_{inef,2}$$

$$p = \frac{N_{eff}}{N_{tot}} \ ; \ p_1 = \frac{N_{inef,1}}{N_{tot}} \ ; \ p_2 = \frac{N_{inef,2}}{N_{tot}}$$

We then have:

$$V_{tot} = v_{inef,1} * \left[\left(1 - \%_{Savings,1}\right) * p + p_1 + \frac{\left(1 - \%_{Savings,1}\right)}{\left(1 - \%_{Savings,2}\right)} * p_2\right] * N_{tot}$$

$$V_{tot} = v_{inef,1} * N_{tot} * \left(1 - \%_{Savings,1}\right) * \left[p + \frac{p_1}{\left(1 - \%_{Savings,1}\right)} + \frac{p_2}{\left(1 - \%_{Savings,2}\right)}\right]$$

Applying a similar methodology than previously, we have:

$$V_{min} = v_{inef} * \left(1 - \%_{Savings}\right) * N_{tot}$$

And:

$$C_{pot}(\%) = \frac{V_{pot}}{V_{tot}} = \frac{V_{tot} - V_{min}}{V_{tot}}$$

$$C_{pot}(\%) = \frac{p + \frac{p_1}{\left(1 - \%_{Savings,1}\right)} + \frac{p_2}{\left(1 - \%_{Savings,2}\right)} - 1}{p + \frac{p_1}{\left(1 - \%_{Savings,1}\right)} + \frac{p_2}{\left(1 - \%_{Savings,2}\right)}}$$

$$C_{pot}(\%) = \frac{\frac{p_1}{\left(1 - \%_{Savings,1}\right)} + \frac{p_2}{\left(1 - \%_{Savings,2}\right)} - p_1 - p_2}{p + \sum_{i=1}^{2}\left(\frac{p_i}{1 - \%_{Savings,i}}\right)}$$

$$C_{pot}(\%) = \frac{\sum_{i=1}^{2}\left(\frac{p_i * \%_{Savings,i}}{1 - \%_{Savings,i}}\right)}{p + \sum_{i=1}^{2}\left(\frac{p_i}{1 - \%_{Savings,i}}\right)}$$

Assuming that there are N different inefficient measures and introducing the same applicability factor than before we finally have:

$$C_{pot}(\%) = \frac{\sum_{i=1}^{N}\left(\frac{A_i * p_i * \%_{Savings,i}}{1 - \%_{Savings,i}}\right)}{p + \sum_{i=1}^{N}\left(\frac{p_i}{1 - \%_{Savings,i}}\right)}$$

Appendix 5: Total savings potential

Wastewater treatment plants

The following assumptions were made to calculate the total savings potential of all wastewater treatment plants in KCP&L territory:

1) Only measures with % savings information from the measure characterization table were considered in this savings potential table
2) For measures where cost information was available, only measures with a cost per annual kWh saved lower than $0.4 were considered
3) For measures where cost information was not available, only solutions which are commercially available or which have already been implemented in a full-scale facility were considered
4) The penetration and applicability factors are assumed to be 10% and 90% respectively unless stated otherwise by nationwide sources (not specific to facilities in the KCP&L region)
5) Penetration factor for pumps, motors, VFD are assumed to be the same for WWTP and for Water Treatment Plant
6) Mixing is responsible for 100% of the energy of anaerobic digestion
7) The final total annual savings for all plants have been calculated by summing the average savings of the aeration control measures, the average savings of the blower measures, the average savings of the diffuser measures, the savings of the disinfection measure, the average savings of the mixing measures, the average savings of the pump and motor measures, and the savings of the electric demand management measures.
8) None of the measures related to lighting were used in the savings potential calculation

Table 18. Wastewater total savings potential

Applicable End Use	Measure name	Measure description	Baseline Description	Penetration factor	Applicability factor	Minimum % energy savings of total plant	Minimum total annual energy savings (GWh)	Maximum % energy savings of total plant	Maximum total annual energy savings (GWh)
Design and control of aeration systems	Intermittent Aeration	Reduces number of hours that an aeration system operates or the aeration system capacity.	Continuous aeration	10%	90%	12.2%	7.4	20.6%	21.1

