2016 Hawaii Water Energy Nexus Report

Department of Land and Natural Resources
Commission on Water Resource Management

May 2017

Commission on Water Resource Management
State of Hawaii

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2016 Hawaii Water Energy Nexus Report

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May 2017

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ABBREVIATIONS

$/kgal	Marginal Cost
Avg	Average
AWWA	American Water Works Association
Commission	State of Hawaii, Department of Land and Natural Resources, Commission on Water Resource Management
DLNR	State of Hawaii, Department of Land and Natural Resources
DOE	United States Department of Energy
DOH	State of Hawaii, Department of Health
EPA	Environmental Protection Agency
ESCO	Energy Service Company
ESPC	Energy Savings Performance Contracting
Ft	Feet
HAR	Hawaii Administrative Rules
HRS	Hawaii Revised Statues
IWREDSS	Irrigation Water Requirement Estimation Decision Support System
IWS	Individual Wastewater Systems
Kgal	1,000 gallons
Kgal/kWh	Water Intensity
kWh	Kilowatt hour
kWh/kgal	Energy intensity
OTEC	Ocean Thermal Energy Conversion
PEIS	Programmatic Environmental Impact Study
PUC	Public Utilities Commission
SCADA	Supervisory Control and Data Acquisition
SDWB	State of Hawaii, Department of Health, Safe Drinking Water Branch
SLH	Session Laws of Hawaii
UV	Ultraviolet
VFD	Variable frequency drives

EXECUTIVE SUMMARY

Water is an integral part of Hawaii, both for its use and for its role in Hawaii's culture. The ancient Hawaiians believed that water was a sacred resource and essential source of life. This belief still resonates today with the saying "water is life". As an isolated island state, Hawaii is dependent on its fresh water resources for day to day living and lush environment; without it, Hawaii, as most people know it, would cease to exist. Faced with the impacts of climate change, increasing population, and growing competition for limited supplies, it is important that Hawaii's fresh water resources are used wisely and efficiently.

In utilities, water use is interconnected with energy use. Each resource is necessary for the operation of the other; energy is used to collect, treat and distribute water and wastewater, while water is used for energy production. Reducing water use can reduce the amount of energy needed to operate the water system. Similarly, reducing energy use can reduce the amount of water needed for energy production. Understanding the impact this relationship has on utilities is paramount to developing effective water conservation programs.

In an effort to understand the true cost of water and energy production to utilities, the State of Hawaii, Department of Land and Natural Resources, Commission on Water Resource Management, surveyed water, wastewater, electrical and renewable energy purveyors throughout the State. The intent of the survey was to characterize, compare and provide a baseline for water and energy use for the operation of the various utilities over the 2014 and 2015 calendar years. A total of 137 utility companies were identified and contacted for participation in the study. Entities were identified based on registration with the Public Utilities Commission (PUC), DOH, and/or the Commission. Systems requiring little to no energy use, such as individual wastewater systems, wind farms and solar fields, were exempt from the study. Participation in the study was voluntary.

Water and energy consumption data was obtained from 39 public and private utilities throughout the State. To quantify the water energy relationship, energy intensity, or the amount of energy required to collect, treat and distribute 1,000 gallons of water, was calculated for each individual system or facility. Likewise, for electrical systems which consume water for energy production, water intensity, or the amount of water needed to produce a unit of energy, was calculated for each facility. Marginal cost, or the cost to produce a unit of water, was used to visually represent the cost of water use to the utility. Table 1 summarizes the energy intensities and marginal costs for water, wastewater and recycled water industries in 2014 and 2015. Table 2 summarizes the water use by electrical utilities in 2014 and 2015. Cost information for electrical utilities was not available. The findings presented herein are based on the data collected from the 39 participating utilities and may not accurately represent the industry as a whole.

Table 1. 2014 and 2015 Water and Energy Use

Year[1]	Industry	Energy Intensity (kWh/kgal)		Marginal Cost ($/kgal)	
		Range	Average	Range	Average
2014	Water	0.0 – 24.6	4.4	$0.06 - $9.22	$1.66
2015	Water	0.0 – 23.9	5.1	$0.03 - $7.50	$1.70
2014	Wastewater	2.1 – 23.5	7.2	$0.49 - $8.66	$2.54
2015	Wastewater	3.1 – 24.2	12.1	$0.91 – 6.98	$3.87
2015	Recycled Water	0.1 – 6.3	3.5	-	-

[1] The number of participating utilities varied for each year; therefore, data for 2014 and 2015 cannot be compared against each other as the number of utilities or participating utilities may not be the same.

Table 2. 2014 and 2015 Electrical Water Use

Year[1]	Water Intensity (kgal/kWh)	
	Range	Average
2014	0.00 – 1.09	0.15
2015	0.00 – 1.45	0.35

The energy intensities for each industry varied from system to system, depending on system characteristics. Table 3 summarizes some of the primary drivers of energy and water use for each industry. Understanding the primary drivers of energy use can help utilities develop and implement energy management strategies to decrease energy use and minimize operating costs. Opportunities for energy management include optimizing the operations of the system, using renewable energy sources, mitigating energy use during peak energy demand periods and monitoring energy consumption. These strategies target energy reduction and water use by association.

Table 3. Primary Drivers of Energy and Water Use

Water	• Pumping: elevation, distance, volume, pressure • Volume treated • Source: surface water, brackish, ocean, groundwater • Treatment technology
Wastewater	• Pumping • Volume collected and treated • Level of treatment: primary, secondary, tertiary • Treatment technology: activated sludge, UV disinfection
Recycled Water	• Pumping - distribution • Volume collected and treated • Level of treatment: R-1, R-2, R-3, R-O • Treatment technology: trickling sand filter, UV disinfection • Effluent distribution
Electrical	• Volume of electricity generated • Type of electricity production: fossil fuels, renewable energy

In addition to energy management programs, water conservation programs targeting both utilities and end users should be initiated to protect Hawaii's fresh water resources. Utilities and agencies often pursue water conservation programs independently with dispersed results. Greater collaboration between utilities and government agencies is necessary to develop effective and mutually beneficial conservation initiatives and programs, including partnerships and collaboration between energy and water utilities. Water conservation benefits everyone and as such, should be perceived as a partnership effort by all users. Strategies requiring collaboration between multiple stakeholders include promoting the use of recycled water, joint infrastructure improvements and development of appropriate water use polices. Working together in unison will yield greater net benefits and long term results for both users and the environment.

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1) INTRODUCTION

a) Background

Limited Fresh Water Resources

Over the past 30 years, there has been observed increases in drought conditions, rising sea levels, shifting rainfall patterns and decreased stream flow and aquifer levels. If these trends continue, it may be challenging to meet the current and future fresh water needs of Hawaii's growing population. Some areas of the State have already reached their limits of available ground water. As Hawaii's fresh water resources diminish, it is imperative that water is used both wisely and efficiently. In order to ensure that water is used for its highest potential, it is important to understand all applications of water use including energy production.

Water-Energy Nexus

Water and energy use are embedded in each other. Energy is necessary for water and wastewater systems to pump, transport, distribute and treat water and wastewater. Likewise, water is necessary for energy production for resource extraction, processing of fossil fuels and, power plant cooling. Neither resource can be produced or distributed without the other. Consequently, reducing the use of one resource can also reduce the use of the other. Understanding the relationship between water and energy can help stakeholders and utilities make informed decisions related to both water and energy conservation, which can lead to cost savings for both utility companies and consumers. Since water costs are relatively inexpensive, measures focused purely on water conservation have long pay back periods which discourage implementation. Understanding the high cost of energy embedded in water will incentivize utilities and other consumers to conserve water.

b) Purpose of Report

The purpose of this study is to understand the relationship between water and energy use in Hawaii and provide the State of Hawaii, Department of Land and Natural Resources, Commission on Water Resource Management, herein referred to as the "Commission", and other stakeholders with a framework to:

- Understand how energy is used in the various water and wastewater processes (Chapters 2 and 3)
- Understand how water is used for different types of energy production (Chapter 4)

- Establish a baseline for water and energy production and disposal (Chapters 5 to 11)
- Identify opportunities to coordinate water conversation and energy efficiency programs (Chapter 12 and 13)
- Identify areas for further study and analysis (Chapter 14)

The information presented in this study will help the Commission develop and implement water conservation programs protecting Hawaii's fresh water resources, while considering the implications of energy uses in the water and wastewater industries.

2) UTILITY WATER USE

Potable water systems transport water from its source to treatment plants, storage facilities and consumers. Depending on the source, treatment can range from little to no treatment, to more energy intensive technologies, such as filtration and ultraviolet radiation. After treatment, water is transported to elevated storage facilities where it is stored until it is needed for distribution. Booster pumps are used to pressurize the pipelines and distribute water throughout the system. More energy is required to pump water to service areas located at higher elevations. The most common uses of water are for domestic, agricultural and industrial purposes.

a) Source

The main sources of water used by utilities for their operations are ground water, surface water and brackish water.

i) Ground Water

Ground water is the primary source of potable water in Hawaii. Ground water is found in naturally occurring, underground water formations called aquifers. Aquifers are naturally recharged by rainfall and fog interception, and to a lesser degree, surface water, percolating into the ground.

Each aquifer has a designated sustainable yield, or maximum amount of water that can be withdrawn each day without adversely affecting the aquifer. There are currently 32 aquifer sector areas in Hawaii. Of those, ten are designated as Water Management Areas by the Commission. Well owners in these areas are subject to more stringent use regulations as water availability and/or water quality in those areas are a concern.

As ground water is pumped up to its sustainable yield, aquifer water levels will decline to a pre-identified level, that allows for optimal development of the resource without compromising water quality and existing infrastructure. However, as a result, utilities will be forced to pump water from greater depths which will require more energy. Some very old wells that were drilled before the Hawaii Well Construction and Pump Installation Standards (2004) were developed may be drilled too deep. In these cases, water salinity levels most likely will increase, potentially compromising water quality. If this occurs, additional treatment processes may be required to meet the State of Hawaii, Department of Health's (DOH) Safe Drinking Water Standards. Water may be blended with less saline water to reduce chlorides to an acceptable level.

ii) Surface Water

In some areas on the islands of Hawaii, Kauai, Molokai and Maui, surface water is used to supplement ground water for domestic uses and power hydroelectric facilities. Surface water comes from rainfall runoff stored in streams and ground water discharge. Hawaii has approximately 376 streams that flow continuously throughout the year. Use of these streams are regulated by the Commission under the Hawaii Administrative Rules (HAR) Chapter 13-169 Protection of Instream Uses of Water.

iii) Brackish/Ocean Water

Brackish and ocean water is most commonly used for industrial purposes such as cooling water for power generation. Brackish water is comprised of both fresh water and salt water mixed together. Due to their salt contents, brackish and ocean water need to be treated via desalination, or blended in the case of brackish water, prior to irrigation and urban uses.

Desalination is a process that removes salt and other minerals from saline water. The process is typically more energy intensive than the treatment processes required for other sources. However, recent advances in technology have reduced the cost and energy requirements of desalination, making it a more viable option for domestic uses. In areas across the United States where fresh water is limited, the use of brackish and ocean water for potable use is becoming more widespread. Today, there are desalination plants in over 150 counties including Australia, Italy and Saudi Arabia.

Domestically, the County of Carlsbad in California recently completed construction of the largest seawater desalination plant in the Western Hemisphere. The plant which intakes more than 100 million gallons of seawater daily, produces 54 million gallons of potable water for San Diego County. Water for Southern California was previously transported from the Colorado River in Northern California via transmission mains. Use of the desalination plant will help to reduce the demand on California's fresh water resources.

To date, the use of brackish and ocean water in Hawaii is limited to industrial and irrigation purposes, with the exception of a few companies in Kailua-Kona on the island of Hawaii, that are using desalinated seawater to produce bottled beverages. With current resources and population growth in mind, companies on Lanai and Oahu are considering using treated brackish and ocean water for domestic use in an attempt to diversify available water sources. Plans for the development of desalination plants in Lanai and West Oahu are currently on hold.

b) Treatment

Chapter 11-20, HAR specifies monitoring requirements, maximum allowable levels of contaminants, and treatment requirements for public water systems. Public water systems are defined as systems that provide potable water for human consumption and consist of a minimum of 15 service connections or serve at least 25 individuals a day for at least 60 days out of the year. Due to varying water qualities, treatment requirements vary by source.

i) Ground Water

In general, ground water in Hawaii is naturally filtered by abundantly occurring volcanic rock. This results in water that requires little to no treatment. To comply with the Environmental Protection Agency (EPA) regulations, a minimal amount of chlorine is added to potable water to prevent contamination from waterborne diseases. In aquifers previously used for extensive agricultural farming, ground water is passed through an activated carbon filtration system to remove residual pesticide contamination. The system is a passive system with no energy use.

Under Section 11-20-50 HAR, additional ground water treatment is only required if testing reveals significant deficiencies or fecal contamination. Significant deficiencies include testing positive for *E. Coli* or exceeding maximum allowable contaminant levels.

ii) Surface Water

Utility companies on the islands of Maui, Kauai, Molokai, and Hawaii use surface water to supplement ground water resources. Surface water typically contains suspended solids, bacteria and organic matter. Prior to consumption, surface water or ground water that is under the direct influence of surface water, is treated to achieve safe contaminant levels. Water that is acceptable for consumption is free of harmful substances, colorless, odorless, pleasant to taste and does not stain.

In accordance with Section 11-20-46 HAR and EPA regulations, the DOH Safe Drinking Water Branch (SDWB) developed the Surface Water Treatment Rules which establishes minimum water treatment and performance requirements. Accepted methods of treatment, listed by increasing energy use, include:

- Slow Sand Filtration –Water is passed through a bed of sand at low velocities. Sand filters typically do not require energy as the water sits on top of the sand filter, providing head pressure.

- Direct Filtration – A series of processes that includes coagulation, flocculation and filtration. Energy is required to operate pumps used during the coagulation and flocculation processes.
- Conventional Filtration – Follows the same processes as direct filtration, but includes a sedimentation stage after flocculation. This process is used in cases where raw water has low turbidity and color.
- Diatomaceous Earth Filtration – Water is passed through a diatomaceous earth filter media. Energy is required to pump water through the filter with occasional backwashing.
- Microfiltration – Water is passed through pore-sized membranes to remove microorganisms and suspended solids

Direct filtration is the most commonly used method of surface water treatment in Hawaii. Figure 1 depicts the typical treatment processes in a direct filtration plant. Microfiltration, an alternative to direct filtration, is also used to treat surface water on the island of Maui

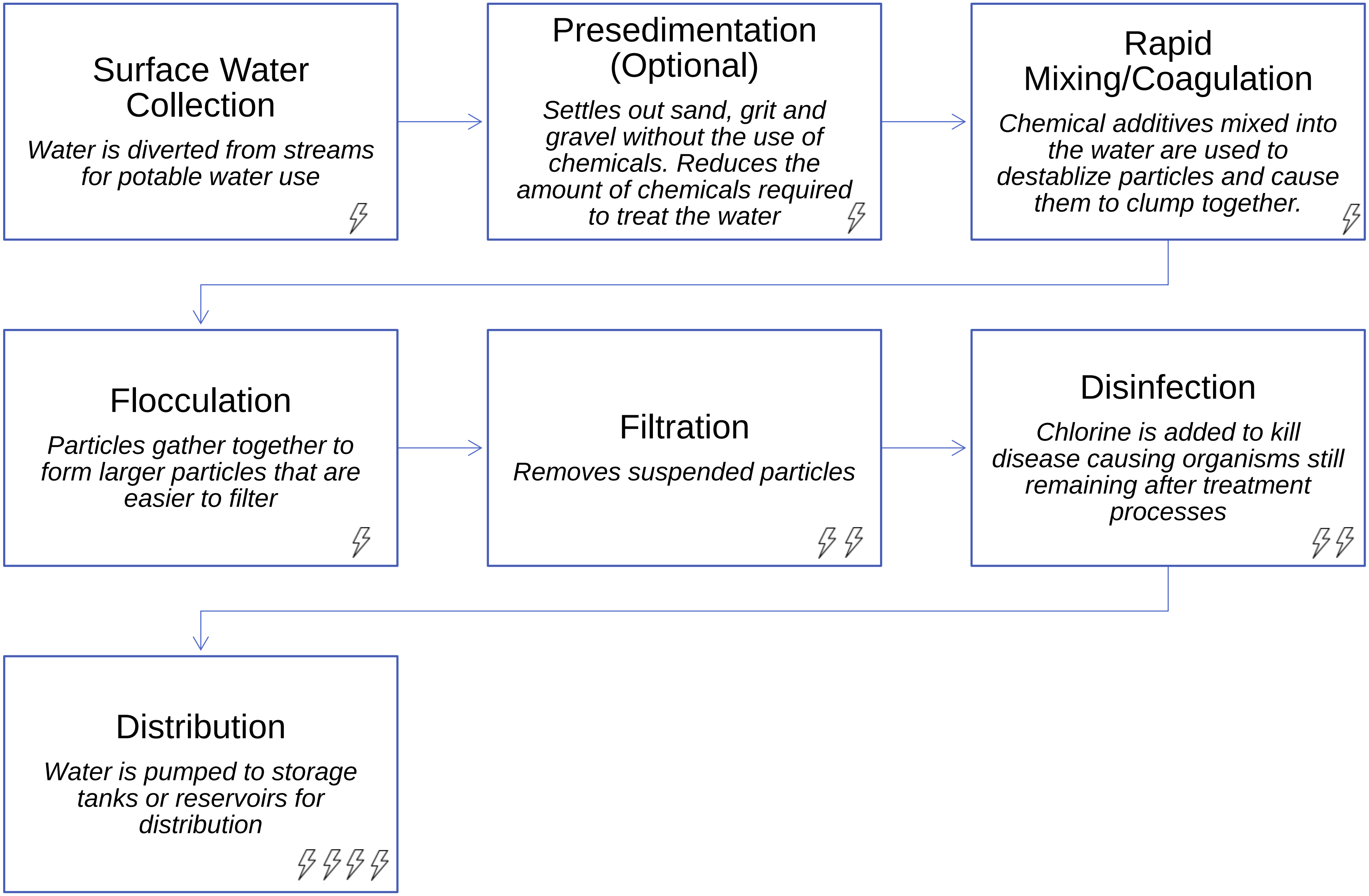

Figure 1. Typical Processes in a Direct Filtration Plant[1]

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[1]Relative energy use for each process is represented by ⚡. Electric Power Research Institute. Electricity Use and Management in the Municipal Water Supply and Wastewater Industries. Palo Alto: November 2013.

iii) Desalination

The most common form of desalination is reverse osmosis which pumps seawater at high pressures through a series of membranes, separating the water from the salt. Since the pores in the membranes are microscopic, pretreatment to remove organic materials and minimize the amount of pollutants from clogging the membrane is required. Desalination can be used to produce potable, irrigation, process and demineralized water. Since reverse osmosis removes mineral components essential for drinking water, post treatment is required to remineralise desalinated water and increase calcium hardness and alkalinity. Figure 2 depicts the processes associated with desalination.

There are many environmental concerns associated with the use of desalination plants including:

- Impacts to wildlife –Fish, shellfish and eggs may be sucked into the system by the intake and killed or injured. Alternative subsurface intakes are available but require significantly more energy to pump water from those depths and pose construction challenges.
- Pollution from desalination byproduct – Desalination produces large quantities of brine which may contain residuals contaminants from the treatment processes. Brine also has a higher salinity content than seawater which requires it to be diluted prior to discharge.
- Public health concerns – The removal of iodine may cause iodine deficiency disorders in populations reliant on desalinated seawater for potable water use.

An alternative to reverse osmosis is thermal distillation. Thermal distillation uses energy to boil and evaporate water which is later condensed to produce fresh water. Methods of evaporation include multistage flash evaporation, multi effect distillation and vapor compression.

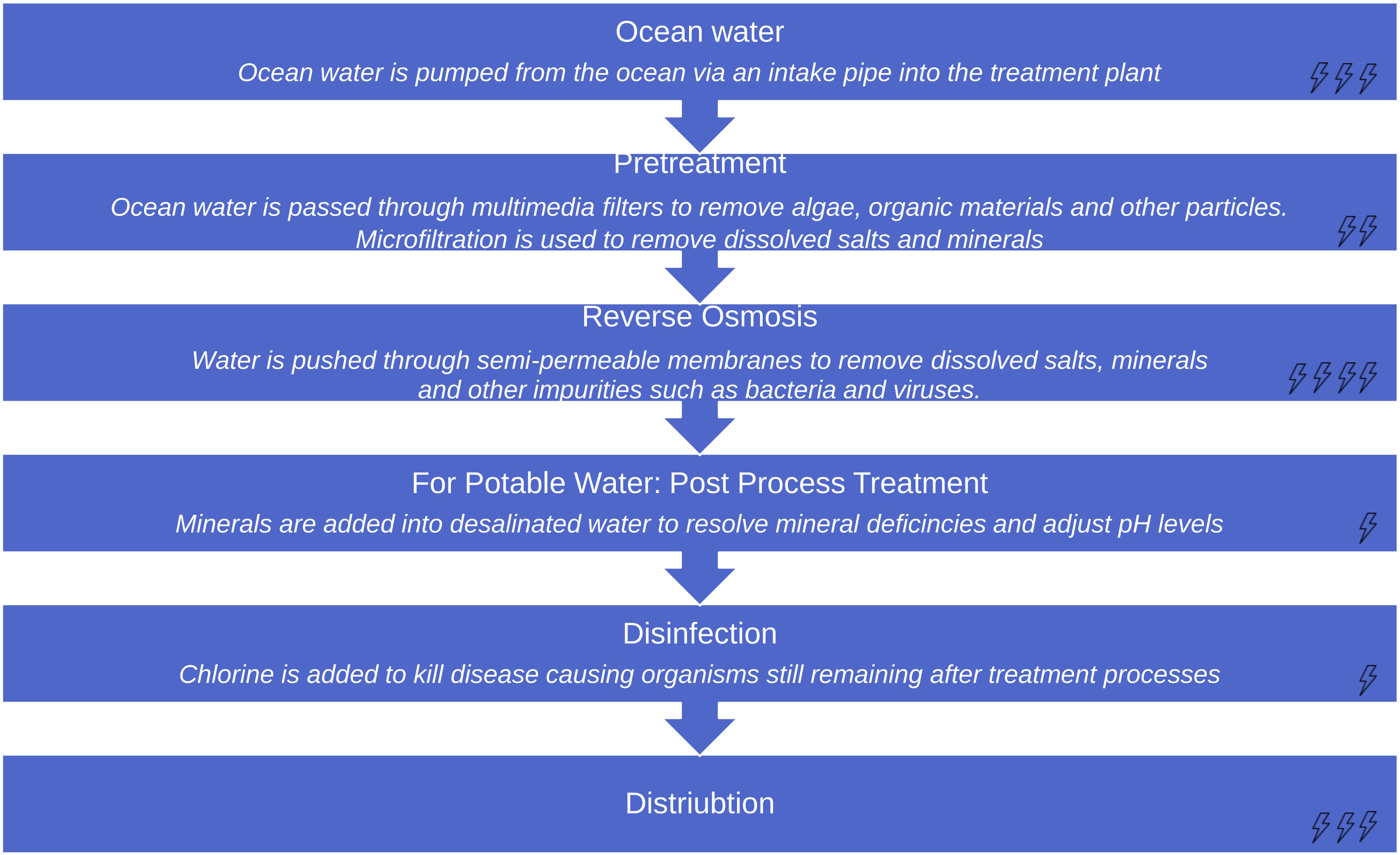

Figure 2. Typical Desalination Process[2]

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[2]Water Reuse Association. Seawater Desalination Power Consumption White Paper. November 2011.

c) Distribution and Storage

After treatment, water is conveyed into the distribution system for customer use. Water is pumped via transmission mains into elevated storage tanks and reservoirs until it is needed for use. Pressurized distribution mains are used to distribute water to customers throughout the system.

Booster pumps are used to transport water to higher distribution zones and provide adequate water pressures in the pipes.

d) Water Related Energy Use

Energy is required to pump, treat and distribute water throughout the system.

i) Source

- Ground water: Pumping accounts for the majority of energy use in systems dependent on ground water. The amount of energy needed to pump ground water is directly dependent on the depth to which ground water is needed to be lifted. As aquifer levels decrease, more energy is required to pump water from deeper depths.
- Surface Water: Water systems that utilize surface water use limited amounts of energy as the depth to which water is pumped from is comparatively less than that from ground water. In some cases, surface water is gravity fed into the system.
- Brackish Water/Ocean: The amount of energy needed to intake ocean water is dependent on the depth to which ocean water is being taken. Systems that use subsurface intakes to minimize environmental impacts on wildlife, require significantly more energy than open ocean intakes due to the difference in pumping depths.

ii) Treatment

Energy use is directly correlated to the level of treatment required for the source.

- Ground water: Since the water quality of ground water in Hawaii is nearly pristine, little to no treatment is required. As such, the energy use associated with ground water treatment is low.
- Surface Water: Surface water treatment to meet drinking water standards consumes more energy than ground water treatment.
- Brackish/ Ocean Water: On the high end of the spectrum, desalination of ocean water requires huge amounts of energy due to extensive treatment requirements and processes. Though technology advances have

decreased energy requirements, desalination still requires more energy than the treatment of other sources. Since brackish water has a lower salinity level than ocean water, less energy is required to treat brackish water.

In the future, potable water may be required to meet more stringent regulations and standards for water treatment. In order to meet these standards, additional treatment processes such as ultraviolet treatment or additional filtration may be required, which may lead to increased energy consumption.

iii) Distribution

The majority of energy consumption associated with distribution is attributed to pressurized pipes and operation of booster pumps to lift water to higher elevations.

iv) Discharge Management

In general, there is no byproduct of water treatment other than potable water. With desalination, because salt is being removed from ocean water, brine is a byproduct of desalination. While brine can be disposed of without treatment, there may be impacts to the environment. There are a number of different techniques and methods to discharge brine, including diluting the brine with wastewater effluent or cooling water, or using diffusers to promote mixing of the brine and ocean water. Energy requirements for the different disposal methods vary.

3) UTILITY WASTEWATER TREATMENT

Debris, organic solids and pathogens found in wastewater, if left untreated, can pose threats to public health. Wastewater systems collect wastewater from dischargers and transport flows to treatment plants where it is treated to conditions suitable for disposal or reuse. Figure 3 shows the typical wastewater treatment process.

a) Wastewater Treatment Cycle

i) Collection

To the extent possible, wastewater systems rely on gravity flow to transport flows from consumers to treatment plants. In areas where the topography does not allow for gravity flow, pump stations and pressurized pipelines, also called force mains, are used to lift flows to higher elevations. Wastewater pumps are inherently more inefficient than water booster pumps as they are required to pump both liquids and solids.

In rural regions where there is no nearby municipal wastewater system, individual wastewater systems (IWS) are used to collect and treat onsite wastewater flows. IWS systems typically consist of a septic tank or household aerobic unit that discharges to a soil absorption system, sand filter or subsurface irrigation system. Construction of cesspools are strictly prohibited as adequate treatment is not provided prior to discharge into the ground. IWS systems are regulated by the DOH to ensure that the system does not adversely affect the underlying aquifer. Since IWS systems are typically gravity fed, no energy consumption is associated with use of this system.

ii) Treatment

Depending on the method of discharge, wastewater is treated to different levels of treatment. At a minimum, wastewater is required to undergo primary treatment. Applications that reuse, or recycle wastewater require secondary and in some cases tertiary treatment depending on the end use.

(1) Prescreening

Prior to primary treatment, incoming wastewater is screened to remove large debris and grit that may block or damage the plant's equipment. Accumulated trash is collected and compacted in hoppers for transport to the landfill or reuse as fertilizer.

(2) Primary Treatment

The majority of wastewater treatment plants in Hawaii provide only primary treatment. After screening, wastewater is pumped into large open air settlement tanks, called clarifiers, to slow the movement of the water. As the water stills, oil and grease float to the top while solids sink to the bottom. Revolving scrapers at the top and bottom of the tank push grease, oils and solids toward the center of the tank where it is collected for further treatment. The resulting water is typically disinfected and discharged into the ocean.

(3) Secondary Treatment

While primary treatment treats the physical properties of wastewater, secondary treatment changes the biological features of the water. Secondary treatment is used to remove the organic material still remaining after primary treatment. Primary effluent is pumped through a series of aeration tanks filled with bacteria and other microbes. Air is pumped into the tanks to breakdown pollutants more quickly and prompt the microbes to consume the remaining organic materials and nutrients. The water and microbes are then placed into a secondary settling tank where microbes clump together and settle to the bottom of the tank. Some of the settled sludge is recirculated back into the aeration tanks for additional use; the rest of the sludge is removed and further treated.

Depending on the level of disinfection, effluent from secondary treatment can produce R-3 or R-2 recycled water. R-3 is secondary treated recycled water that is not disinfected. Permitted uses of R-3 include surface, drip or subsurface irrigation for crops or feed that will not be consumed by humans. R-2 is disinfected secondary treated recycled water, suitable for subsurface irrigation applications including golf courses, vineyards and orchards, landscape and turf on parks, elementary schools and pastures. Restrictions on the use of R-3 and R-2 are outlined in DOH's Guidelines for the Treatment and Use of Recycled Water.

Effluent from secondary treatment can also be further treated through reverse osmosis to produce R-O water. Reverse osmosis removes dissolved solids, bacteria, organic pollutants, viruses and other dissolved contaminants from the water. R-O water is suitable for industrial processes and above surface irrigation.

(4) Tertiary Treatment

Tertiary treatment is used to produce R-1, a higher quality wastewater effluent that can be recycled and reused for non-potable uses. Advance treatments such as sand or disc filtering and ultraviolet disinfection is used to remove up to 95 percent of suspended materials. R-1 water can be used for spray irrigation without restrictions.

(5) Disinfection

After treatment, wastewater is disinfected to kill any remaining bacteria. Chlorine and UV disinfection is used to produce effluent that is suitable for discharge into public waterways.

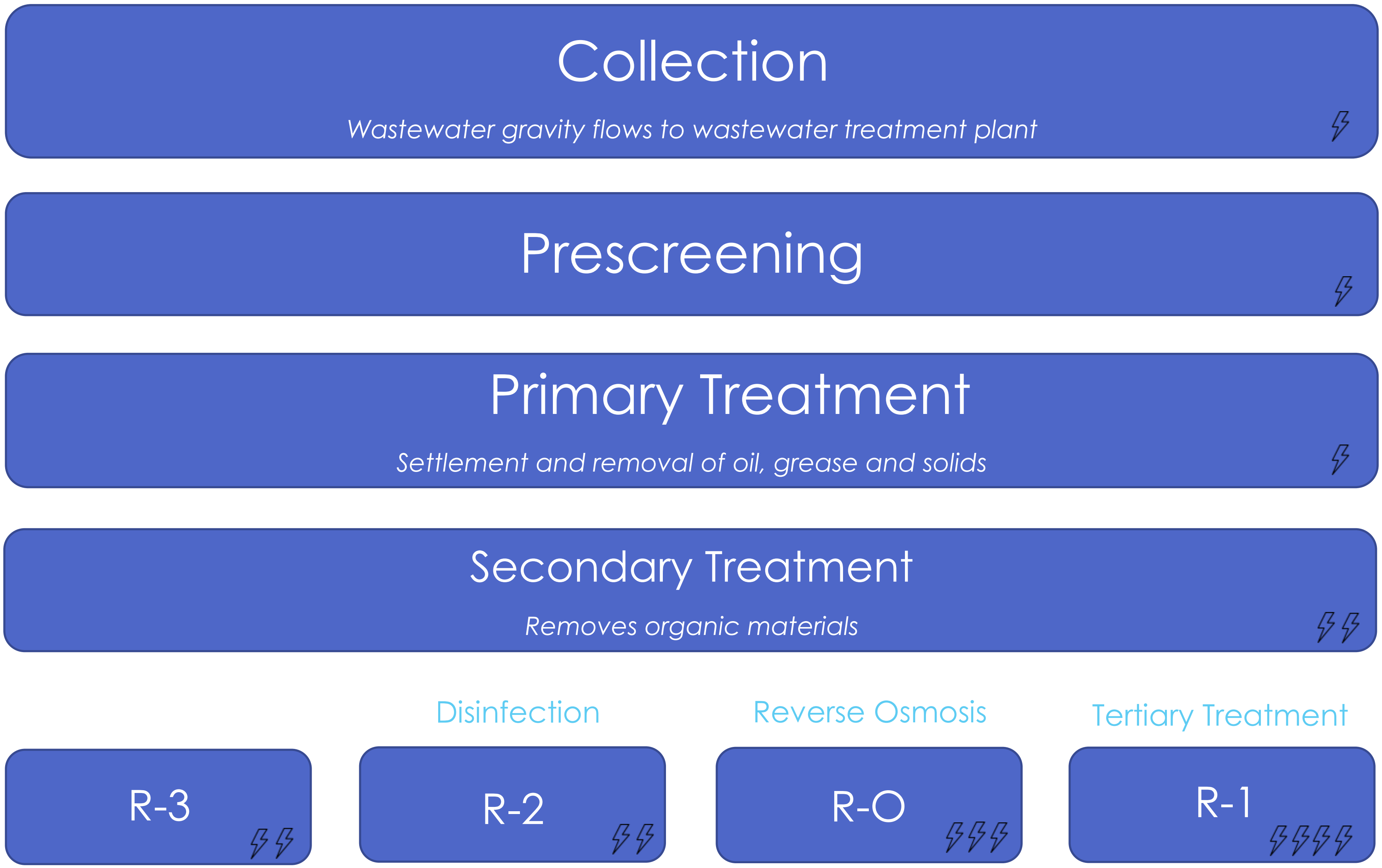


Figure 3. Typical Wastewater Treatment Process

iii) Disposal

(1) Wastewater Effluent

Under the Clean Water Act of 1972, treated water can be discharged to the ocean, reservoir or underground injection well. Most of Hawaii's treated effluent is pumped into the ocean or injected underground via gravity.

The sludge collected from primary and secondary treatment is placed in thickening tanks for up to 24 hours to settle and separate from water. The remaining sludge is placed in oxygen free tanks and heated to at least 95 degrees Fahrenheit for 15 to 20 days. During this process the material is converted into water, carbon dioxide, methane gas and digested sludge. The digested sludge is then pumped to a dewatering facility, where water is removed to produce biosolids. The remaining biosolids can be used as fertilizer or to generate methane for electricity production, or hauled to landfills for disposal.

(2) Recycled Water

Recycled water is distributed to recycled water users via a separate recycled water piped system. Infrastructure for recycled water systems is currently limited to areas where recycled water is being produced. Applications for recycled water in Hawaii include irrigation for landscaping, farms, golf courses and schools and dust control for construction activities.

b) Wastewater Energy Use

Energy is used to transport, treat and dispose of wastewater.

- Collection
  Energy used to convey flows from the customer to the treatment facility is dependent on the topography and age of the system. Where feasible, gravity mains are used to minimize energy use. Force mains and pump stations use energy to lift flows to higher elevations. As expected, more energy is required to lift flows to greater heights.

  Energy use is also proportional to the amount of wastewater conveyed through the system. It takes more energy to transport, treat and dispose of larger quantities of wastewater. During rain events, stormwater can infiltrate into wastewater systems via cracks, joints and leaks in pipes and manholes. This results in increased flows and higher energy consumption during the winter months when rainfall events are frequent.

- Treatment
  The amount of energy used to treat wastewater is dependent on the level of treatment and system processes. More energy is required for higher levels of treatment, as processes are more energy intensive. Primary treatment has the lowest energy use with tertiary treatment at the highest. Advances in technology are providing options for more energy efficient system components and overall energy savings.

- Disposal
  Energy costs associated with disposal is dependent on the method of disposal. Disposal of wastewater effluent to nearby ocean outfalls or via underground injection requires minimal amounts of energy. In comparison, disposal of wastewater effluent requires less energy than the distribution of recycled water. Similar to water distribution, more energy is required to pump recycled water to further distances and higher elevations.

4) UTILITY ENERGY PRODUCTION

a) Type of Energy Production

i) Fossil Fuels

Fossil fuels are presently the most commonly used sources of energy in Hawaii. Fossil fuels, derived from the remains of animals and plants from millions of years ago, cannot be easily created and are considered to be diminishing resources. The three major types of fossil fuels are coal, petroleum, and natural gas.

- Coal –Coal is found in underground and surface mines. After mining, coal is cleaned and shipped to power plants, where it is burned to heat water in boilers to create steam. The steam is used to power turbines, which in turns powers generators and creates electricity. After the steam passes through the turbine, it is drawn into a condenser and converted back into water. The water is then returned back to the boiler for reuse. A concern with the use of coal power plants is the emission of harmful chemicals. Coal power plants produce carbon dioxide and sulfur emissions, which can react with oxygen to produce sulfur dioxide or water to produce acid rain. Figure 4 shows the typical electrical production process for coal.

- Petroleum –Petroleum from crude oil is the largest source of energy used in Hawaii. Crude oil is found in deep underground pockets of porous rock, which requires drilling for extraction. After oil is drilled, it is pumped to the surface and transported to oil refineries for processing. Oil is piped through hot furnaces to create liquids and vapors. The resulting liquids and vapors are separated by weight and boiling point into petroleum components, called fractions. The lightest fractions are condensed and used for gasoline and liquid petroleum gas. Heavier fractions are further processed and converted into lighter products, such as gasoline or kerosene. Additional treatment is required to achieve various octane levels, vapor pressures and special properties for uses in extreme environments.

- Natural Gas – Hawaii uses limited quantities of natural gas to produce electricity. Natural gas is trapped in deep underground pockets of porous rock. In order to access the gas, the rock needs to be drilled. Natural gas produced at the wellhead contains contaminants and impurities, which need to be processed and removed to produce dry natural gas. The gas is then compressed and stored. Electricity is generated by burning natural gas to produce hot gas used to power turbines.

ii) Renewable Energy

In an effort to reduce its dependence on imported oil, Hawaii has undertaken a clean energy initiative to achieve 100 percent renewable energy for electricity by 2045. There are currently 60 renewable energy projects throughout the State. Renewable energy sources currently used throughout Hawaii include biomass, geothermal, hydroelectric, solar, waste-to-energy and wind.

- Biomass –Biomass consists of organic matter such as plants, woods, oils and animal fats and is a readily available resource. Biomass can be heated or gasified to produce steam or gas to power turbines which generate electricity.

- Geothermal – Geothermal energy uses underground reservoirs of steam and hot water produced by volcanic activity. Hot water extracted from the ground is converted into vapor to power steam turbines and generate electricity. Geothermal energy is only produced on the island of Hawaii, which is home to the State's only active volcano.

- Hydroelectric – Hydroelectric power converts the kinetic energy from running water due to a change in elevation into electricity. Water from a river or stream is diverted into reservoirs, where it flows through turbines that rotate and power generators. The electricity produced by the generator is transferred to transmission lines for distribution. After flowing through the turbines, the water is returned back into the river or stream. Water loss due to evaporation within the system is negligible.

- Solar – Solar powered photovoltaics are used to convert sunlight into electricity. When sunlight hits the panels, an electric current is generated. An inverter is used to convert the electric current into energy that is suitable for use. An alternative to the use of photovoltaics is concentrated solar power, which uses lenses or mirrors to focus sunlight into a small beam. Heat from the sunlight is used to power steam turbines and generate electricity.

- Waste-to-energy – Solid waste, or household garbage, can be burned to produce electricity. Solid waste is typically mass burned as it requires minimal processing prior to combustion. Heat from combustion is used to turn water into steam which powers turbine-generators for electricity.

- Wind – Wind is currently the largest source of renewable energy in the State. Wind turbines are used to convert the kinetic energy from wind into electricity. The rotation of the turbine blades turn a turbine shaft which produces electricity. Turbine blades are positioned high above the ground to take advantage of stronger, less turbulent winds.

- Ocean Thermal Energy Conversion (OTEC) – OTEC uses the temperature difference between cold, deep ocean water and the warm top layer of the ocean to generate electric power. The system uses the warm water to vaporize ammonia and power a turbine to generate electricity. The vapor is then cooled by the cold water and condensed back into ammonia to be reused. Aside from electricity production, cold water used by the system can be reused for air conditioning cooling, aquaculture and agriculture. The cold water allows for the growth of plants and farming of cold water sea creatures that are not normally found in Hawaii's subtropic environment. Mostly notably, OTEC can produce fresh water comparable to that from desalination plants. In addition to high upfront investment costs, there are only a handful of locations where OTEC plants can be feasible.

b) Energy Related Water/Wastewater Use

Water is essential for the production of energy from non-renewable sources. Most electric power plants require water to operate. Water is used throughout the various stages of electricity production including fuel extraction, production, processing, transportation and emissions control. The largest use of water by electrical power plants is cooling. Similarly, biomass, geothermal and waste-to energy renewable energy facilities also require water for cooling.

There are three types of cooling systems: closed loop, once-through, and dry-cooling systems.

- *Closed loop cooling systems* withdraw limited amounts of water as it reuses the water throughout the system. Additional water is only withdrawn to make up any water that is lost through evaporation. Due to operational costs, once-through cooling systems are more common.
- *Once-through systems* circulate water through the pipes and discharge it back to the source. With the once-through system, water is continually withdrawn.
- *Dry-cooling systems* use air instead of water to cool the steam that powers the turbine. Plants that use dry-cooling systems have higher costs and lower production efficiencies.

Hydroelectric facilities are dependent on water to produce electricity. Without water, these facilities cannot run. Although these facilities withdraw water from streams and lakes, the water used by the facility is returned back to its original source. No water is required for the production of solar and wind energy.

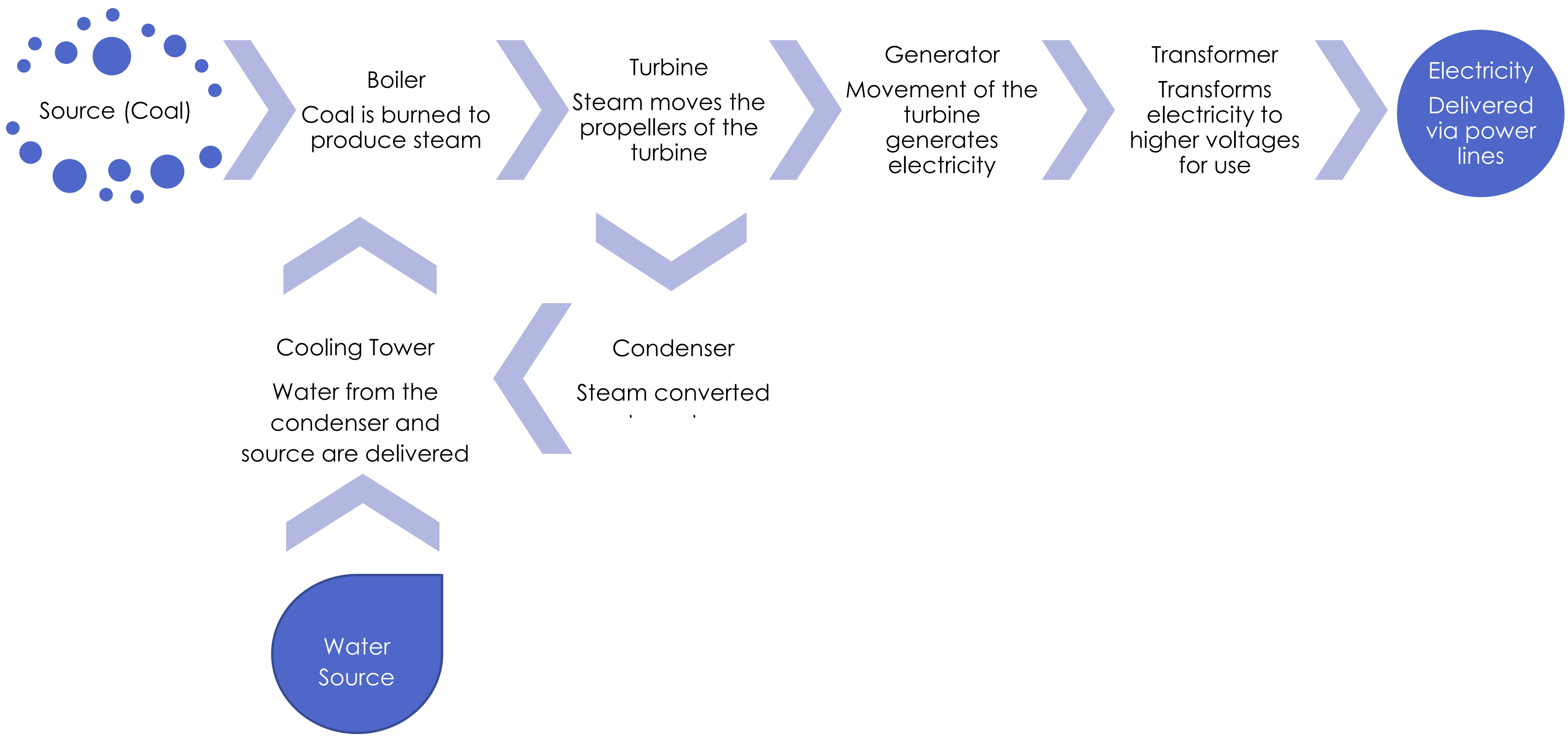


Figure 4. Electrical Production from Fossil Fuel

5) ENERGY INTENSITY

The efficiency of energy consumption for water production or wastewater treatment can be measured by its energy intensity. Energy intensity is the amount of energy used for a particular unit of work and is represented as the amount of energy used to collect, treat and distribute 1,000 gallons of water (kWh/kgal).

$$Energy\ Intensity\ (kWh/kgal) = \frac{Total\ Energy\ Consumption(kWh)}{Total\ Water\ Use\ (kgal)} \qquad (1)$$

Energy intensity, as calculated by Equation (1), will be used in this study to compare the relative energy values of different types of utility systems throughout Hawaii. Comparing the intensities of similarly characterized systems will help to illustrate the water energy relationship and allow utilities to gauge their system's performance against other systems and identify opportunities for energy and water conservation.

Similarly, for electricity production, the efficiency of water use for energy production can be measured by its water intensity. Water intensity represents the amount of water necessary to produce 1 kilowatt of energy, as shown is Equation (2).

$$Water\ Intensity\ (kgal/kWh) = \frac{Total\ Water\ Use\ (kgal)}{Total\ Energy\ Production\ (kWh)} \qquad (2)$$

Another indicator of energy use is marginal cost. Marginal cost is the cost to use or produce a unit of water, represented by Equation (3). Evaluation of the marginal cost will help utilities to better understand the energy use and associated cost of their system.

$$Marginal\ Cost\ (\$/kgal) = \frac{Total\ Energy\ Cost\ (\$)}{Total\ Water\ Use\ (kgal)} \qquad (3)$$

The data presented in this report is intended to be used as a baseline to characterize the water energy relationship. The information presented can be used for future studies as a benchmark to track the results of water conservation and energy efficiency efforts.

6) SURVEY DATA COLLECTION

In an effort to understand water and energy use in Hawaii, survey questionnaires were distributed to both municipal and private water, wastewater, electrical and renewable energy utilities across the State. Copies of the surveys can be found in Appendix A. The intent of the survey was to characterize and compare the water and energy use for the operation of the various utilities over the 2014 and 2015 calendar years. Entities were identified based on registration with the Public Utilities Commission (PUC), DOH, and/or the Commission. Systems requiring little to no energy or water use, such as individual wastewater systems, wind farms and solar fields, were exempt from the study. Participation in the study was voluntary. All data collected through this study is anonymous and has been consolidated by system characteristics to characterize the different utility industries throughout the State.