	Optical DO probe	Measures changes in light emitted by a luminescent or fluorescent chemical and relates the rates of change in the emission to the DO concentration in solution.	Membrane DO probe	10%	90%	7.6%	4.6	21.6%	22.3
	Most Open Valve (MOV) control	Ensures the control butterfly valve serving the zone with the highest oxygen demand is essentially full open.	Standard aeration control system	10%	90%	11.6%	7.0	11.6%	11.8
	Automated SRT (standard residence time) /DO (dissolved oxygen) Control System	Optimize the DO and SRT levels with an algorithm based on activated sludge modeling, plant historical data, and statistical process control	No DO control system	28%	90%	10%	4.9	33%	29.3
	Off-gas monitoring and control	Determines in-process oxygen transfer efficiency (OTE) based on a gas-phase mass balance	conventional feedback-based DO control systems	10%	90%	10.8%	6.5	10.8%	11.0
Blower and Diffuser Technology for Aeration Systems	High-speed gearless (Turbo) blowers. (Air bearing or magnetic bearing)	Design to operate at higher speed (upwards of 40,000 revolutions per minute [rpm]). Is friction free	Conventional multi-stage centrifugal or positive displacement blowers	10%	90%	5.4%	3.3	27.1%	28.0

	Single-stage centrifugal blowers with inlet guide vanes and variable diffuser vanes	Pre-rotate the intake air before it enters the high speed blower impellers. This reduces flow efficiently. Improves control of the output air volume	conventional single-stage or multi-stage centrifugal blowers	10%	90%	15%	9.2	27%	27.4
	Ultra-fine bubble diffusers. (Traditional ceramic and elastomeric membrane)	Increased oxygen transfer rates afforded by the high surface area of the fine bubbles (0.2-1mm). More resistant to fouling	mechanical or coarse bubble diffusers	47%	90%	16.2%	6.2	32.5%	22.7
	Ultra-fine bubble diffusers. (Strip homogeneou s thermoplastic membrane)	Less prone to tearing. Also, the smaller strips allow tapering of the diffuser placement to match oxygen demand across the basin.	Ultra-fine bubble diffusers. (Traditional ceramic and elastomeric membrane)	10%	90%	1.6%	1.0	6.5%	6.6
	Rotary screw compressor	Rotary screw compressor	rotary lobe blower	10%	90%	14.9%	9.0	27.1%	28.0
Selected Treatment Processes	Low-pressure high-output lamps for UV disinfection	Used mercury amalgam so they can operate at higher internal lamp pressures. It reduces lamp requirements (quantity) and energy requirements	low-pressure low-intensity lamps	10%	90%	7%	0.9	20%	4.3
	Hyperbolic mixers	The stirrer is equipped with transport ribs that cause acceleration of the wastewater in a radial	Traditional submersible mixers	10%	90%	8.9%	2.3	8.9%	3.9

		direction to promote complete mixing							
	Pulsed Large Bubble Mixing (e.g., Biomx)	Reduces energy required for anoxic or anaerobic zone mixing by firing short bursts of compressed air into the zone. The large air bubbles minimize oxygen transfer and maintain anoxic or anaerobic conditions	Submersible propeller mixers (mechanical)	10%	90%	6.4%	1.7	8.5%	3.7
Solids Processing	Vertical linear motion mixer	Prevents solids deposition and minimizes scum and foam formation. Mixes digester contents by moving a thin steel disk in an up and down motion to create axial and lateral agitation.	Recirculation pumps or conventional propeller-type mixers	10%	90%	7.1%	1.8	12.8%	5.6
Pump / motor	Optimized motor	Replace old inefficient motor with new more efficient ones	Old inefficient motor	50%	90%	4%	1.4	8%	4.7
	Optimized pumping system	Replace inefficient pumps with more efficient ones or optimize sizing or replace large capacities pumps with smaller capacities pumps	Standard pumping system	50%	90%	1.5%	0.5	6.5%	3.8
	Variable Frequency Drive (VFD)	Varies the speed of a pump to match the flow conditions. Controls the speed of a motor by	Standard drives	50%	90%	13%	4.6	13%	7.8

		varying the frequency of the power delivered to the motor.							
Electric demand management	Electric demand management	Monitoring total energy use/demand with installation of electrical metering, maximizing off-peak operations	No electric demand management	10%	90%	0.70%	0.4	7.30%	7.4