A total of 137 utilities companies were identified and contacted for participation in the study. A list of all the contacted utilities can be found in Appendix B. Due to a lack of readily available records, manpower and/or time, not all companies who responded to the survey participated in the study. Thirty nine municipal and private utilities participated in the study, as detailed in Table 4.

Table 4. Summary of Survey Responses

Industry	No. of Surveys Sent	No. of Responses	No. of Participants
Water	68	29	23
Wastewater	24	15	6
Recycled Water	19	9	3
Electrical	26	11	7
Total	*137*	*64*	*39*

7) METHODOLOGY

a) Compiling Data

All data was self-reported. Follow up coordination to confirm data discrepancies and omissions was conducted. In cases where the discrepancies and omissions could not be rectified, data outliers were removed. In an attempt to more accurately quantity the water energy relationship, where feasible, the remaining data was interpolated, based on the average values of the available data, to determine a reasonable value for the missing data attributed to outliers.

Collected information included monthly and/or annual water pumpage, energy consumption and production data, and electricity and water costs. Due to limitations in available records and resources, information for both the 2014 and 2015 calendar year was not readily available for all participating utilities. Attempts were made to obtain a least one year of complete data from each utility. As a result, the data presented herein cannot be compared chronologically as the number of participants and the participating companies vary between years. In addition, electrical rates decreased between 2014 and 2015. Any cost information presented cannot be compared between the years as rate decreases may not be unilateral or uniform amongst all utilities.

Since billing periods typically do not correspond to whole calendar months, monthly bills and meter readings were prorated for the calendar month and annualized for the 2014 and 2015 calendar years. Where feasible, water use and energy consumption data was compiled by individual water system, wastewater treatment plant, recycling facility or energy facility.

Additional limitations and methodology for compiling the reported data, specific to each industry, are discussed in its respective section.

b) Identifying Trends

No two systems, treatment plants or facilities are the same; each has varying conditions and characteristics (i.e. service population, equipment, layout, miles of piping, etc.) To accurately represent the water energy relationship of utilities throughout the State, where feasible, the energy/water intensities and marginal costs were calculated for each system, plant and facility. Since utility companies many have varying types of systems and facilities within their portfolio, representing each system as a separate entity more accurately characterizes the operations of the utility; aggregating the data by utility may misrepresent the true water energy relationship.

To identify trends in water and energy use, the data was organized by system characteristics such as location (island), utility type (municipal versus private) and water source. For each subset, the average energy/water intensities were based on the energy/water intensities of each system within the subset, rather than the total water and energy use of the subset. Minimum and maximum values were reported to provide the range of energy/water intensity values for the subset.

Due to limitations in data, further analysis of the water energy relationship for detailed analyses such as different methods of treatment technologies, seasonal use, pumping distances, isolated water sources, etc. are not available at this time. Additional studies further evaluating the intricacies of each system should be completed to further understand the water energy relationship in utilities.

8) WATER SYSTEMS IN HAWAII

Out of all of the industries, the water industry had the highest participation, with 23 utilities participating in the study. Data for 2014 was provided by 23 utilities representing 65 water systems. Meanwhile, data for 2015 was provided by 19 utilities representing 45 water systems.

For the purposes of the study, water consumption was based on well pumpage and stream diversion data, and does not account for water losses throughout the system. Water losses contribute to excess energy consumption from pumping as additional water is required to replace the water that is lost. By analyzing the energy intensity for well pumpage instead of water delivered to customers, the energy intensity reflects the true cost of water production to the utility. To check for accuracy in reporting, the water consumption data reported by the utility was compared to the Commission's well reporting pumping records. Discrepancies in the data were resolved with the individual utility.

To the extent practicable, the energy use of each major component of the system (i.e. pump station, booster pump, etc.) was taken into account to show an accurate representation of the total cost of the entire system. Detailed information regarding energy use at each stage of the water cycle was not available. The energy use presented in the study was limited to the operations of the water system infrastructure and does not include the energy use for operation of buildings and offices.

There are rural areas in Hawaii that rely on rain water catchment systems to provide potable water, as there are no wells or surface water supplies in the area. Residents in these areas rely on rainfall to fulfill their water needs. To be considered safe for consumption, catchment water is minimally treated with chemical additions. In other areas, such as Pohakuloa on the island of Hawaii, where there is no water system and water catchment is not feasible due to the regional climate, potable water is trucked in and stored in reservoirs. Because these systems do not collect and distribute water conventionally, they were exempt from the study.

Figures 5 and 6 depict the total annual water use by water utilities plotted against their respective energy intensities. The data is organized by increasing water use. As shown by the data, there is no linear relationship between volume of water and energy use, suggesting that multiple factors influence energy use. However, the data shows that in 2014 the five utilities with the highest annual water use had energy intensities near or below 5 kwh/kgal, and some of the utilities with the lowest annual water use had the highest energy intensities. To understand the energy use of water utilities, data was organized by island, municipal vs private, population, water source and well depth.

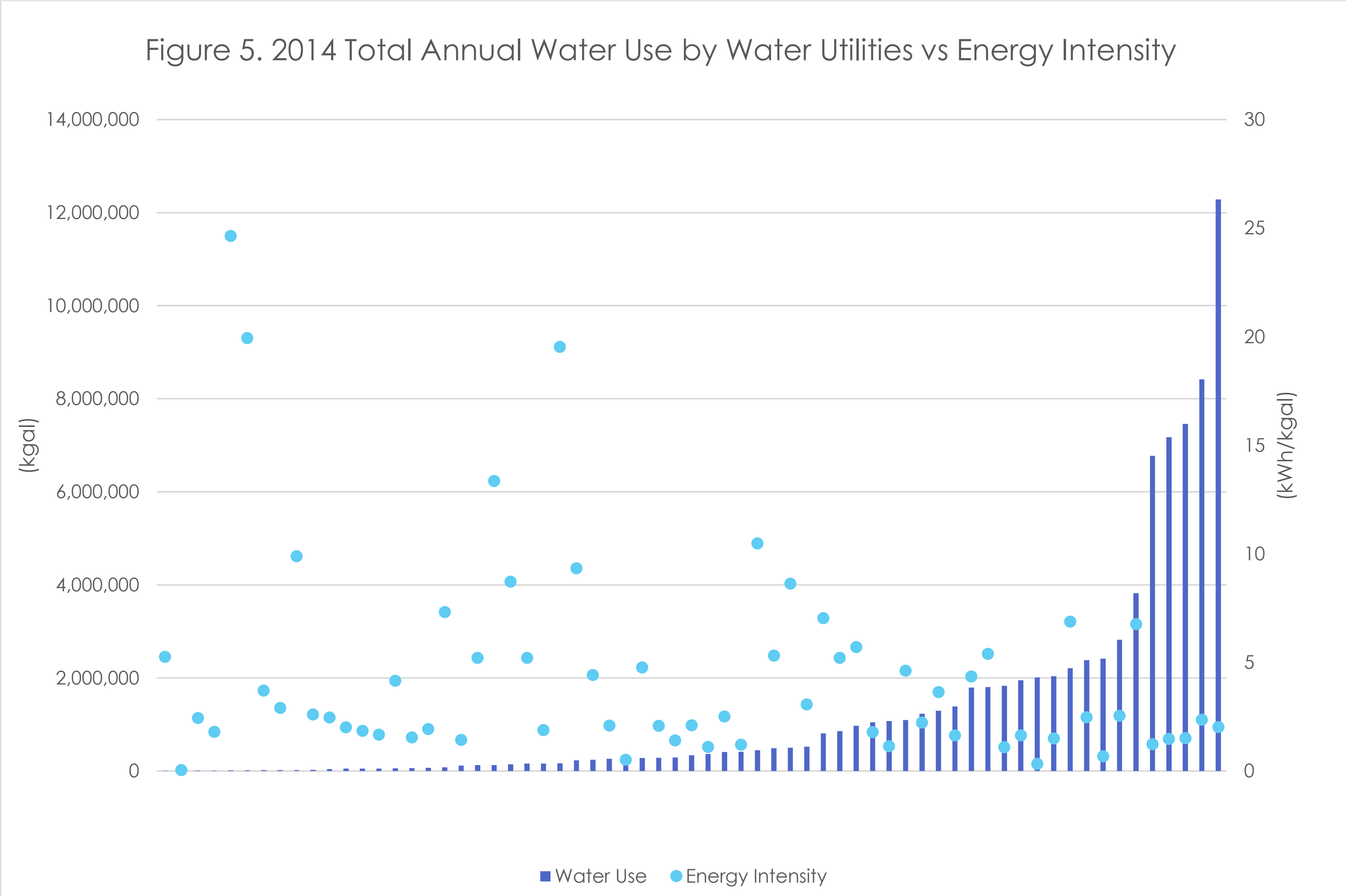
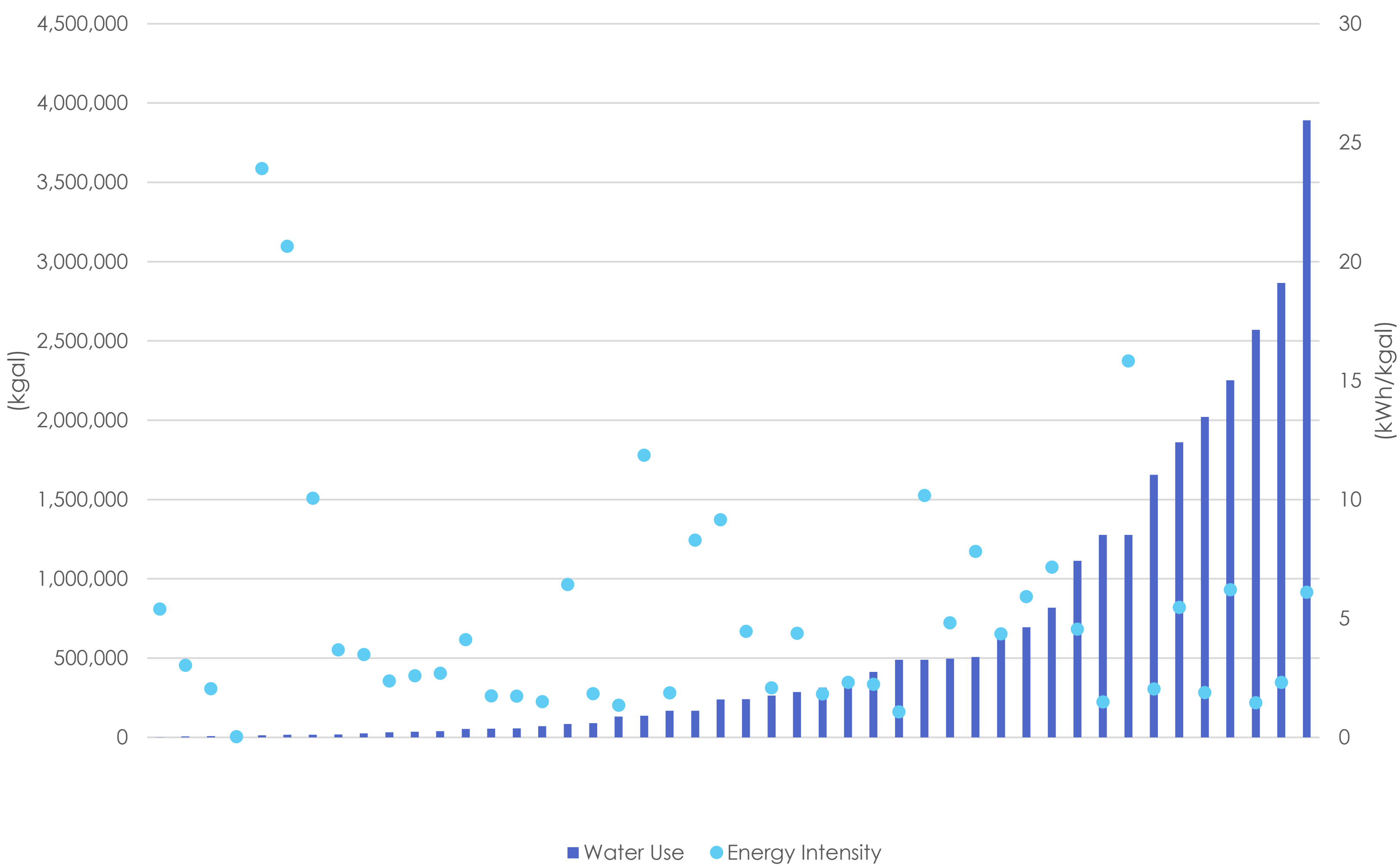


Figure 5. 2014 Total Annual Water Use by Water Utilities vs Energy Intensity
14,000,000
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
0
(kgal)
30
25
20
15
10
5
0
(kWh/kgal)
Water Use
Energy Intensity

Figure 6. 2015 Total Annual Water Use by Water Utilities vs Energy Intensity



a) By Island

Depending on their location, utility costs can vary between islands and towns. To determine if there are any differences between water and energy use for the different islands, Figures 7 through 14 shows the breakdown of water and energy use by island. Table 5 summarizes the number of systems on each island. There is no data available for water systems on Lanai.

Table 5. Number of System Representing Each Island

Island	**2014**	**2015**
Hawaii	17	17
Kauai	9	9
Maui	13	13
Molokai	4	4
Oahu	22	4
Total	*65*	*47*

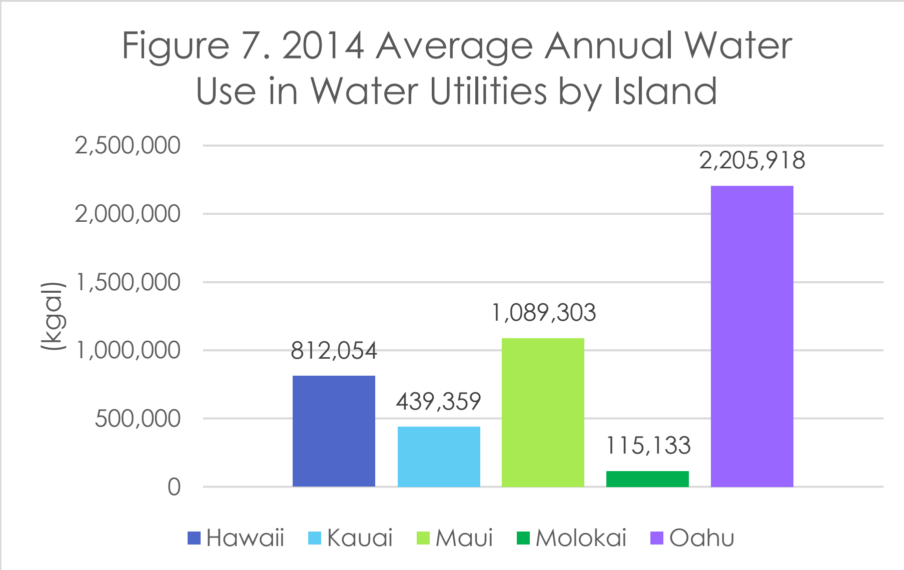


Figure 7. 2014 Average Annual Water Use in Water Utilities by Island
(kgal)
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
812,054
439,359
1,089,303
115,133
2,205,918
Hawaii
Kauai
Maui
Molokai
Oahu

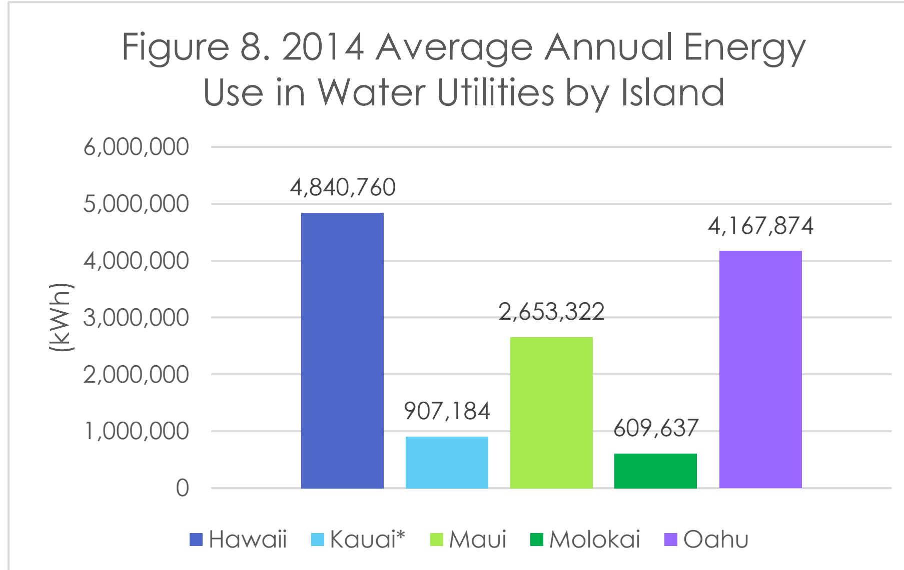


Figure 8. 2014 Average Annual Energy Use in Water Utilities by Island
(kWh)
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
4,840,760
907,184
2,653,322
609,637
4,167,874
Hawaii
Kauai*
Maui
Molokai
Oahu

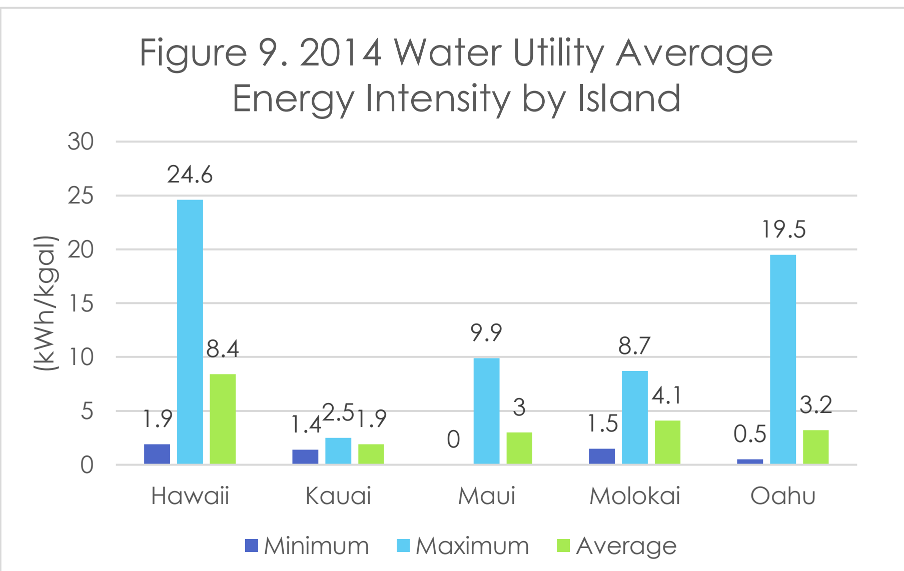


Figure 9. 2014 Water Utility Average Energy Intensity by Island
(kWh/kgal)
30
25
20
15
10
5
0
1.9
24.6
8.4
1.4
2.5
1.9
0
9.9
3
1.5
8.7
4.1
0.5
19.5
3.2
Hawaii
Kauai
Maui
Molokai
Oahu
Minimum
Maximum
Average

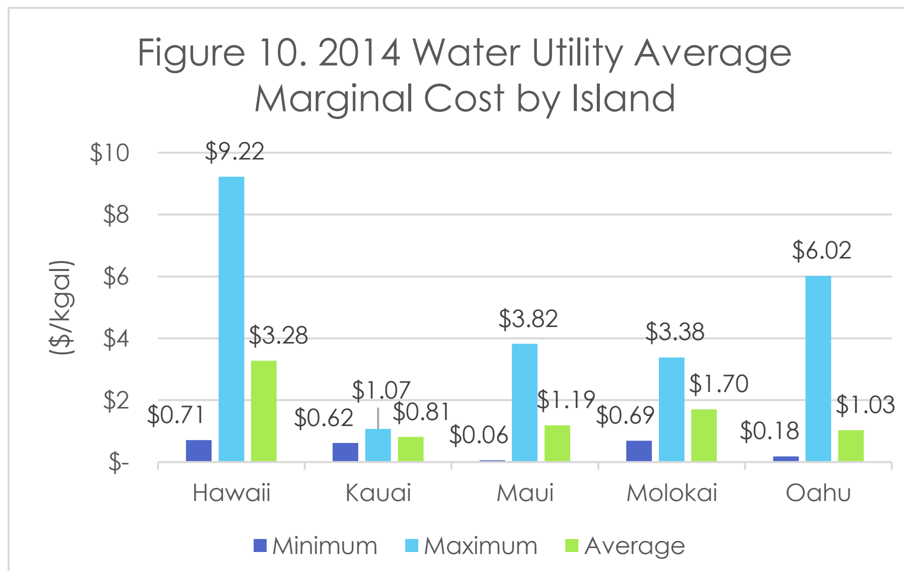


Figure 10. 2014 Water Utility Average Marginal Cost by Island
($/kgal)
$10
$8
$6
$4
$2
$-
$0.71
$9.22
$3.28
$0.62
$1.07
$0.81
$0.06
$3.82
$1.19
$0.69
$3.38
$1.70
$0.18
$6.02
$1.03
Hawaii
Kauai
Maui
Molokai
Oahu
Minimum
Maximum
Average

Figure 11. 2015 Average Annual Water Use in Water Utilities by Island

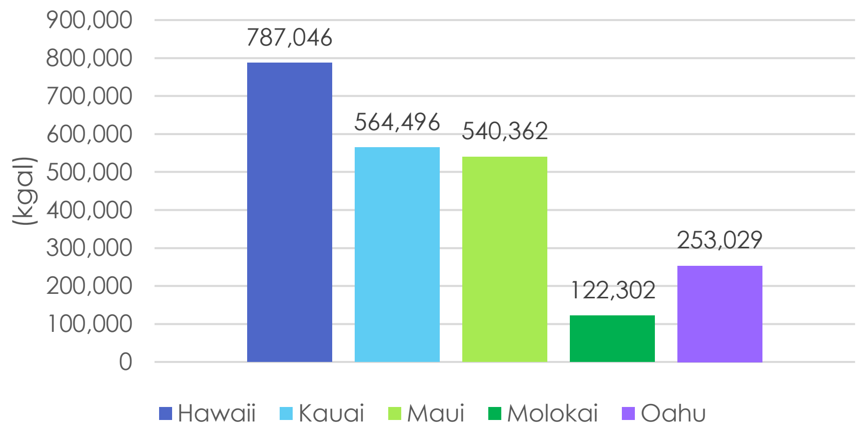


Figure 12. 2015 Average Annual Energy Use in Water Utilities by Island

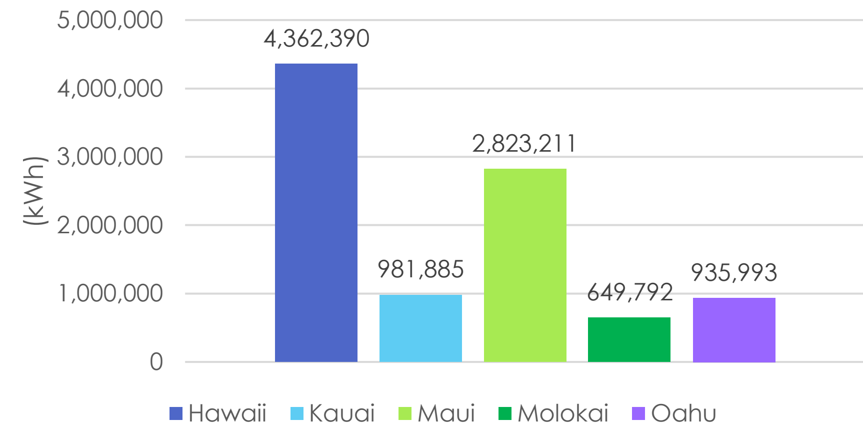


Figure 13. 2015 Water Utility Average Energy Intensity by Island

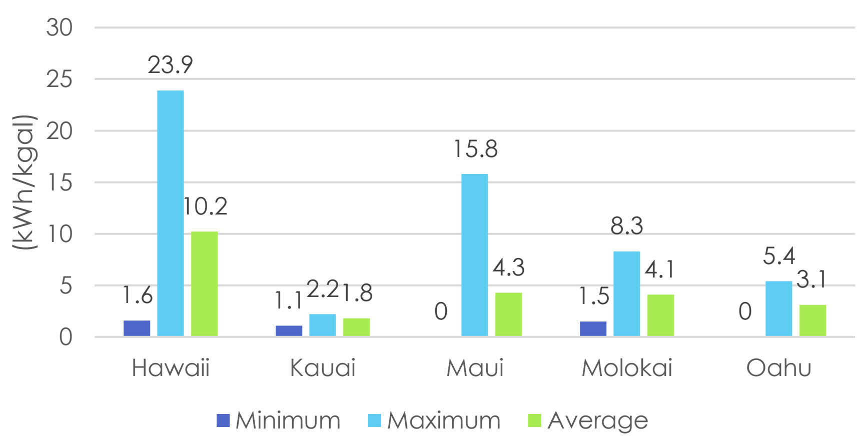
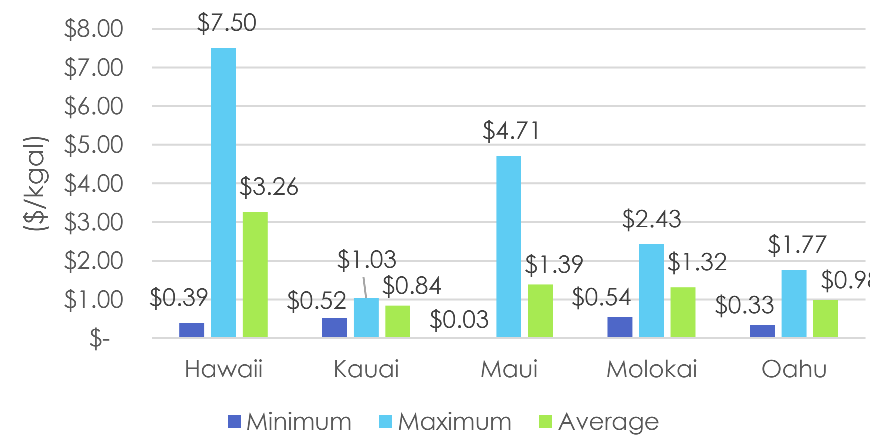


Figure 14. 2015 Water Utility Average Marginal Cost by Island



In general, water systems on Kauai had the lowest average energy intensity (1.8 & 1.9 kWh/kgal) and marginal cost ($0.81 & 0.84/kgal) in both 2014 and 2015. Meanwhile, water systems on Hawaii Island had the highest average energy intensity (8.4 & 10.2 kWh/kgal) and marginal cost ($3.28 & $3.26/kgal). As shown in Figures 7 to 10, the high energy intensity and marginal cost for Hawaii Island, correlates to systems with high energy use but relatively low water use, suggesting system inefficiencies. This could also be associated with system operations that require extensive amounts of energy for collection or distribution such as pumping deep wells or pumping to high elevations and elevated reservoirs.

There is no trend amongst marginal costs between Oahu and the neighbor islands.

b) Municipal vs Private

As shown in Figures 15 to 18, private water systems have higher energy intensities and marginal costs than municipal systems. In 2014, the average intensity for a municipal water system was 3.4 kWh/kgal compared to 6.6 kWh/kgal for private water systems. This results in a cost differential of $1.38 per 1,000 gallons of water used.

The higher energy intensities could be attributed to the layout of private water systems. Private water systems typically service smaller, rural areas that are less densely populated. Although the system may only service a handful of customers, the infrastructure needed to service those customers may be expansive and require more piping and booster pumps than a municipal system with the same number of customers. Since more energy is required to distribute water to further distances and to higher elevations, the energy intensities for those systems are higher. The higher energy intensities could also be due to energy inefficiencies. Private water systems may not have the available resources to identify and rectify system inefficiencies and leaks within their system.

Figure 15. 2014 Average Energy Intensity: Municipal vs Private Water Systems

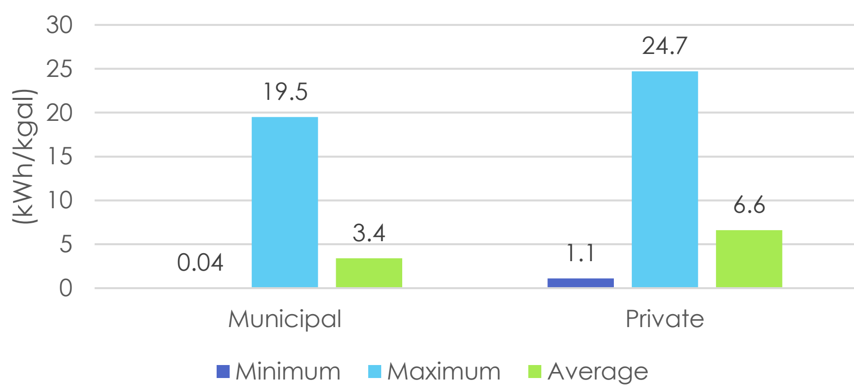


Figure 16. 2014 Average Marginal Cost: Municipal vs Private Water Systems

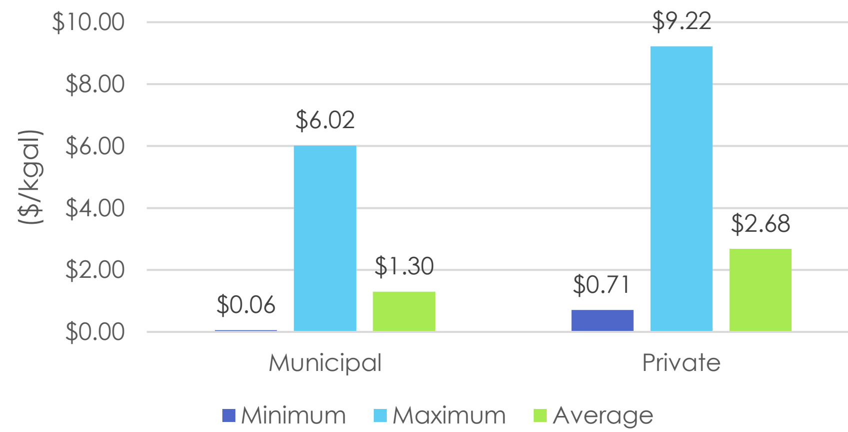


Figure 17. 2015 Average Energy Intensity: Municipal vs Private Water Systems

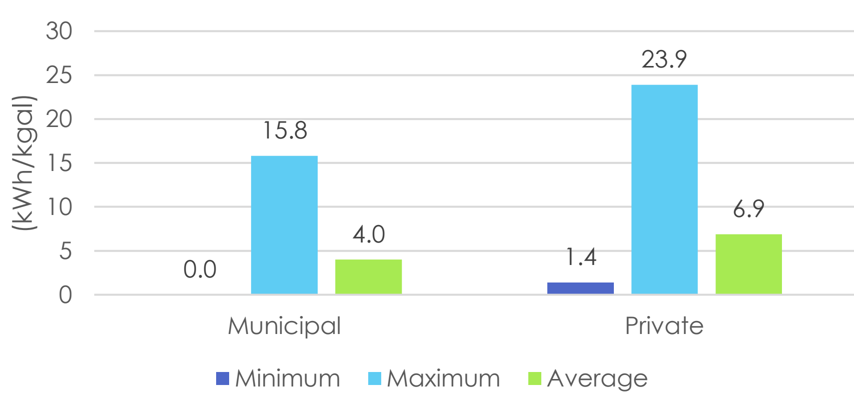
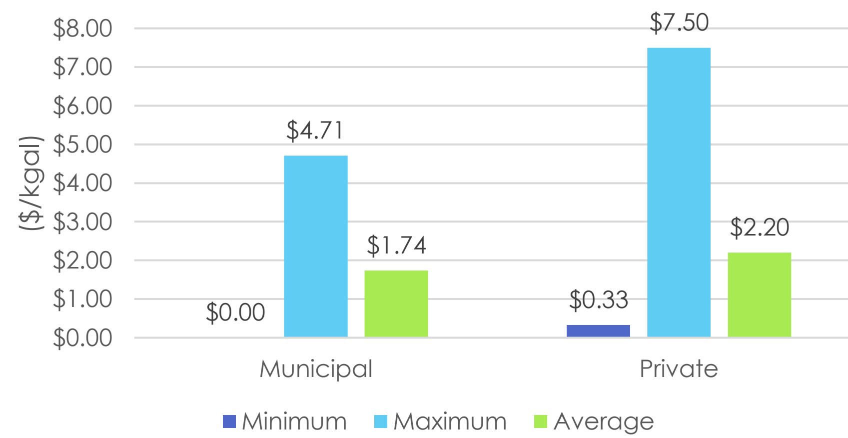


Figure 18. 2015 Average Marginal Cost: Municipal vs Private Water Systems



c) Population

The service populations of water systems in Hawaii range from less than 50 to nearly 270,000 people. To determine if there is a correlation between service population and water and energy use, the data was classified by population ranges. Systems that service less than 10,000 people are classified as small or rural water systems.

As shown in Tables 6 and 8 and Figures 20 and 23, in general, energy intensity decreased as population increased. Smaller systems tend to lack the resources that enable large systems to regularly maintain and regulate their system. As a result, the high energy intensities of small systems could be representative of system inefficiencies. There is a slight increase in energy intensities between the less than 1,000 and 1,000 to 10,000 thresholds for Maui and Molokai. This could be due to the range of energy intensity values.

Figure 19. 2014 Total Annual Water Use in Water Utilities by Service Population (kgal)

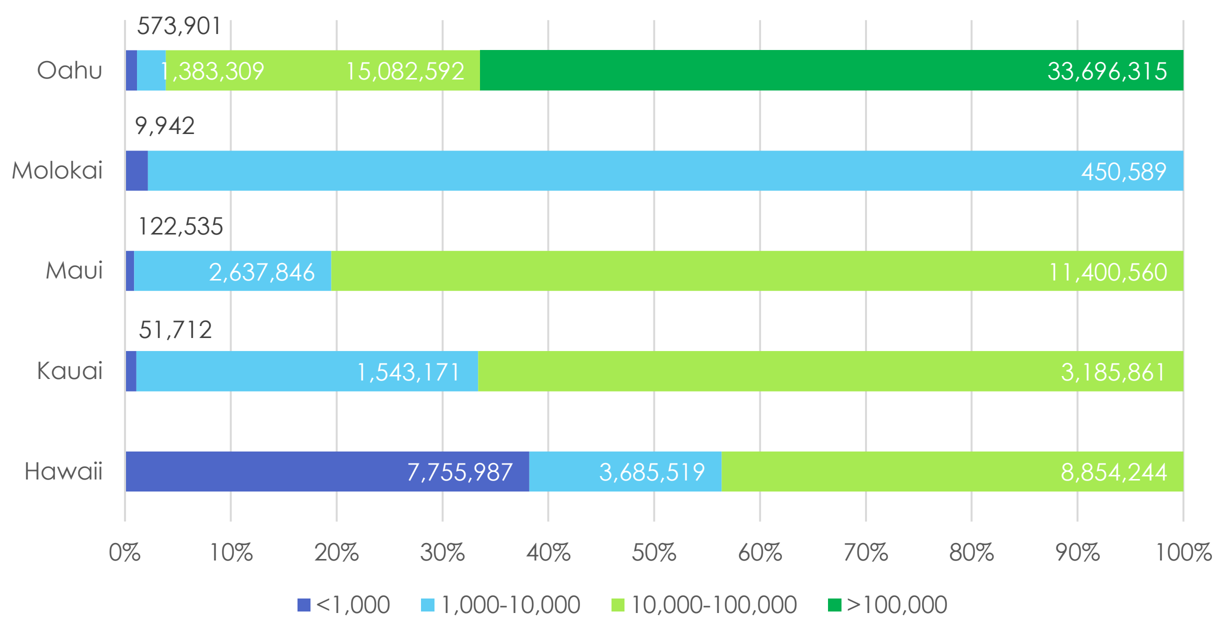


Figure 20. 2014 Water Utility Average Energy Intensity by Service Population

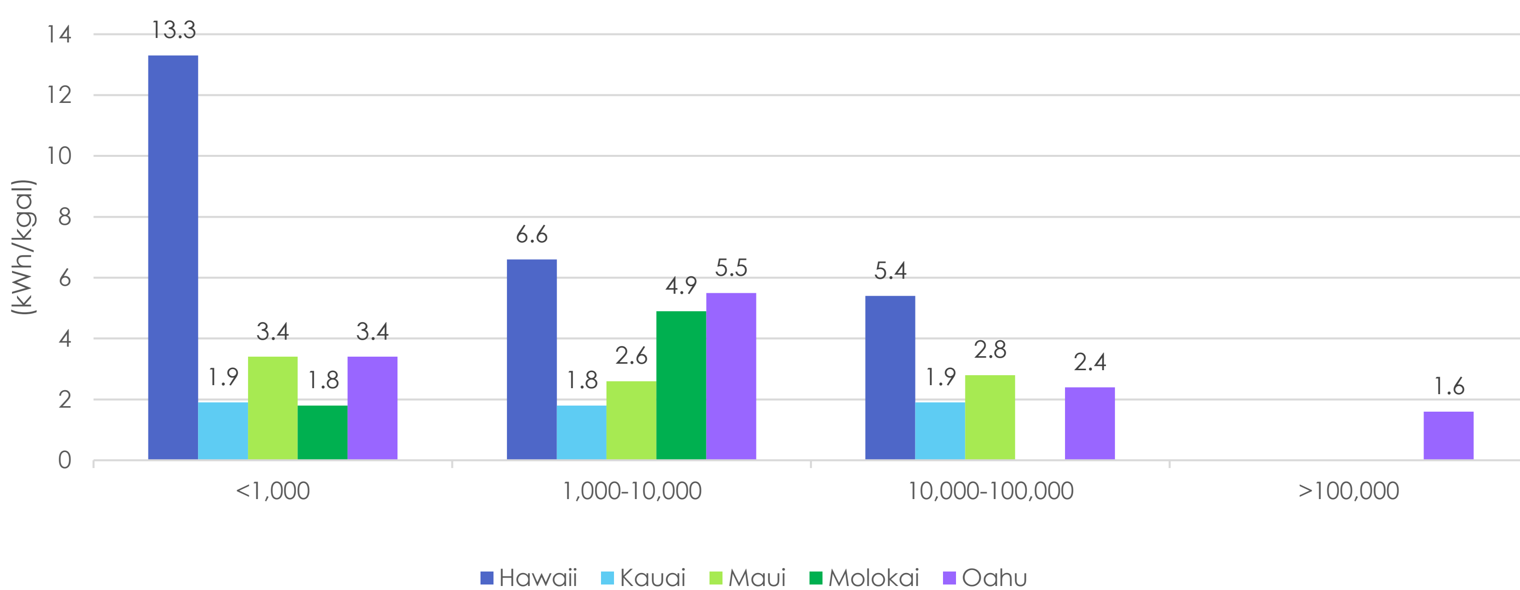


Table 6. Range of 2014 Average Energy Intensity Values in Water Utilities by Population (kWh/kgal)

Island	<1,000	1,000-10,000	10,000-100,000	>100,000
Hawaii	1.9 - 24.6 *(5)*	3.7 – 13.4 *(9)*	2.6 – 6.9 *(3)*	
Kauai	1.9 *(1)*	1.2 – 2.5 *(6)*	1.6 – 2.2 *(2)*	
Maui	0.0 – 9.9 *(6)*	1.8 – 4.6 *(4)*	0.3 – 5.7 *(3)*	
Molokai	1.8 *(1)*	1.5 – 8.7 *(3)*		
Oahu	2.0 – 5.3 *(3)*	0.5 – 19.5 *(6)*	0.7 – 5.2 *(9)*	1.2 – 2.0 *(4)*

(X) Represents the number of systems within the specified range

Figure 21. 2014 Water Utility Average Marginal Cost by Service Population

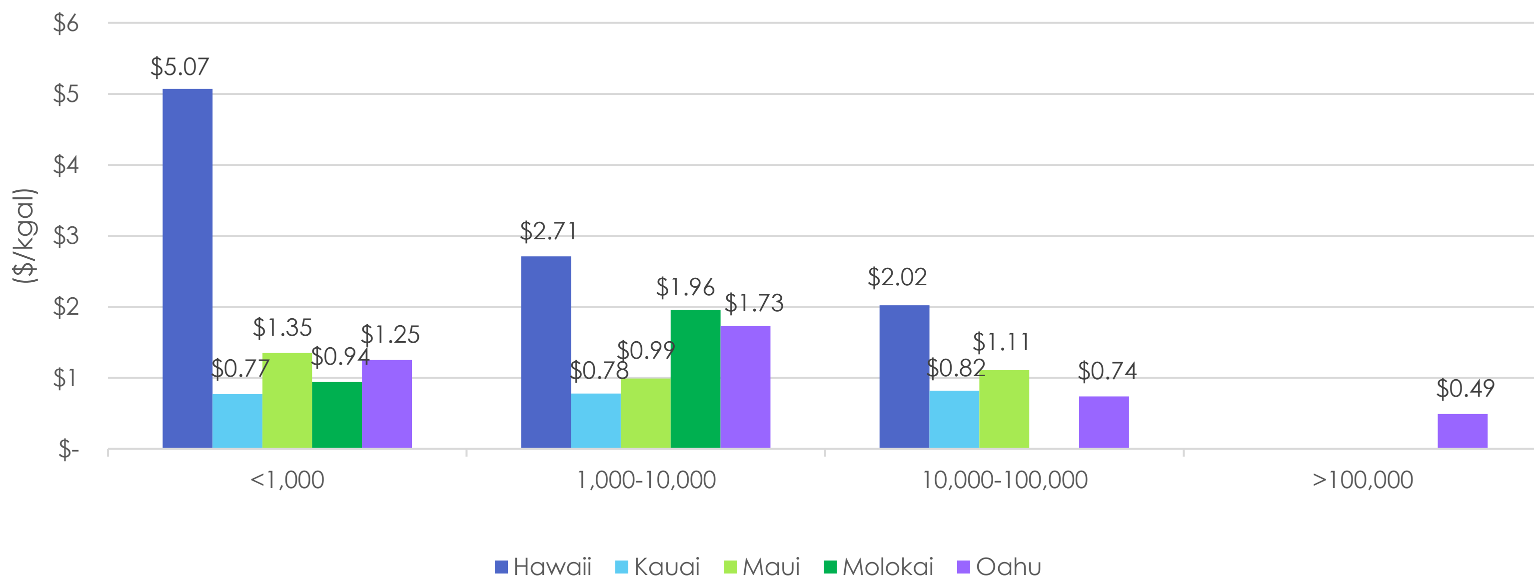


Table 7. Range of 2014 Average Marginal Costs in Water Utilities by Population ($/kgal)

Island	<1,000	1,000-10,000	10,000-100,000	>100,000
Hawaii	$0.71 - $9.22 *(5)*	$1.80 - $5.70 *(9)*	$0.96 - $2.58 *(3)*	
Kauai	$0.77 *(1)*	$0.50 - $1.07 *(6)*	$0.66 - $0.98 *(2)*	
Maui	$0.06 - $3.82 *(6)*	$0.69 - $1.73 *(4)*	$0.13 - $2.36 *(3)*	
Molokai	$0.94 *(1)*	$0.69 - $3.38 *(3)*		
Oahu	$0.74 - $2.18 *(3)*	$0.18 - $6.02 *(6)*	$0.23 - $1.64 (9)	$0.38 - $0.64 *(4)*

(X) Represents the number of systems within the specified range

Figure 22. 2015 Total Annual Water Use in Water Utilities by Service Population (kgal)

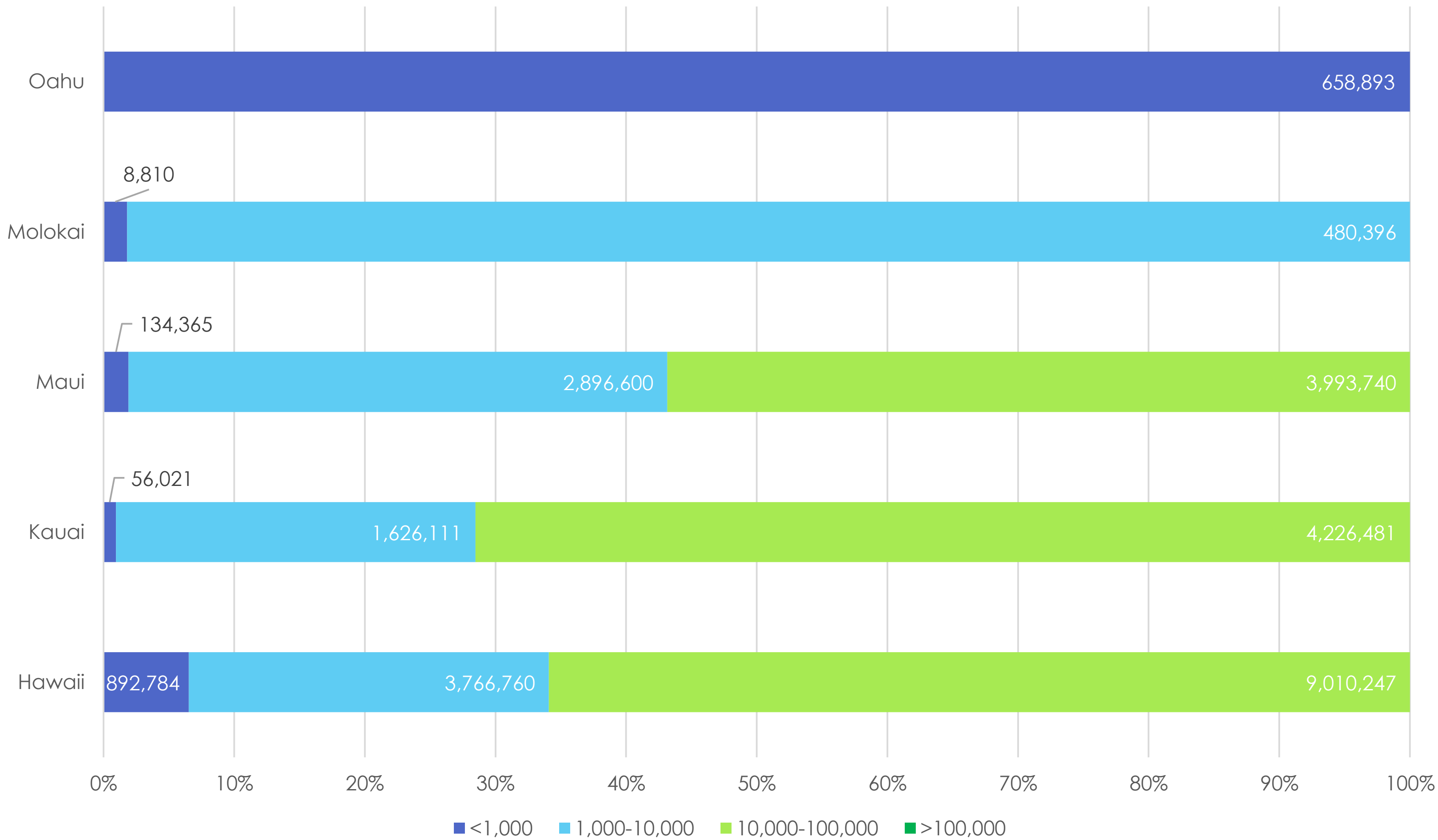


Figure 23. 2015 Water Utility Average Energy Intensity by Service Population

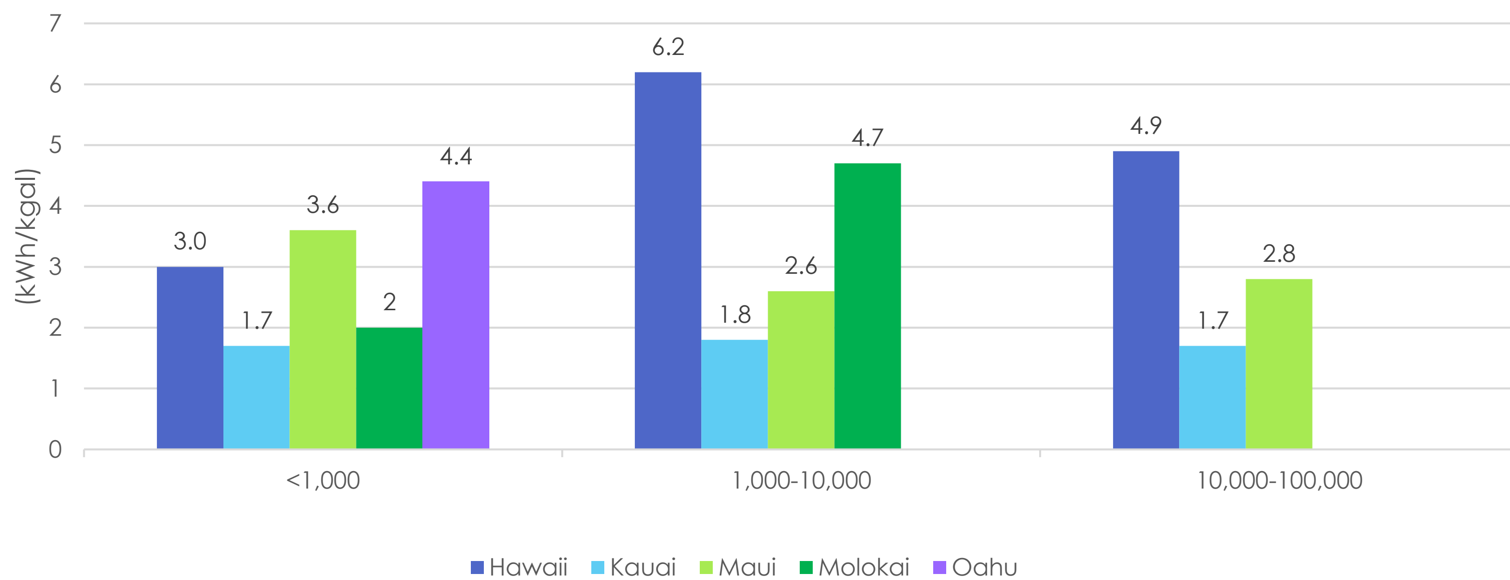


Table 8. Range of 2015 Average Energy Intensities in Water Utilities by Population (kWh/kgal)