Water treatment plants

The following assumptions were made to calculate the total savings potential of all water treatment plants in KCP&L territory:

1) Only measures with % savings information from the measure characterization table were considered in this savings potential table
2) For measures where cost information was available, only measures with a cost per annual kWh saved lower than $0.4 were considered
3) For measures where cost information was not available, only solutions which are commercially available or which have already been implemented in a full-scale facility were considered
4) The penetration and applicability factors are assumed to be 10% and 90% respectively unless stated otherwise by nationwide sources (not specific to facilities in the KCP&L region)
5) Penetration factor for pumps, motors, VFD are assumed to be the same for WWTP and for Water Treatment Plant
6) The treatment processes listed for the water treatment plants account for 100% of the treatment energy consumption
7) The final total annual savings for all plants have been calculated by summing the average savings of the pumps and motor measures, the average of the distribution measures, the treatment process measures, and the electric demand management measures.
8) None of the measures related to lighting were used in the savings potential calculation

Table 19. Water treatment plant total savings potential

Applicable End Use	Measure name	Measure description	Baseline Description	Penetration factor	Applicability factor	Minimum % energy savings of total plant	Minimum total annual energy savings (GWh)	Maximum % energy savings of total plant	Maximum total annual energy savings (GWh)

Pump / motor	high efficiency pump/motor system	high efficiency pump/motor system	pump/motor system with low efficiency	50%	90%	8.60%	4.8	25.80%	15.9
	Pump modification	adjusting effluent pumping, inline flow meters in collection/distribution systems, and pump controls	Non-optimized pump	10%	90%	12.90%	12.7	25.80%	25.7
	Variable frequency drive	Varies the speed of a pump to match the flow conditions. Controls the speed of a motor by varying the frequency of the power delivered to the motor.	Pump with standard drive	50%	90%	8.60%	4.8	17.20%	10.1
Distribution	Pipeline optimization	Reduce power required to overcome friction of a pumping system by selecting appropriate check valves, optimizing pipe diameter, optimizing flow rate	non-optimized pipeline	10%	90%	4.3%	4.2	17.2%	17.0
	Advanced SCADA systems	This advanced control system can be applied to raw water pumping, treatment and distribution. Reduce pumping and treatment energy consumption. Increase quality and reliability. Decrease operation and maintenance costs.	No SCADA system	10%	90%	10%	9.8	20%	19.8

	Automatic meter reading (AMR) /Acoustic leak detection integration	Monitors consumption of water and detects leaks in pipeline	No AMR	10%	90%	4.3%	4.2	12.9%	12.7
Treatment processes	Advanced membranes	Separate particulate matter with a size higher than the size of the membrane	Standard membrane filtration	10%	90%	2.1%	0.3	3.5%	0.5
	Advanced Ozonation	Reduce energy consumption of ozone generators by half. Decrease need for water transport pumping through use of local water sources. Reduce operation costs.	Standard ozone generators	10%	90%	1.4%	0.2	2.8%	0.4
	Advanced UV (low-pressure high-output (LPHO))	The short UV wavelength radiation physically penetrates the cell wall of microorganisms and has a germicidal effect.	Standard UV (low-pressure (LP) and medium-pressure (MP))	10%	90%	1.4%	0.1	4.2%	0.3
	Advanced reverse osmosis	Greatly reduce baseline energy consumption for desalination through optimizing components and energy recovery. Reduce operating costs.	Desalination (seawater or brackish water) without RO	10%	90%	7.0%	0.1	7.0%	0.1
Electric demand management	Electric demand management	monitoring total energy use/demand with installation of electrical metering, maximizing off-peak operations	No electric demand management	10%	90%	0.7%	0.7	7.3%	7.1