Island	<1,000	1,000 – 10,000	10,000 – 100,000
Hawaii	1.3 - 23.9 *(5)*	3.7 - 11.9 *(9)*	2.3 – 6.2 *(3)*
Kauai	1.7 *(1)*	1.1 - 2.2 *(6)*	1.5 - 2.0 *(2)*
Maui	0.0 – 10.1 *(6)*	1.5 - 4.6 *(4)*	0.0 – 5.7 *(3)*
Molokai	2 *(1)*	1.5 – 8.3 *(3)*	
Oahu	2.6 – 5.4 *(3)*		

(X) Represents the number of systems within the specified range

Figure 24. 2015 Water Utility Average Marginal Cost by Service Population

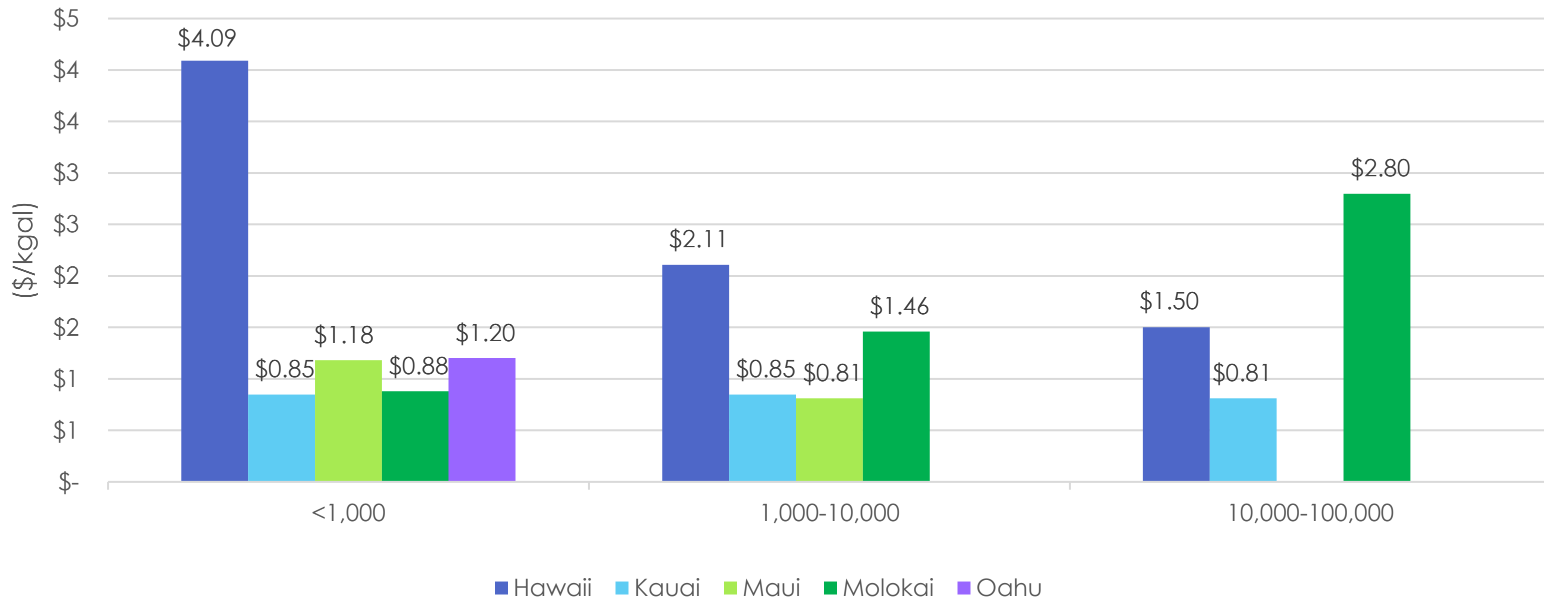


Table 9. Range of 2015 Average Marginal Costs in Water Utilities by Population ($/kgal)

Island	<1,000	1,000-10,000	10,000-100,000
Hawaii	$0.39 - $7.50 *(5)*	$1.36 - $4.07 *(9)*	$0.72 - $1.92 *(3)*
Kauai	$0.85 *(1)*	$0.52 - $1.03 *(6)*	$0.70 - $0.93 *(2)*
Maui	$0.03 - $3.27 *(6)*	$0.50 - $1.39 *(4)*	$0.33 - $5.70 *(3)*
Molokai	$0.88 *(1)*	$0.54 - $2.43 *(3)*	
Oahu	$0.80 - $1.77 *(3)*		

(X) Represents the number of systems within the specified range

d) Water Source

Water use by water utilities was categorized by its source into ground water, ground water/surface water and purchase from other utilities. Attempts were made to separate ground water use from surface water. However, since surface water is combined with ground water prior to distribution, the amount of energy used to distribute only surface water could not be determined separately. The energy intensity for the utility companies purchasing water represents distribution only and does not take into account energy for pumping or treatment.

As shown in Figures 25 and 28, the majority of potable water in Hawaii comes from ground water. The islands of Hawaii, Kauai and Maui use surface water to supplement its ground water sources. The variations in energy intensity demonstrate that different water sources have different energy requirements. In 2014, energy intensities for water systems across the State that utilize ground water, ranged from 1.9 to 9.0 kW/h. In comparison, water systems that rely on both ground water and surface water exhibited energy intensities between 1.6 to 3.7 kWh/kgal, suggesting that less energy is used to collect, treat and distribute ground water combined with surface water.

Although surface water is gravity fed into the water system and does not require energy for collection, water treatment is required. Depending on the treatment methods, treatment of the surface water could require extensive amounts of energy. Without isolating the energy use required for surface water treatment, it is difficult to determine if the energy required to treat surface water is less than the amount of energy required to collect ground water.

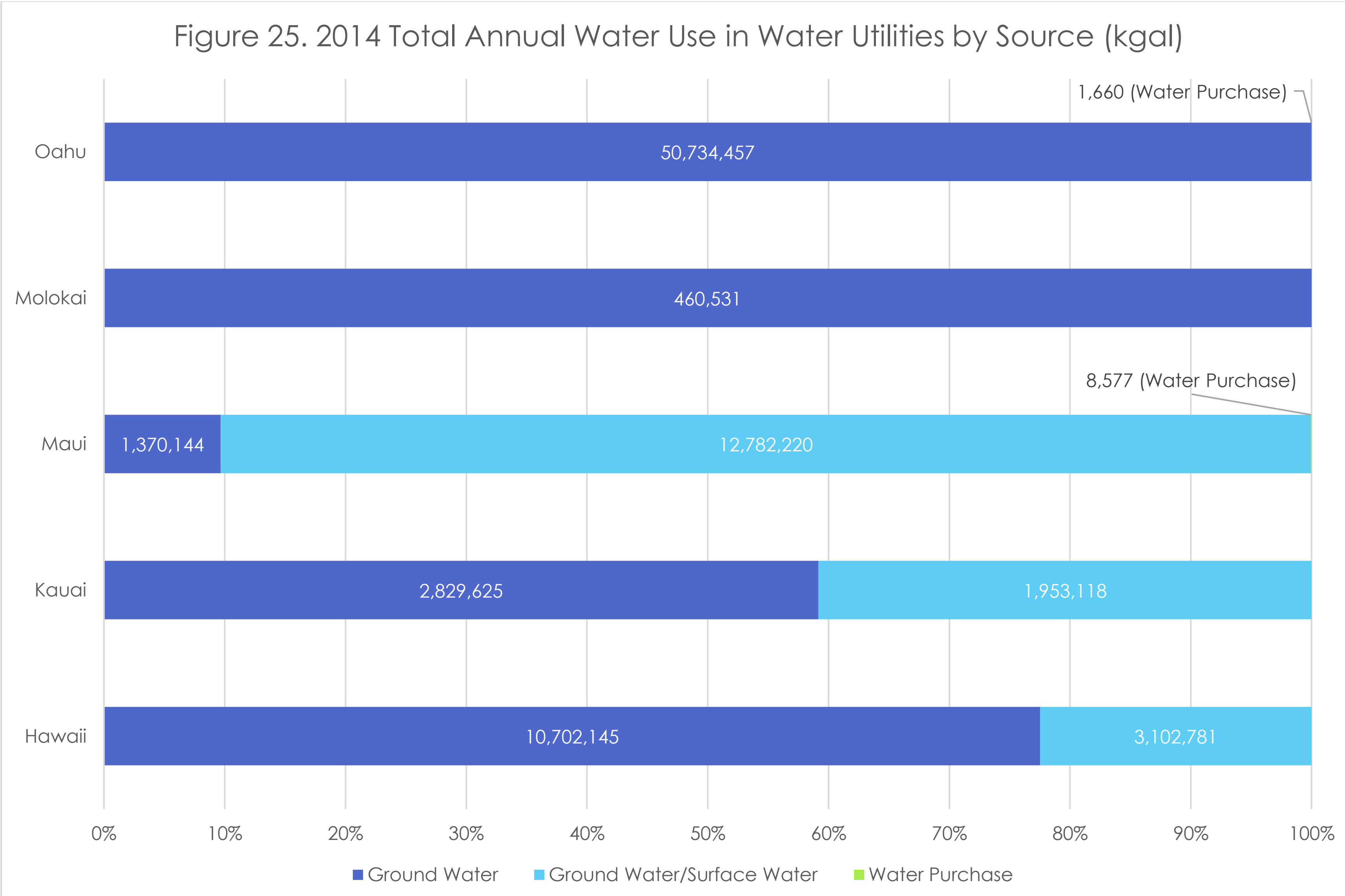


Figure 25. 2014 Total Annual Water Use in Water Utilities by Source (kgal)
1,660 (Water Purchase)
Oahu
50,734,457
Molokai
460,531
8,577 (Water Purchase)
Maui
1,370,144
12,782,220
Kauai
2,829,625
1,953,118
Hawaii
10,702,145
3,102,781
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Ground Water
Ground Water/Surface Water
Water Purchase

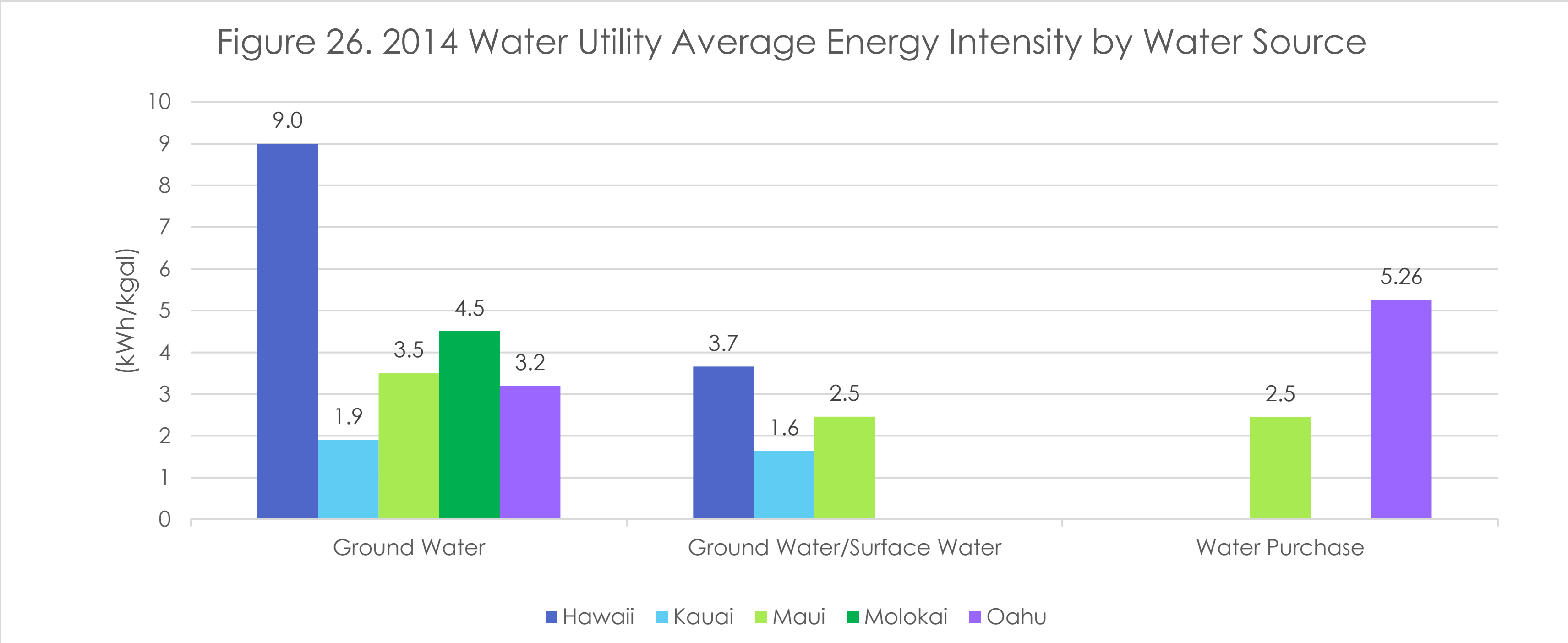


Table 10. Range of Energy Intensities in Water Utilities in 2014 by Water Source (kWh/kgal)

Island	Ground Water	Ground Water/ Surface Water	Water Purchase
Hawaii	1.9 – 24.6 *(16)*	2.5 – 4.8 *(2)*	
Kauai	1.2 – 2.5 *(8)*	1.6 *(1)*	
Maui	0.0 – 9.9 *(7)*	0.3 – 5.7 *(5)*	2.5 *(1)*
Molokai	2.8 – 5.0 *(4)*		
Oahu	0.5-19.5 *(22)*		5.26 *(1)*

(X) Represents the number of systems within the specified range

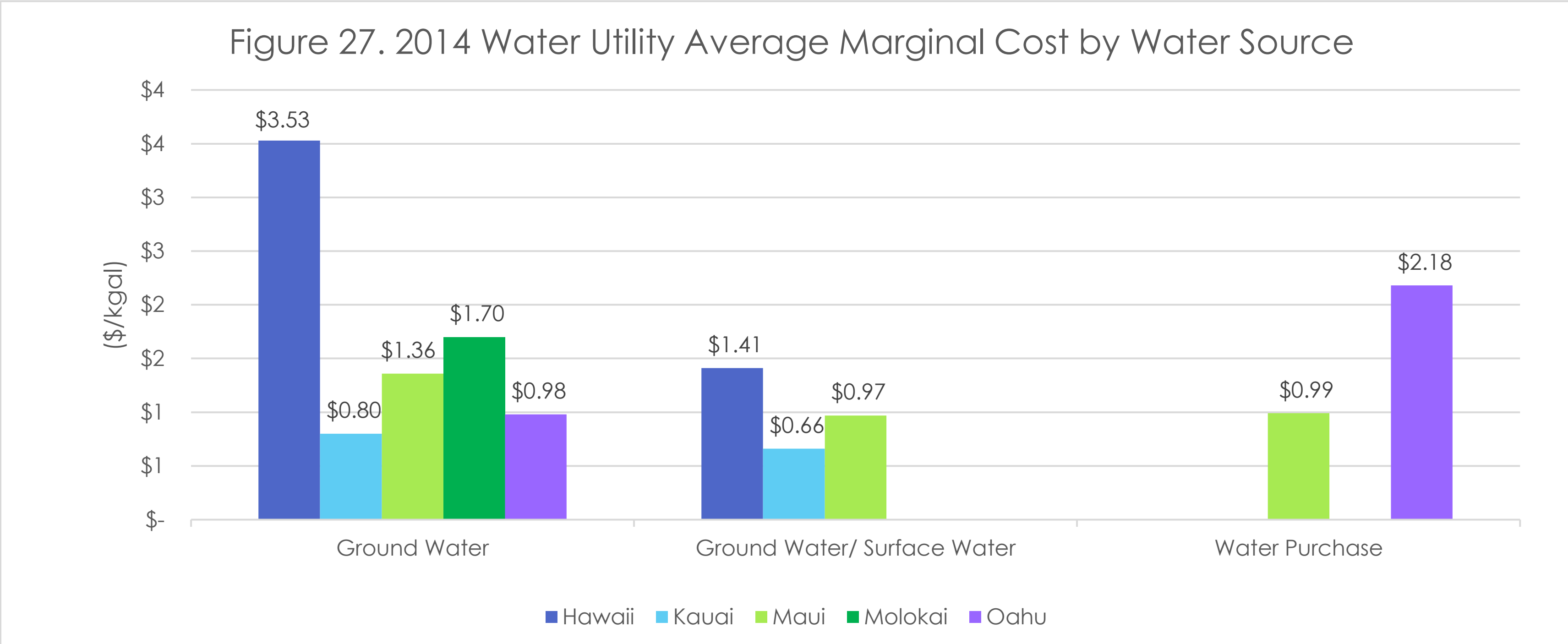


Table 11. Range of Average Marginal Costs in Water Utilities in 2014 by Water Source ($/kgal)

Island	Ground Water	Ground Water/ Surface Water	Water Purchase
Hawaii	$0.71 - $9.22 *(16)*	$0.96 - $1.85 *(2)*	
Kauai	$0.50 - $1.07 *(8)*	$0.66 *(1)*	
Maui	$0.06 - $3.82 *(7)*	$0.13 - $2.36 *(5)*	$0.99 *(1)*
Molokai	$0.69 - $3.38 *(4)*		
Oahu	$0.18 - $6.02 *(22)*		$2.18 *(1)*

(X) Represents the number of systems within the specified range

Figure 28. 2015 Total Annual Water Use in Water Utilities by Source (kgal)

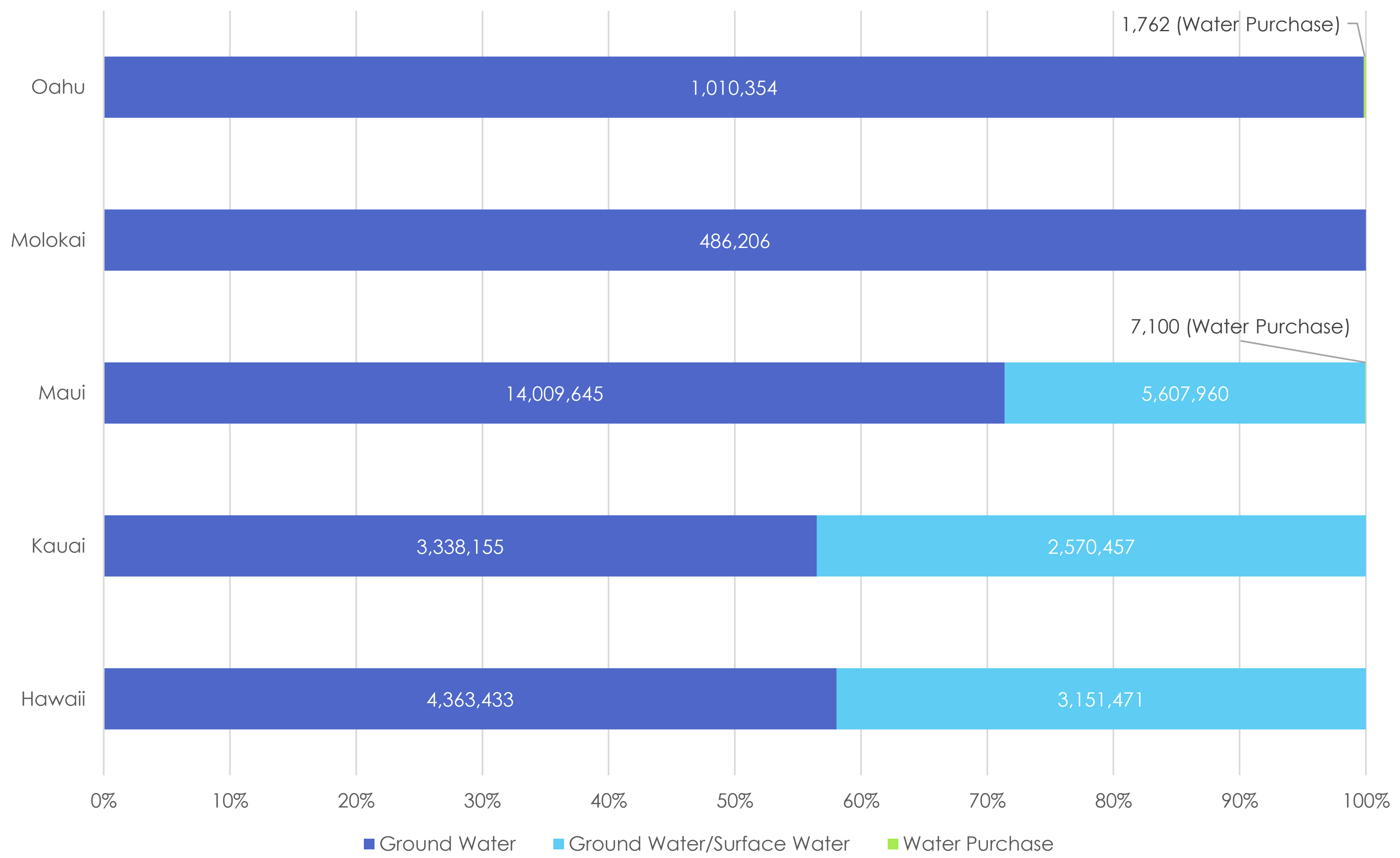


Figure 29. 2015 Water Utility Average Energy Intensity by Water Source

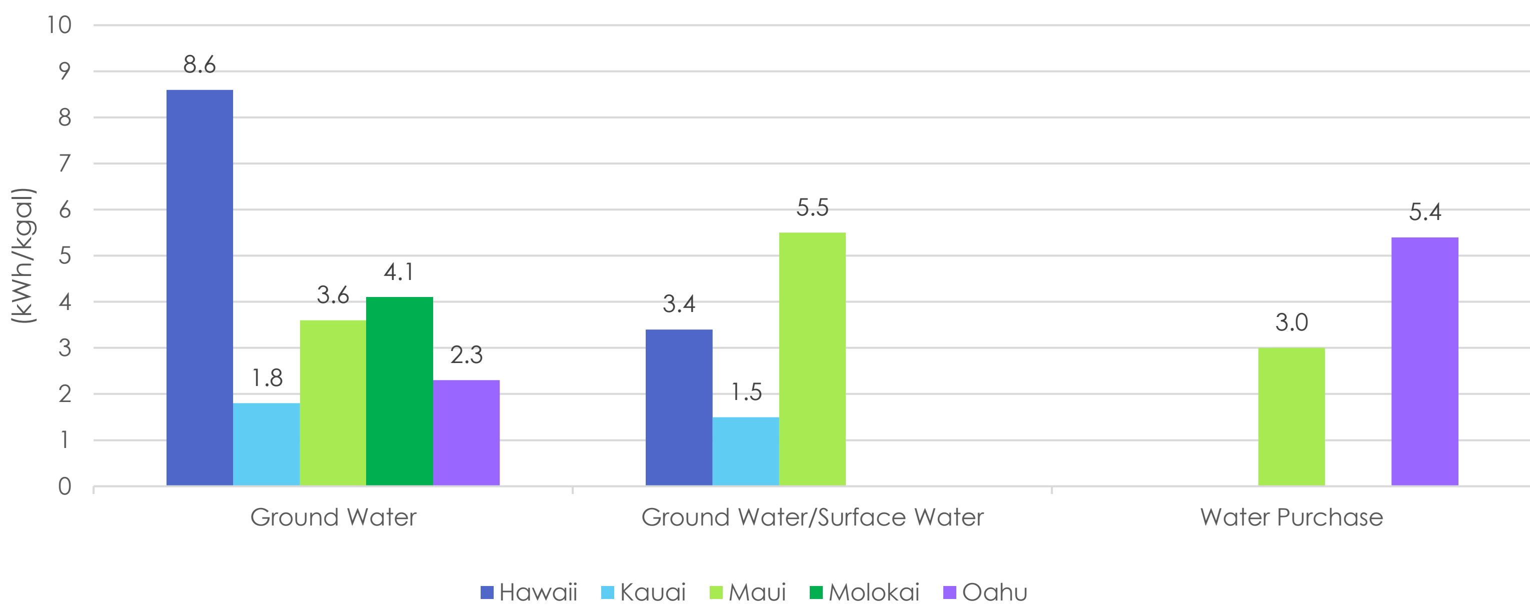


Table 12. Range of 2014 Average Energy Intensities in Water Utilities by Water Source (kWh/kgal)

Island	Ground Water	Ground Water/ Surface Water	Water Purchase
Hawaii	1.4 - 23.9 *(6)*	2.3 – 4.4 *(2)*	
Kauai	1.1 – 2.2 *(8)*	1.5 *(1)*	
Maui	0.0 – 10.1 *(7)*	1.5 – 15.8 *(5)*	3.0 *(1)*
Molokai	1.5 – 4.1 *(4)*		
Oahu	0.0 - 2.3 *(6)*		5.4 *(1)*

(X) Represents the number of systems within the specified range

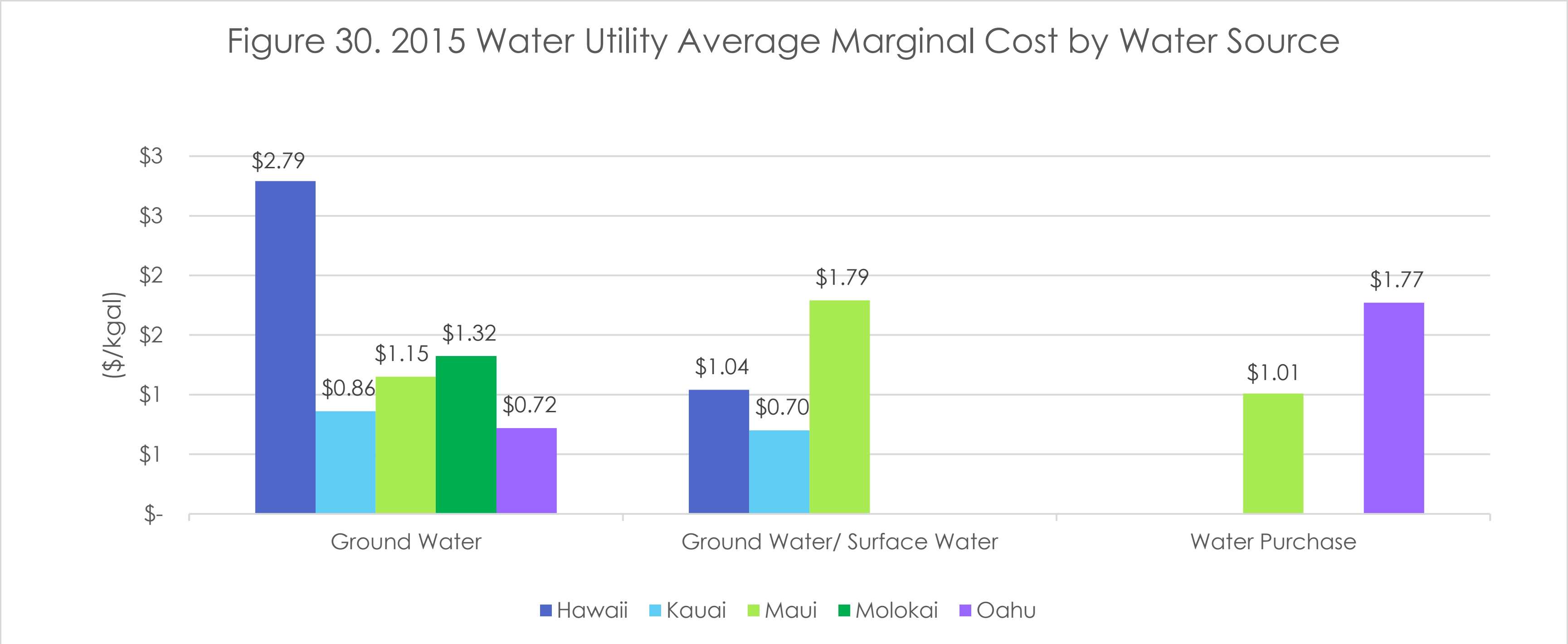


Table 13. Range of 2015 Average Marginal Costs in Water Utilities by Water Source ($/kgal)

Island	Ground Water	Ground Water/ Surface Water	Water Purchase
Hawaii	$0.39 - $7.50 *(6)*	$0.72 - $1.36 *(2)*	
Kauai	$0.52 - $1.03 *(8)*	$0.70 *(1)*	
Maui	$0.03 - $3.27 *(7)*	$0.50 - $4.71 *(5)*	$1.01 *(1)*
Molokai	$0.54 - $2.43 *(4)*		
Oahu	$0.33 - $1.03 *(6)*		$1.77 *(1)*

(X) Represents the number of systems within the specified range

e) Well Depth

The energy required to pump ground water is dependent on well depth. To determine a baseline energy intensity in relation to well depth, the data was classified by the average well depth of the water system. Systems that utilize surface water and other utilities were removed from the data subset to isolate the relationship between well depth and energy use.

As shown in Figures 31 to 36, Hawaii Island has the highest average energy intensity represented by an average well depth of 939 feet. The depth of the wells could be the driving factor behind the high overall energy intensity for Hawaii Island, as the majority of the wells are deeper than 1,000 feet. In addition, Kauai has relatively shallow wells which could contribute to the overall low energy intensities.

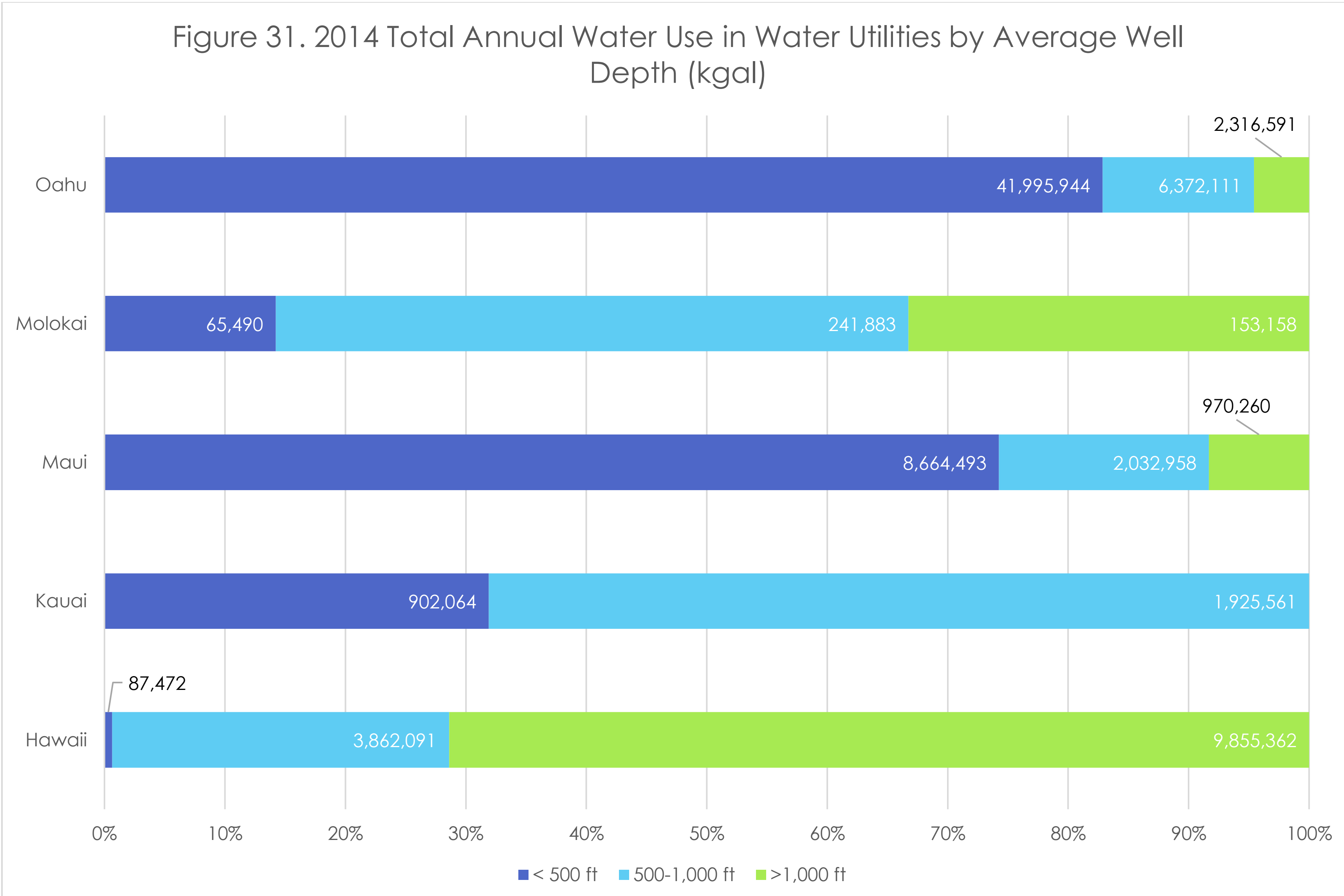


Figure 31. 2014 Total Annual Water Use in Water Utilities by Average Well Depth (kgal)
Oahu
41,995,944
6,372,111
2,316,591
Molokai
65,490
241,883
153,158
Maui
8,664,493
2,032,958
970,260
Kauai
902,064
1,925,561
Hawaii
87,472
3,862,091
9,855,362
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
< 500 ft
500-1,000 ft
>1,000 ft

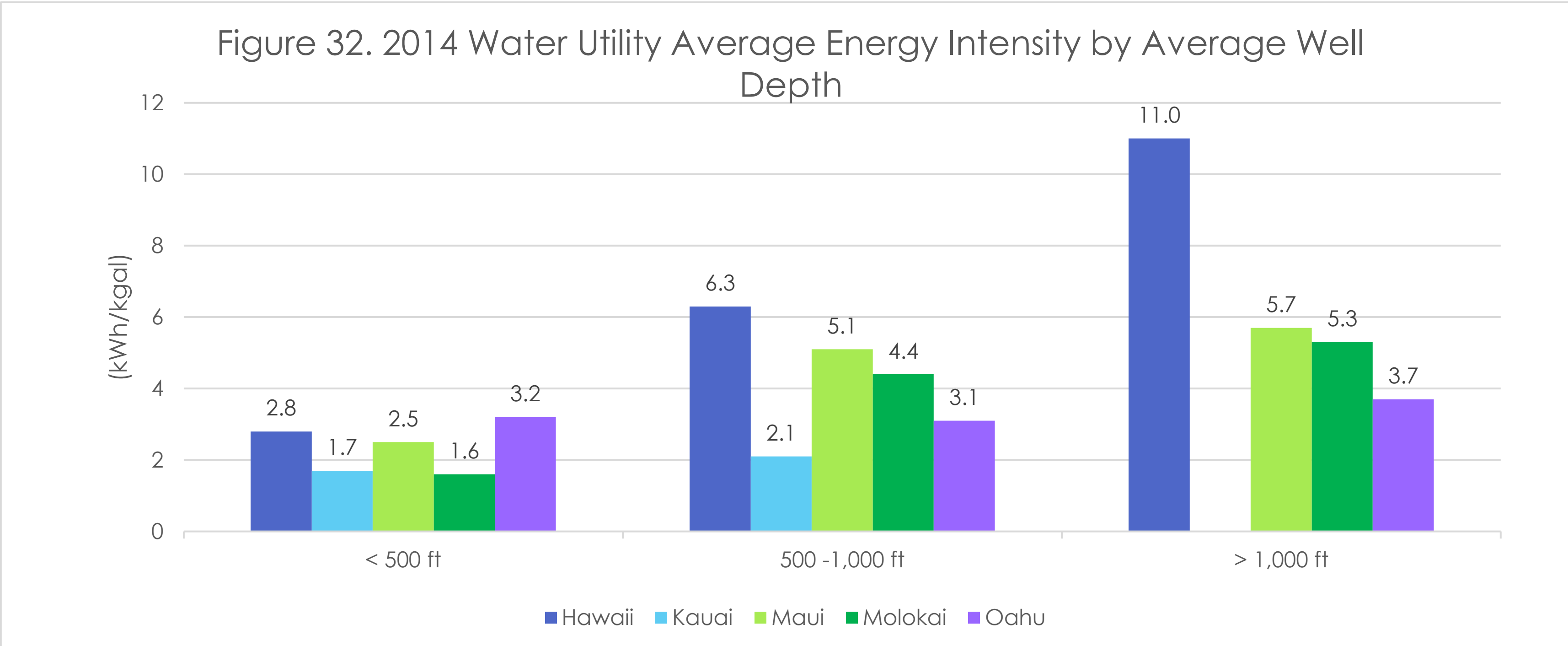


Table 14. Range of Average Energy Intensities in Water Utilities in 2014 by Well Depth (kWh/kgal)

Island	< 500 ft	500 -1,000 ft	> 1,000 ft
Hawaii	1.9 – 3.7 *(2)*	2.6 - 13.4 *(6)*	6.8 -24.6 *(9)*
Kauai	1.2 – 2.1 *(5)*	1.6 – 2.5 *(3)*	
Maui	0.0 – 2.9 *(5)*	0.3 – 9.9 *(2)*	5.7 *(1)*
Molokai	1.6 *(1)*	4.4 *(1)*	1.8 – 8.7 *(2)*
Oahu	0.5 – 19.5 *(14)*	1.1 – 5.2 *(5)*	3.1 – 4.4 *(2)*

(X) Represents the number of systems within the specified range

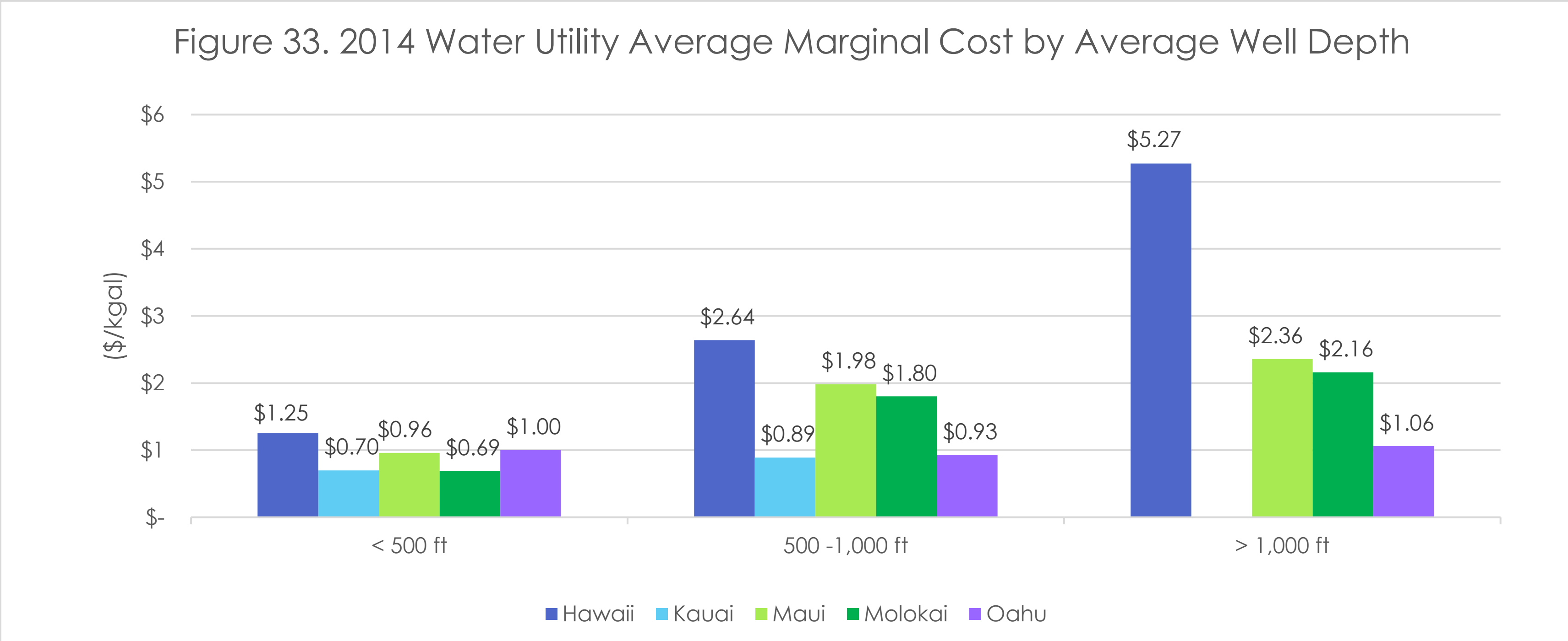


Table 15. Range of 2014 Average Marginal Costs in Water Utilities by Average Well Depth ($/kgal)

Island	< 500 ft	500 -1,000 ft	> 1,000 ft
Hawaii	$0.71 - $1.80 *(2)*	$0.96 - $5.70 *(6)*	$2.51 - $9.22 *(9)*
Kauai	$0.50 - $0.90 *(5)*	$0.66 - $1.07 *(3)*	
Maui	$0.06 - $1.25 *(5)*	$0.13 - $3.82 *(2)*	$2.36 *(1)*
Molokai	$0.69 *(1)*	$1.80 *(1)*	$0.94 - $3.38 *(2)*
Oahu	$0.18 - $6.02 *(14)*	$0.32 - $1.64 *(5)*	$0.84 - $1.28 *(2)*

(X) Represents the number of systems within the specified range

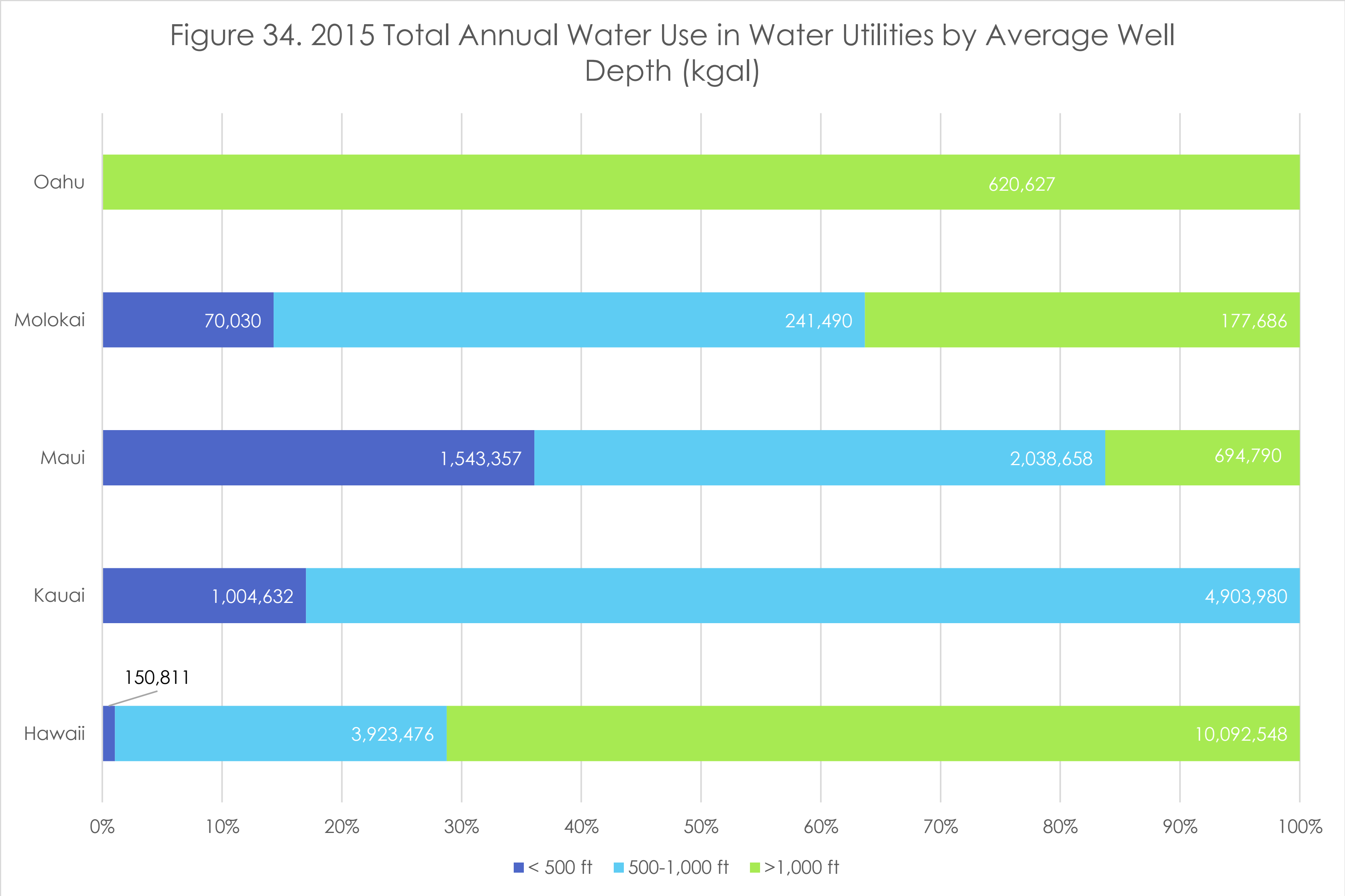


Figure 34. 2015 Total Annual Water Use in Water Utilities by Average Well Depth (kgal)
Oahu
620,627
Molokai
70,030
241,490
177,686
Maui
1,543,357
2,038,658
694,790
Kauai
1,004,632
4,903,980
150,811
Hawaii
3,923,476
10,092,548
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
< 500 ft
500-1,000 ft
>1,000 ft