Restaurant

The following assumptions were made to calculate the total savings potential of all restaurants in KCP&L territory:

1. Steam cooker is responsible for 50% of "Food prep" for water consumption
2. All equipment were assumed to be electric
3. Only measures with an incremental cost per annual kWh saved lower than $0.4 were taken into consideration
4. None of the measures related to lighting were used in the savings potential calculation

Table 20. Restaurant total savings potential

Applicable End Use	Applicable technology	Measure name	Measure description	Baseline Description	Penetration factor of the new measure	Applicability factor	Total annual energy savings (GWh)	Percent energy savings of total restaurant	Total annual savings (Mgal)	Percent water savings of total restaurant
Commercial kitchen	Dishwasher	Low temperature under counter	Energy Star model	Standard model	38%	90%	2.5	0.4%	71	2.3%
		Low temperature stationary single tank door					4.7	0.8%	106	3.4%
		Low temperature single tank conveyor					3.6	0.6%	94	3.1%
		Low temperature Multi Tank Conveyor					4.2	0.7%	118	3.9%
		High temperature Under Counter					2.7	0.5%	46	1.5%
		High temperature Stationary Single Tank Door					3.2	0.6%	71	2.3%
		High temperature Single Tank Conveyor					2.1	0.4%	42	1.4%
		High temperature Multi Tank Conveyor					4.3	0.7%	107	3.5%
	Freezer	Solid door			10%		1.4	0.2%	-	-

		Glass door					3.5	0.6%	-	-
	Fryer	Electric Standard			10%		0.3	0.1%	-	-
		Electric Large Vat					0.9	0.2%	-	-
	Griddle	Electric			10%		0.2	0.0%	-	-
	Hot food holding cabinet	Hot food holding cabinet			10%		0.5	0.1%	-	-
	Ice Machine	Batch, Ice Making Head			25%		2.4	0.4%	32	1.1%
		Batch, Remote Condensing Unit					1.6	0.3%	21	0.7%
		Batch, Self-Contained Unit					1.8	0.3%	74	2.4%
		Continuous, Ice Making Head					2.9	0.5%	-	-
		Continuous, Remote Condensing Unit					2.5	0.4%	-	-
		Continuous, Self-Contained Unit					1.3	0.2%	-	-
	Oven	Convection, electric, full size			10%		3.0	0.5%	-	-
		Convection, electric, half size					0.5	0.1%	-	-
		Combination, Electric					6.5	1.1%	-	-
	Refrigerator	Solid door			10%		1.5	0.3%	-	-
		Glass door					2.6	0.4%	-	-
	Steam cooker	Electric			10%		1.1	0.2%	56	1.8%
	Pre-Rinse spray valve	Pre-Rinse spray valve	WaterSense model		10%		-	-	35	1.1%

Restroom	Toilet	Ultra-low flush toilet	Ultra-low flow toilet 1.6 gpf	Toilet 3.5 gpf and 5 gpf	38% and 18%[28]		-	-	288	9.4%
	Urinal	Ultra-low flush urinal	Ultra-low flush urinal 1 gpf	Conventional urinal 1.5 gpf	23%		-	-	42	1.4%
	Faucet	Faucet aerator	Faucet 1gpm	Faucet 2 gpm	10%		-	-	17	0.5%
Landscaping	Landscaping	Water sensing for turf	Water sensing for turf	Conventional watering	10%		-	-	31	1.0%

In addition to the energy savings coming from these measures, the project team also calculated the embedded energy savings associated with the water savings, using the energy intensity calculated in Appendix 3. These savings are shown in the table below:

Table 21. Restaurant total embedded energy savings potential associated with water savings

	Total annual embedded energy savings (GWh)	Percent energy savings of total restaurant
TOTAL MIN	1.8	0.3%
TOTAL AVERAGE	2.1	0.4%
TOTAL MAX	2.3	0.4%

School

The following assumptions were made to calculate the total savings potential of all schools in KCP&L territory:

1. Steam cooker is responsible for 50% of "Food prep" for water consumption

[28] These values correspond to the penetration factor of the inefficient measures, i.e. toilet with 3.5 and 5 gpf respectively

2. All equipment were assumed to be electric
3. Only measures with an incremental cost per annual kWh saved lower than $0.4 were taken into consideration
4. None of the measures related to lighting were used in the savings potential calculation

Table 22. School total savings potential

Applicable End Use	Applicable technology	Measure name	Measure description	Baseline Description	Penetration factor of the new measure	Applicability factor	Total annual energy savings (GWh)	Percent energy savings of total restaurant	Total annual savings (Mgal)	Percent water savings of total restaurant
Commercial kitchen	Dishwasher	Low temperature under counter	Energy Star model	Standard model	38%	90%	2.5	0.4%	71	2.3%
		Low temperature stationary single tank door					4.7	0.8%	106	3.4%
		Low temperature single tank conveyor					3.6	0.6%	94	3.1%
		Low temperature Multi Tank Conveyor					4.2	0.7%	118	3.9%
		High temperature Under Counter					2.7	0.5%	46	1.5%
		High temperature Stationary Single Tank Door					3.2	0.6%	71	2.3%
		High temperature Single Tank Conveyor					2.1	0.4%	42	1.4%
		High temperature Multi Tank Conveyor					4.3	0.7%	107	3.5%
	Freezer	Solid door			10%		1.4	0.2%	-	-
		Glass door					3.5	0.6%	-	-
	Fryer	Electric Standard			10%		0.3	0.1%	-	-
		Electric Large Vat					0.9	0.2%	-	-

	Griddle	Electric			10%		0.2	0.0%	-	-
	Hot food holding cabinet	Hot food holding cabinet			10%		0.5	0.1%	-	-
	Ice Machine	Batch, Ice Making Head			25%		2.4	0.4%	32	1.1%
		Batch, Remote Condensing Unit					1.6	0.3%	21	0.7%
		Batch, Self-Contained Unit					1.8	0.3%	74	2.4%
		Continuous, Ice Making Head					2.9	0.5%	-	-
		Continuous, Remote Condensing Unit					2.5	0.4%	-	-
		Continuous, Self-Contained Unit					1.3	0.2%	-	-
	Oven	Convection, electric, full size			10%		3.0	0.5%	-	-
		Convection, electric, half size					0.5	0.1%	-	-
		Combination, Electric					6.5	1.1%	-	-
	Refrigerator	Solid door			10%		1.5	0.3%	-	-
		Glass door					2.6	0.4%	-	-
	Steam cooker	Electric			10%		1.1	0.2%	56	1.8%
	Pre-Rinse spray valve	Pre-Rinse spray valve	WaterSense model		10%		-	-	35	1.1%
Restroom	Toilet	Ultra-low flush toilet	Ultra-low flow toilet 1.6 gpf	Toilet 3.5 gpf and 5 gpf	38% and 18%[29]		-	-	288	9.4%
	Urinal	Ultra-low flush urinal	Ultra-low flush urinal 1 gpf	Conventional urinal 1.5 gpf	23%		-	-	42	1.4%

[29] These values correspond to the penetration factor of the inefficient measures, i.e. toilet with 3.5 and 5 gpf respectively

	Faucet	Faucet aerator	Faucet 1gpm	Faucet 2 gpm	10%		-	-	17	0.5%
Landscaping	Landscaping	Water sensing for turf	Water sensing for turf	Conventional watering	10%		-	-	31	1.0%

The embedded energy savings associated with the water savings are shown in the table below:

Table 23. School total embedded energy savings potential associated with water savings

	Total annual embedded energy savings (GWh)	Percent energy savings of total school
TOTAL MIN	0.9	0.1%
TOTAL AVERAGE	0.9	0.1%
TOTAL MAX	1.0	0.1%

College

The following assumptions were made to calculate the total savings potential of all colleges in KCP&L territory:

1. Steam cooker is responsible for 50% of "Food prep" for water consumption
2. All equipment were assumed to be electric
3. Only measures with an incremental cost per annual kWh saved lower than $0.4 were taken into consideration
4. None of the measures related to lighting were used in the savings potential calculation

Table 24. College total savings potential

Applicable End Use	Applicable technology	Measure name	Measure description	Baseline Description	Penetration factor of the new measure	Applicability factor	Total annual energy savings (GWh)	Percent energy savings of total college	Total annual savings (Mgal)	Percent water savings of total college
Commercial kitchen	Dishwasher	Low temperature under counter	Energy Star model	Standard model	38%	90%	0.9	0.1%	2.9	0.3%
		Low temperature stationary single tank door					1.7	0.3%	4.4	0.5%
		Low temperature single tank conveyor					1.3	0.2%	3.9	0.4%
		Low temperature Multi Tank Conveyor					1.5	0.2%	4.9	0.6%
		High temperature Under Counter					1.0	0.2%	1.9	0.2%
		High temperature Stationary Single Tank Door					1.2	0.2%	2.9	0.3%
		High temperature Single Tank Conveyor					0.8	0.1%	1.8	0.2%
		High temperature Multi Tank Conveyor					1.6	0.2%	4.4	0.5%
	Freezer	Solid door			10%		0.1	0.0%	-	-
		Glass door					0.3	0.0%	-	-
	Fryer	Electric Standard			10%		0.2	0.0%	-	-
		Electric Large Vat					0.5	0.1%	-	-
	Griddle	Electric			10%		0.1	0.0%	-	-
	Hot food holding cabinet	Hot food holding cabinet			10%		0.4	0.1%	-	-
	Ice Machine	Batch, Ice Making Head			25%		0.3	0.0%	1.3	0.2%
		Batch, Remote Condensing Unit					0.2	0.0%	0.9	0.1%

		Batch, Self-Contained Unit					0.2	0.0%	3.1	0.3%
		Continuous, Ice Making Head					0.4	0.1%	-	-
		Continuous, Remote Condensing Unit					0.3	0.0%	-	-
		Continuous, Self-Contained Unit					0.2	0.0%	-	-
	Oven	Convection, electric, full size			10%		0.5	0.1%	-	-
		Convection, electric, half size					0.1	0.0%	-	-
		Combination, Electric					1.1	0.2%	-	-
	Refrigerator	Solid door			10%		0.1	0.0%	-	-
		Glass door					0.2	0.0%	-	-
	Steam cooker	Electric			10%		0.5	0.1%	2.3	0.3%
	Pre-Rinse spray valve	Pre-Rinse spray valve	WaterSense model		10%		-	-	1.4	0.2%
Restroom	Toilet	Ultra-low flush toilet	Ultra-low flow toilet 1.6 gpf	Toilet 3.5 gpf and 5 gpf	38% and 18%[30]		-	-	117.6	13.3%
	Urinal	Ultra-low flush urinal	Ultra-low flush urinal 1 gpf	Conventional urinal 1.5 gpf	23%		-	-	17.0	1.9%
	Faucet	Faucet aerator	Faucet 1gpm	Faucet 2 gpm	10%		-	-	6.8	0.8%

[30] These values correspond to the penetration factor of the inefficient measures, i.e. toilet with 3.5 and 5 gpf respectively.

Laundries	Laundries	80% water recycling	80% water recycling	no water recycling or 30% recycling	30% and 60%[31]		-	-	17.5	2.0%
Landscaping	Landscaping	Water sensing for turf	Water sensing for turf	Conventional watering	10%		-	-	63.3	7.1%

The embedded energy savings associated with the water savings are shown in the table below:

Table 25. College total embedded energy savings potential associated with water savings

	Total annual embedded energy savings (GWh)	Percent energy savings of total college
TOTAL MIN	0.8	0.1%
TOTAL AVERAGE	0.8	0.1%
TOTAL MAX	0.8	0.1%

[31] These values correspond to the penetration factor of the inefficient measures, i.e. washing machine with no water recycling and 30% recycling respectively.