Figure 35. 2015 Water Utility Average Energy Intensity by Average Well Depth

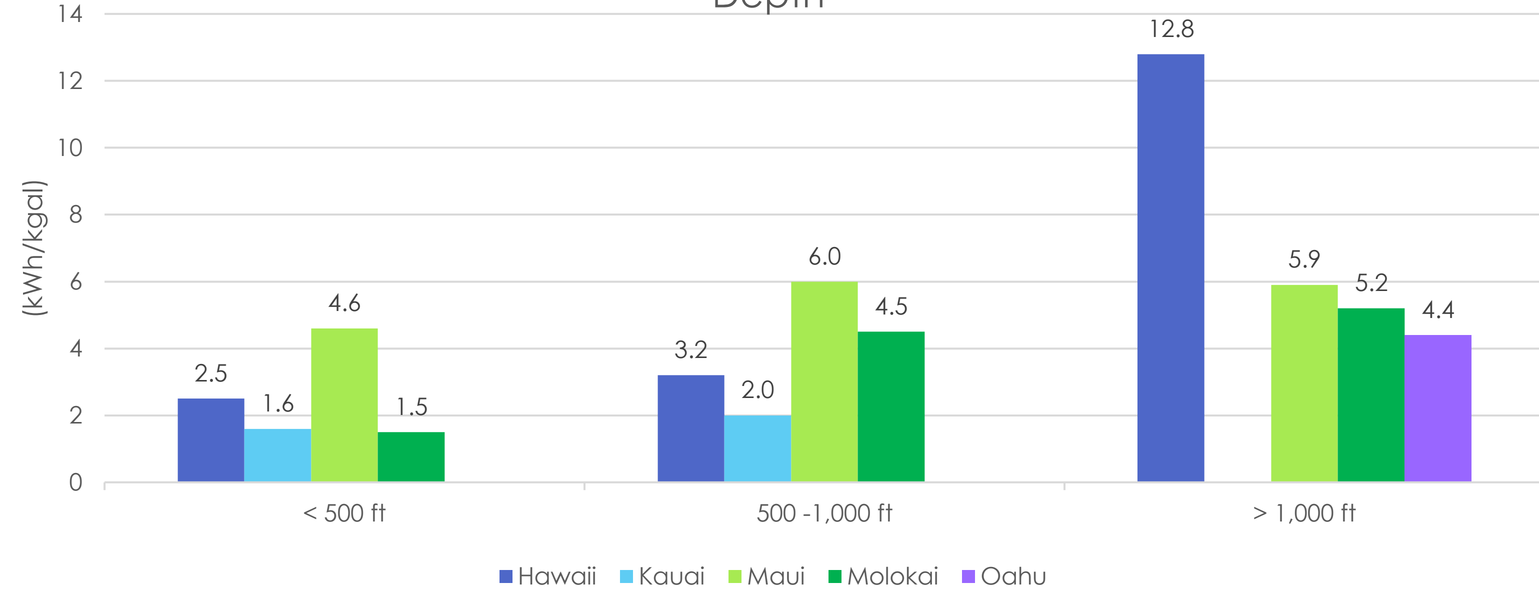


Table 16. Range of Average Energy Intensities in Water Utilities in 2015 by Average Well Depth (kWh/kgal)

Island	< 500 ft	500 -1,000 ft	> 1,000 ft
Hawaii	1.4 – 3.7 *(2)*	2.3 – 11.9 *(6)*	7.2 - 23.9 *(9)*
Kauai	1.1 – 1.8 *(5)*	1.5 - 2.2 *(4)*	
Maui	1.5 -15.8 *(5)*	1.9 – 10.0 *(2)*	5.9 *(1)*
Molokai	1.5 *(1)*	4.5 *(1)*	2.1 – 8.3 *(2)*
Oahu			4.4 *(1)*

(X) Represents the number of systems within the specified range

Figure 36. 2015 Water Utility Average Marginal Cost by Average Well Depth

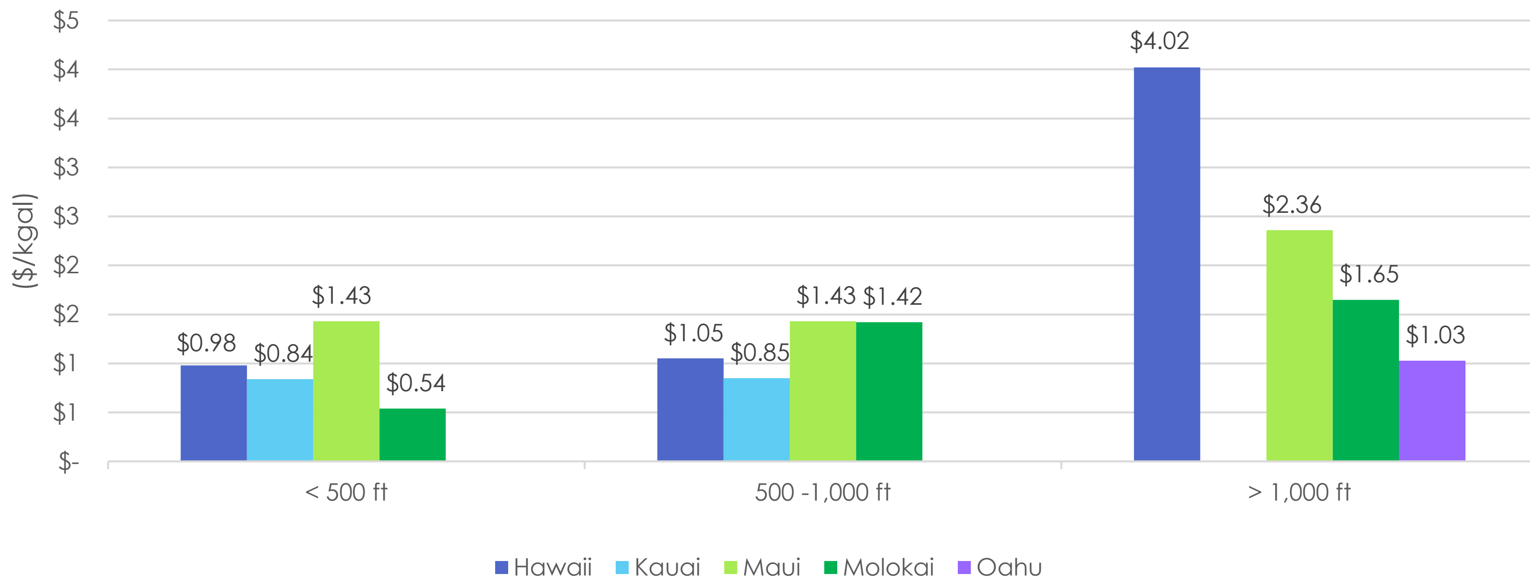


Table 17. Range of 2015 Average Marginal Costs in Water Utilities by Average Well Depth ($/kgal)

Island	< 500 ft	500 -1,000 ft	> 1,000 ft
Hawaii	$0.39 - $1.56 *(2)*	$0.72 - $4.07 *(6)*	$2.52 - $7.50 *(9)*
Kauai	$0.52 - $0.96 *(5)*	$0.70 - $1.03 *(4)*	
Maui	$0.54 - $4.71 *(5)*	$0.60 - $3.27 *(2)*	$2.36 *(1)*
Molokai	$0.54 *(1)*	$1.42 *(1)*	$0.88 - $2.43 *(2)*
Oahu			$1.03 *(1)*

(X) Represents the number of systems within the specified range

f) Summary

Energy consumption in water systems fluctuate with pumped volume, well depth, service population, water source and treatment requirements. For water systems in Hawaii,

- Energy intensities for water systems throughout the State ranged from 0.04 to 24.64 kWh/kgal in 2014. This contributed to a cost of $0.06 to $9.22 for production of 1,000 gallons of potable water.
- In 2015, energy intensities ranged from 0.03 to 23.9 kWh/kgal, with marginal costs ranging from $0.03 to $7.50.
- Water systems on Hawaii Island had the highest average energy intensity. High energy consumption could be attributed to well depth, as the average well depth of the surveyed water systems is 939 feet.
- Private water systems have higher energy intensities and marginal costs than public water systems.
- Water systems that serve less than 1,000 people have the highest average energy intensity, which could be reflective of system inefficiencies.
- Energy intensity and marginal cost increases with well depth. This is expected as more energy is required to pump water from greater depths.

High energy intensities could be representative of system inefficiencies such as water losses, inefficient equipment and inefficient energy practices. As expected, these high energy intensities correlate to high marginal costs. Implementing water conservation practices that reduce the volume of water through the system, can reduce energy use and resultant electrical costs, providing savings in operating costs.

9) WASTEWATER SYSTEMS IN HAWAII

Many parts of the State do not have regional wastewater systems. As a result, residents and businesses in those areas utilize IWS systems or individual wastewater treatment plants. As previously discussed, most IWS systems do not consume energy and were thus, exempt from the study. Meanwhile, individual wastewater treatment plants that have average flows of less than 1,000 gallons per day, or appeared to service condominiums, were exempt from the study as the data may not accurately characterize the energy use for the area.

Due to the limitations in the volume of data, data was classified by island and treatment type. The data for 2014 represents 21 wastewater systems, while the data for 2015 represents 12 wastewater systems. Systems that treat wastewater directly from municipal waste to recycled water quality effluent were analyzed separately. The islands of Maui, Molokai and Lanai are not represented in this section as all of Maui County's wastewater treatment plants produce recycled water quality effluent.

Treated wastewater flows and its associated energy consumption are analyzed in Figures 37 to 42. On average, wastewater systems on Oahu treat more wastewater than other systems in the State. This is indicative of municipal wastewater systems and a larger population on Oahu.

At a regional level, the data does not show a strong correlation between energy use and level of treatment. The 2014 energy intensity for tertiary systems on Kauai and secondary systems on Oahu suggests that higher levels of treatment require less energy. This is counterintuitive as both secondary and tertiary treatment require additional treatment processes to produce higher quality effluent which can be further treated to produce recycled water. This could be attributed to a small sample size. In addition, different types of treatment technologies can also result in variations in energy use for the same level of treatment. Higher energy intensities could be reflective of treatments that require more energy such as ultraviolet disinfection.

In addition, the data for 2015 depicts primary treatment with the highest energy intensity. The high energy intensity corresponds to low average flows, which is indicative of energy inefficiencies. The low flows suggest a small wastewater system, which may not have newer, energy efficient equipment or components.

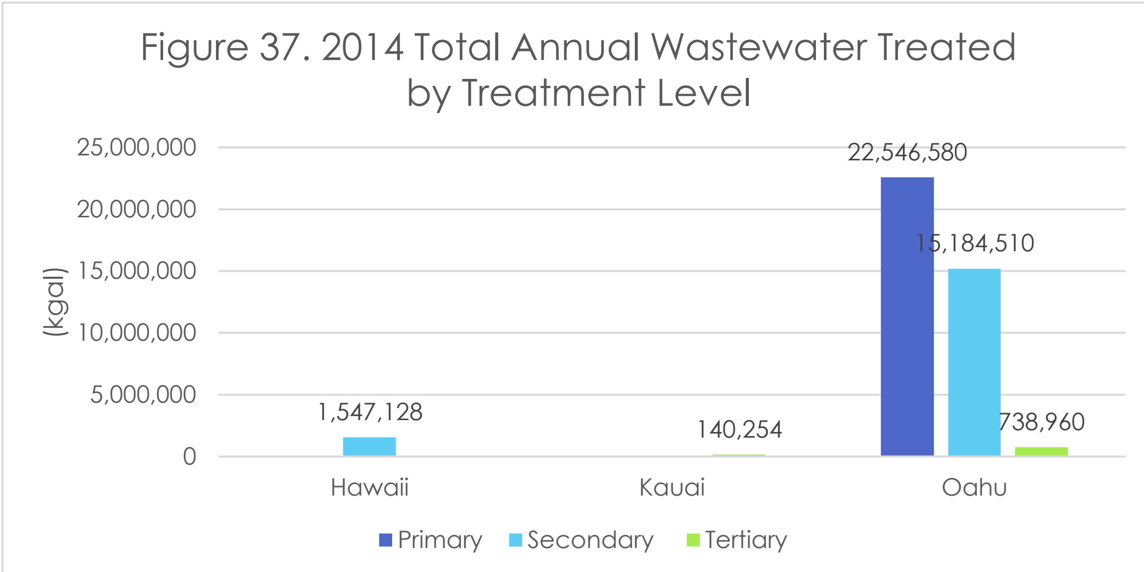


Figure 37. 2014 Total Annual Wastewater Treated by Treatment Level
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
0
(kgal)
22,546,580
15,184,510
1,547,128
140,254
738,960
Hawaii
Kauai
Oahu
Primary
Secondary
Tertiary

Figure 38. 2014 Wastewater Average Energy Intensities by Treatment Level

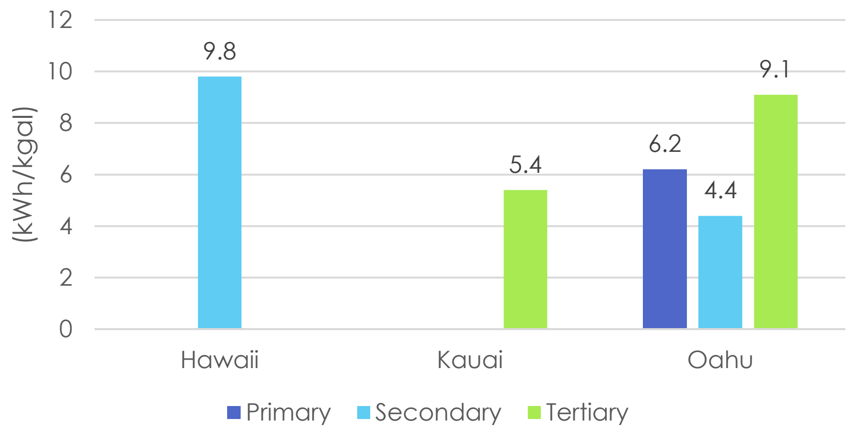


Table 18. Range of 2014 Wastewater Average Energy Intensity Values by Treatment Level (kWh/kgal)

Island	Primary	Secondary	Tertiary
Hawaii		3.1 - 23.5 *(7)*	
Kauai			5.4 *(1)*
Oahu	2.3 - 10.2 *(2)*	2.1 - 7.6 *(6)*	8.7 - 9.5 *(2)*

(X) Represents the number of systems within the specified range

Figure 39. 2014 Wastewater Average Marginal Cost by Treatment Level

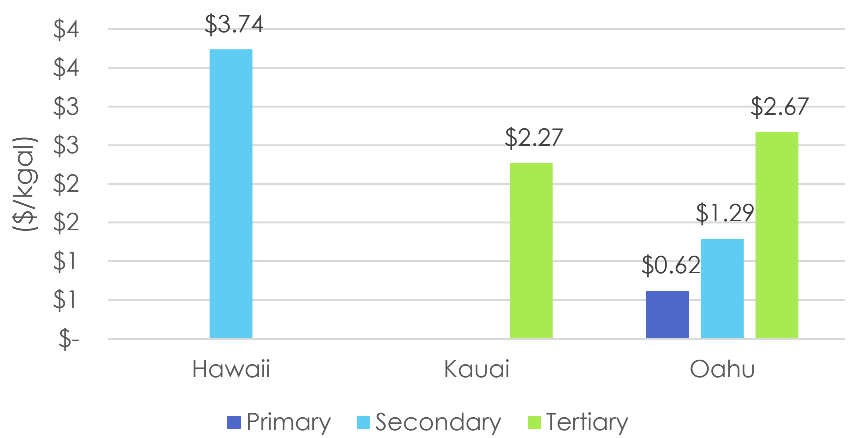


Table 19. Range of 2014 Wastewater Average Marginal Cost by Treatment Level ($/kgal)

Island	Primary	Secondary	Tertiary
Hawaii		$1.12 - $8.66 *(7)*	
Kauai			$2.27 *(1)*
Oahu	$0.62 - $4.48 *(2)*	$0.49 - $2.34 *(6)*	$2.58 - $2.75 *(2)*

(X) Represents the number of systems within the specified range

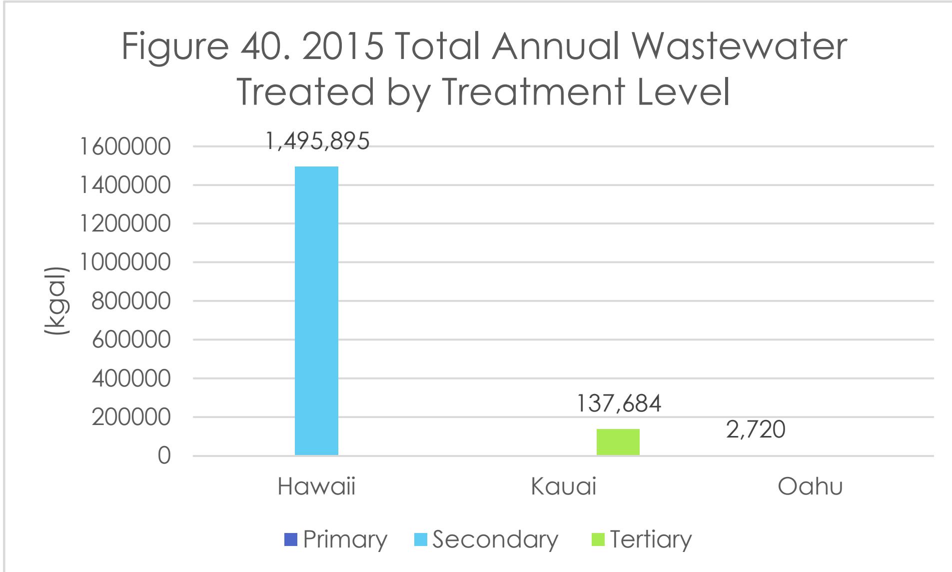


Figure 40. 2015 Total Annual Wastewater Treated by Treatment Level
(kgal)
1600000
1400000
1200000
1000000
800000
600000
400000
200000
0
1,495,895
137,684
2,720
Hawaii
Kauai
Oahu
Primary
Secondary
Tertiary

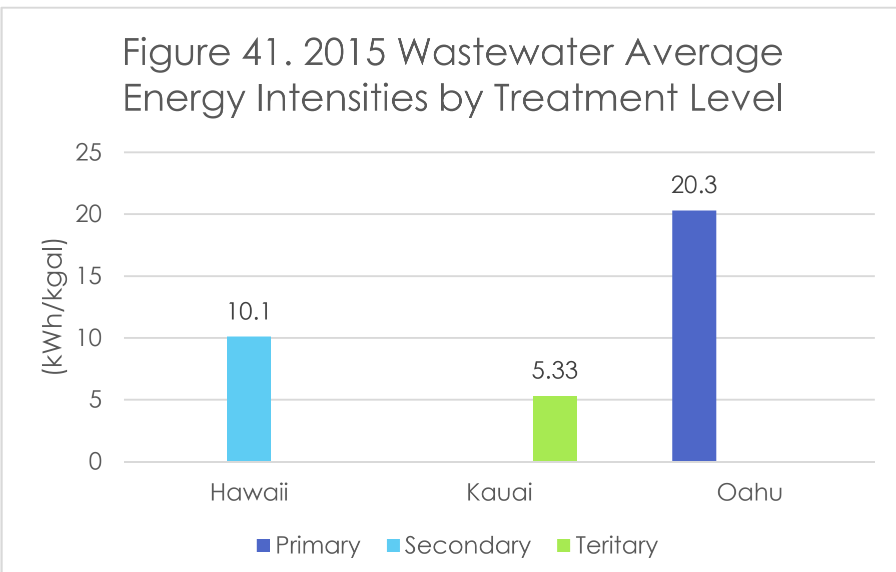


Figure 41. 2015 Wastewater Average Energy Intensities by Treatment Level
(kWh/kgal)
25
20
15
10
5
0
10.1
5.33
20.3
Hawaii
Kauai
Oahu
Primary
Secondary
Teritary

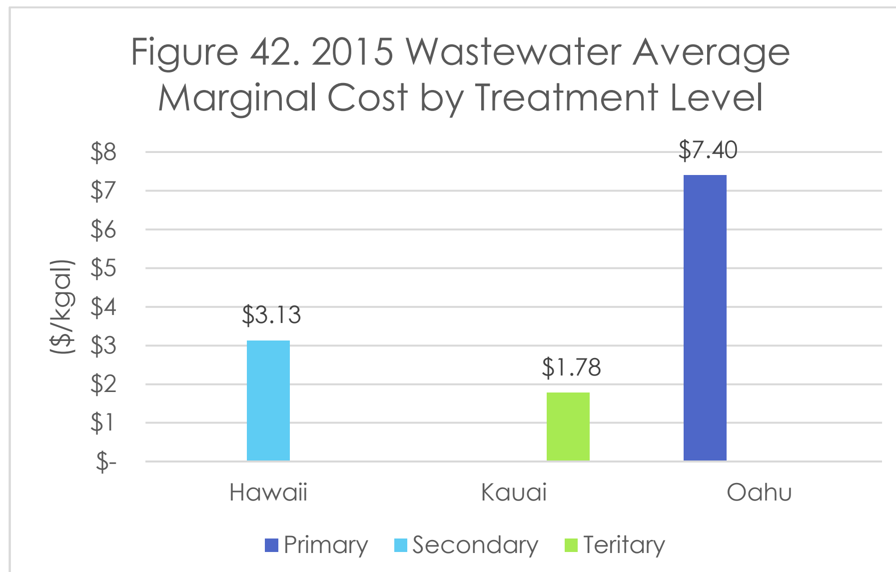


Figure 42. 2015 Wastewater Average Marginal Cost by Treatment Level
($/kgal)
$8
$7
$6
$5
$4
$3
$2
$1
$-
$3.13
$1.78
$7.40
Hawaii
Kauai
Oahu
Primary
Secondary
Teritary

a) Summary

Energy use in wastewater systems is dependent on treated volume, treatment level and type of treatment technology. Energy intensity in wastewater systems throughout Hawaii ranges from 2.3 to 23.5 kWh/kgal. More energy is required to collect, treat and dispose of larger volumes of wastewater effluent. The use of energy efficient technologies can reduce the amount of energy used for wastewater treatment operations. At a minimum, a wastewater system spends an average of $0.62 to treat 1,000 gallons of wastewater influent for primary effluent, the lowest level of treatment. Conserving water at the consumption level equates to smaller volumes of wastewater influent and lower operating costs. Long term conservation practices in conjunction with energy conservation practices has the potential to yield significant savings.

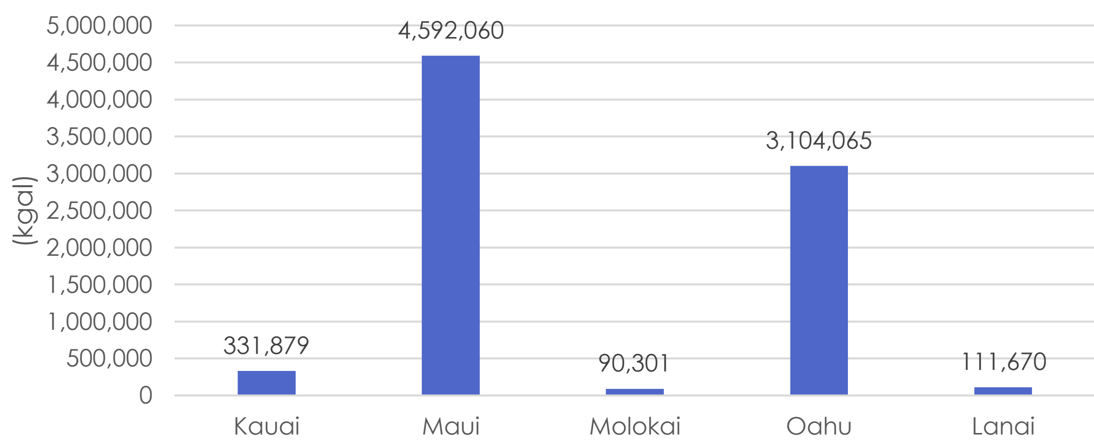
10) RECYCLED WATER

Although all of the islands have recycled water policies, there are only a handful of recycled water facilities on each island. Maui County has the most advanced and extensive recycled water program with all of the County's municipal wastewater treatment facilities producing recycled water quality effluent. Effluent produced at the treatment plants are sold to golf courses and hotels as irrigation water.

Due to limitations in available data, only 2015 data from seven (7) recycling facilities was available. Energy cost information was not available for all facilities. With the exception of treatment plants on Oahu, which accepts previously treated effluent, reported energy consumption is inclusive of the energy required for prescreening and primary and secondary treatment. Figures 43 and 44 classify the recycled water data by island and level of treatment.

R-1 recycled water is derived from tertiary wastewater quality effluent while R-2 recycled water is derived from secondary wastewater quality effluent. Similar to the wastewater energy intensities, the recycled water data suggests that more energy is required to produce lower quality recycled water. Since the data subset is small, the data may not be an accurate representation of the recycled water energy intensity. The higher energy intensity values may also be reflective of more energy intensive treatment methods, such as ultraviolet treatment.

Figure 43. 2015 Total Annual Recycled Water Produced by Island



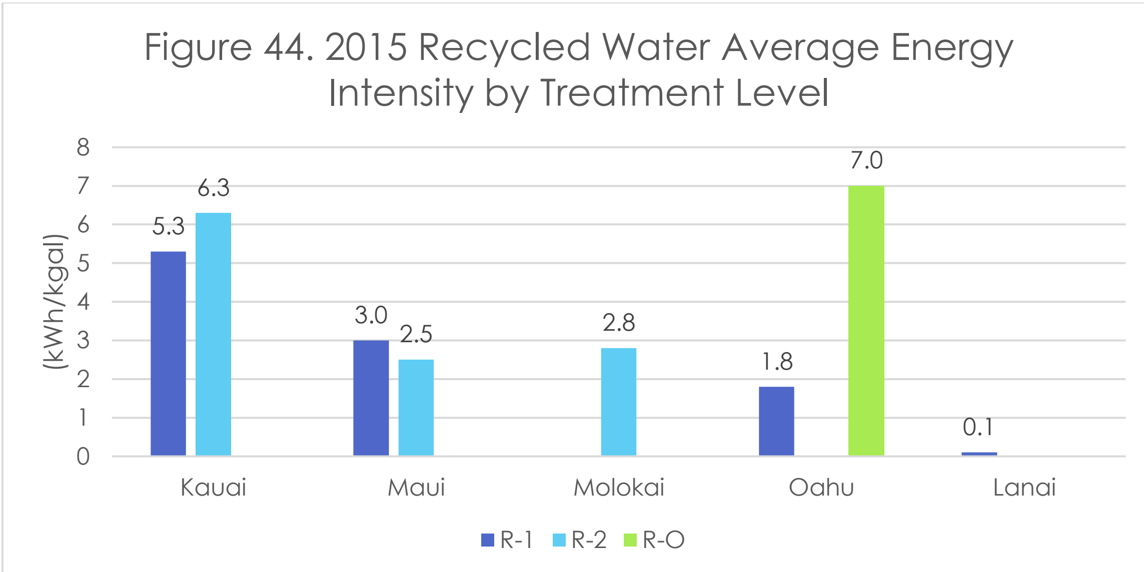


Figure 44. 2015 Recycled Water Average Energy Intensity by Treatment Level
(kWh/kgal)
8
7
6
5
4
3
2
1
0
5.3
6.3
3.0
2.5
2.8
1.8
7.0
0.1
Kauai
Maui
Molokai
Oahu
Lanai
R-1
R-2
R-O

11) ELECTRICAL SYSTEMS IN HAWAII

Tables 20 and 21 show the total annual water use and associated energy production by island. As expected, energy production appears to be based on population, with Oahu having the largest energy production. Maui data may be less accurate due to only a single electric facility reporting data.

Table 20. 2014 Total Energy Produced by Island

Island	No. of Facilities	Total Annual Water Use (kgal)	Total Annual Energy Production (kWh)
Hawaii	5	44,259,000	566,019,138
Kauai	3	538,405	6,984,618
Maui	1	10,457,091	134,856,800
Oahu	4	354,958,482	5,242,127,642

Table 21. 2015 Total Energy Produced by Island

Island	No. of Facilities	Total Annual Water Use (kgal)	Total Annual Energy Production (kWh)
Hawaii	5	40,997,000	490,860,734
Kauai	3	5,183,000	7,275,000
Maui	1	9,802,377	107,289,100
Oahu	4	362,825,908	5,312,099,039

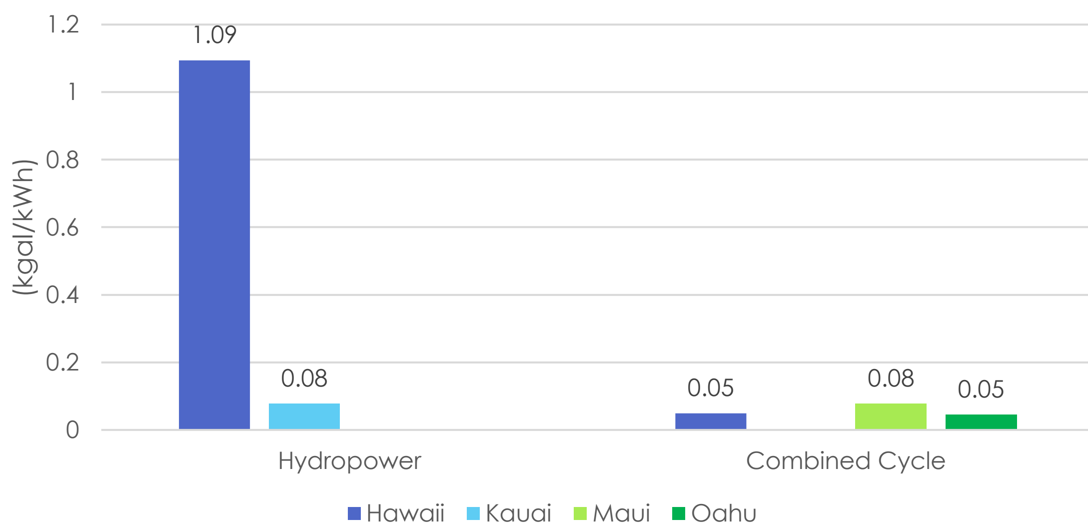
a) Energy Type

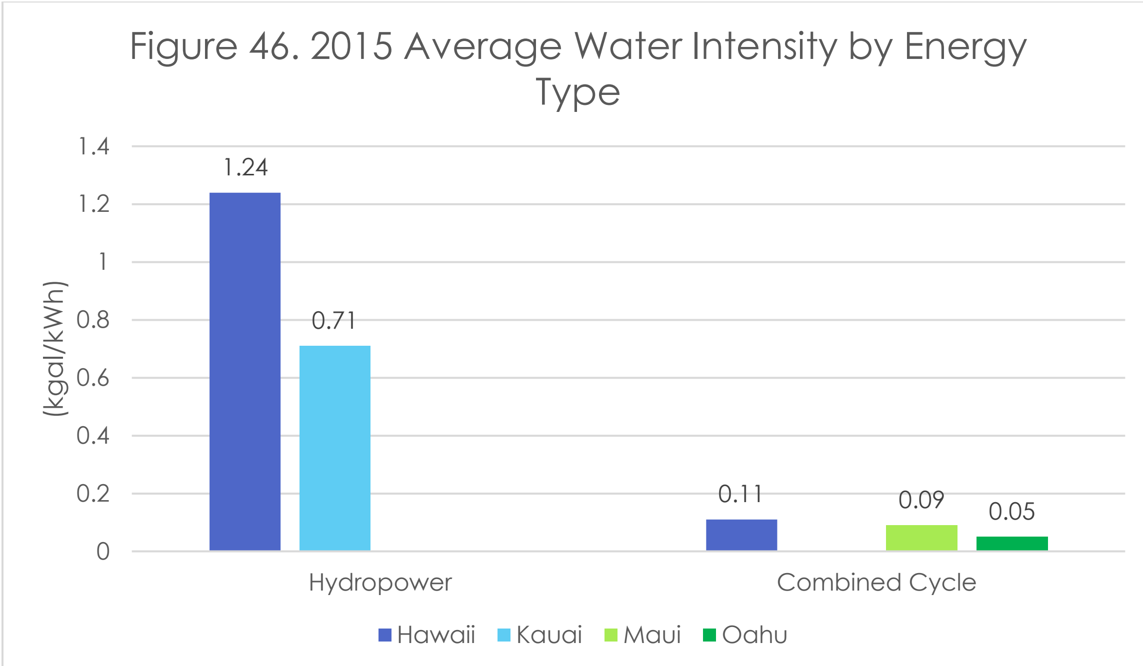
Hawaii's fuel mix currently consists of oil, coal, biomass, geothermal, hydropower, solar, wind and solid waste. The majority of Hawaii's energy comes from oil processed by combined cycle plants. Data was only provided for combined cycle plants and hydroelectric facilities. Combined cycle plants uses both gas and steam turbines to produce electricity. Solar and wind systems were exempt from the study as these systems do not consume any water during energy production.

Figures 45 and 46 shows energy production by energy source. Prior to 2016, hydroelectric facilities were not required to track or report the amount of water being used or diverted from surface waters. As a result, historic data for the water use of hydroelectric facilities is limited. The data presented below is limited to facilities that provided data for both water use and energy production and should not be used to characterize hydropower production across the State. Mandatory documentation and reporting of the water use of hydroelectric facilities is recommended to track the use of fresh water resources.

In 2014, the water intensities for energy production varied from 0.05 to 1.09 kgal/kWh. 2015 had a similar range of values with 0.05 to 1.24 kgal/kWh. Larger energy intensities correlate to more water being used for the production of a unit of energy. The data shows that combined cycle plants require less water than hydroelectric facilities to produce the same unit of energy. However, in combined cycle plants, water is consumed and lost through evaporation, whereas for hydroelectric facilities, water flows through the system, and is returned to its original source. Water used by hydroelectric facilities is not consumed, but is instead required to flow through the system for energy generation.

Figure 45. 2014 Average Water Intensity by Energy Type





b) Water Source

Sources of water for energy production from combined cycle facilities include surface water, ground water, recycled water and brackish water. Figures 47 through 50 compare the water use and water intensity for energy production from different sources of water. In some cases, a mixture of two different sources of water is used to dilute the water's salinity levels (i.e. brackish water/ground water, ocean/surface water, ocean/recycled water). The amounts of each water type could not be accounted for separately.

The data shows that most energy in Hawaii is produced using recycled water and brackish water from the Pacific Ocean. This is reflective of the location of the plants as the majority are located along the coast.

Average water intensities for energy production categorized by water source ranges from 0.00 to 1.24 kgal/kWh. In Figures 48 and 50, it is important to note that the average water intensity value of 0.00 for recycled water is indicative of a small, fractional value, but due to significant figures, appears as 0.00.

The lower water intensities for recycled water and ground water suggest that less recycled water and ground water is required to produce energy. This could be due to the absence of impurities in the water. Likewise the high water intensities for brackish water or ocean water mixtures could indicate low efficiencies associated with impurities in the water quality or high energy consumption associated with desalinating brackish water prior to energy production. Lower efficiencies produce more energy for the same volume of water.

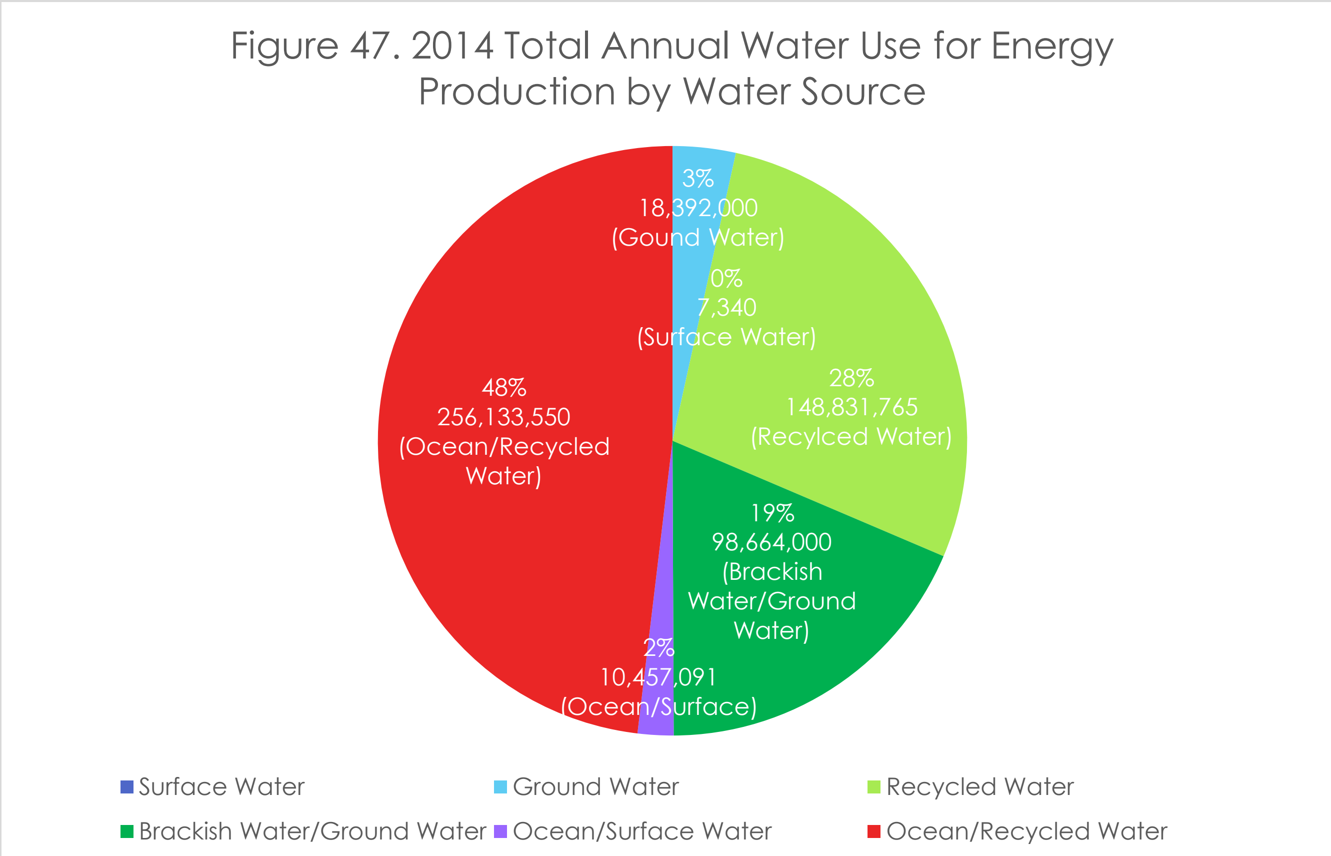


Figure 47. 2014 Total Annual Water Use for Energy Production by Water Source
3%
18,392,000
(Gound Water)
0%
7,340
(Surface Water)
28%
148,831,765
(Recylced Water)
19%
98,664,000
(Brackish Water/Ground Water)
2%
10,457,091
(Ocean/Surface)
48%
256,133,550
(Ocean/Recycled Water)
Surface Water
Ground Water
Recycled Water
Brackish Water/Ground Water
Ocean/Surface Water
Ocean/Recycled Water

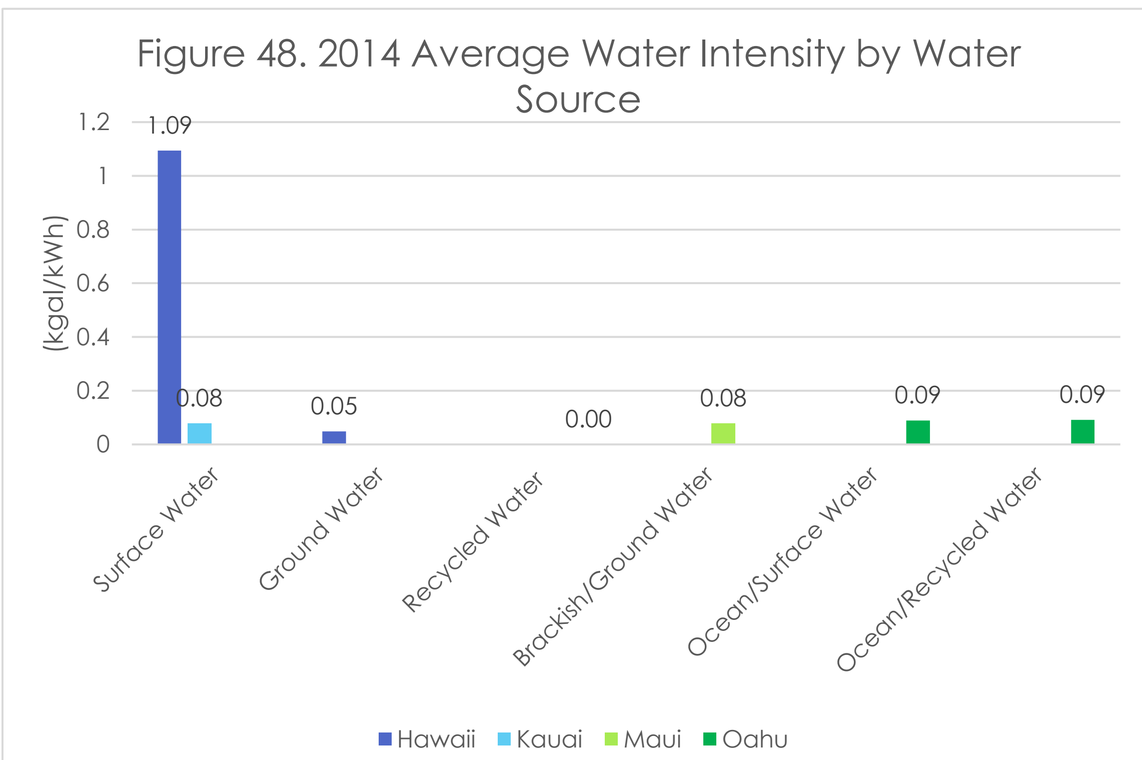


Figure 48. 2014 Average Water Intensity by Water Source
(kgal/kWh)
1.2
1
0.8
0.6
0.4
0.2
0
1.09
0.08
0.05
0.00
0.08
0.09
0.09
Surface Water
Ground Water
Recycled Water
Brackish/Ground Water
Ocean/Surface Water
Ocean/Recycled Water
Hawaii
Kauai
Maui
Oahu

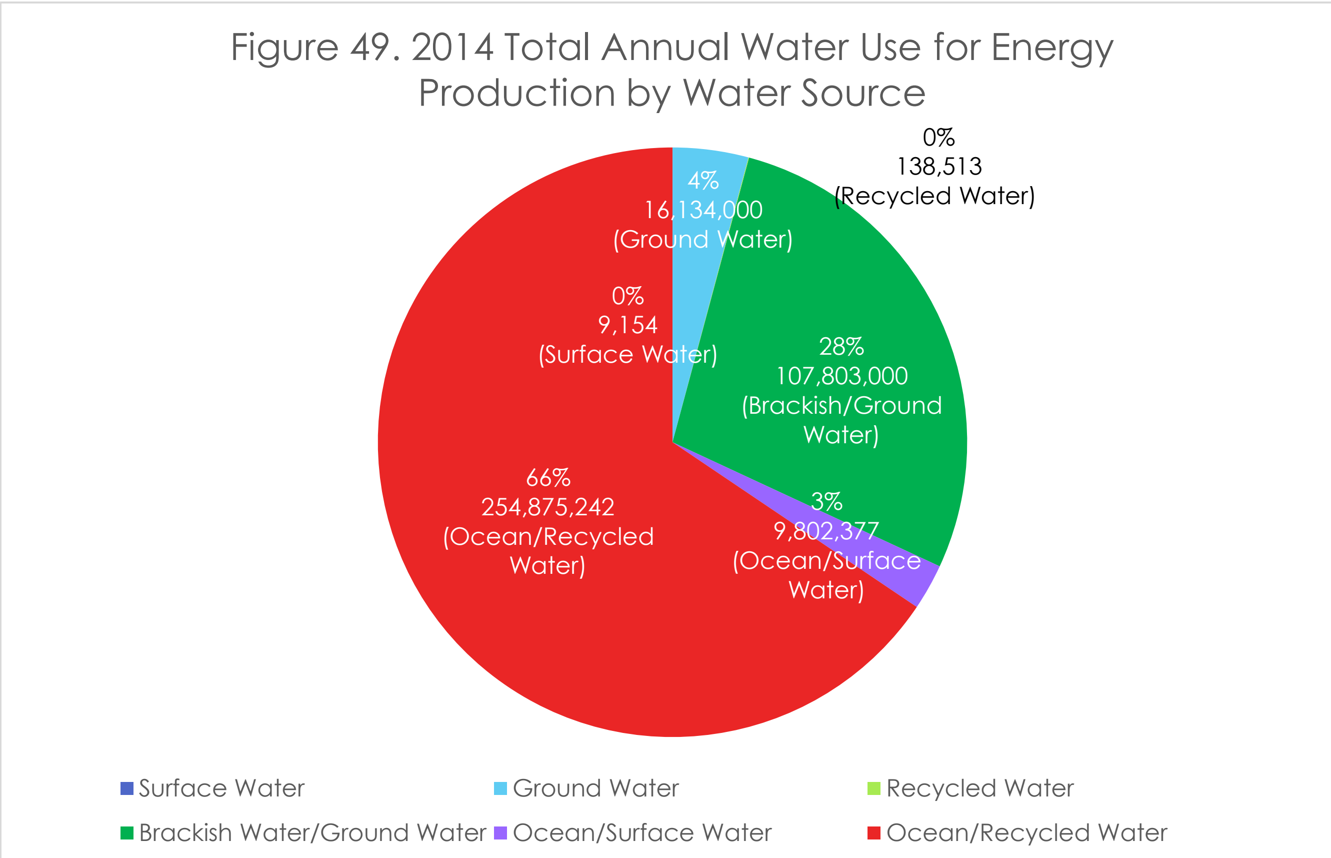


Figure 49. 2014 Total Annual Water Use for Energy Production by Water Source
0%
138,513
(Recycled Water)
4%
16,134,000
(Ground Water)
0%
9,154
(Surface Water)
28%
107,803,000
(Brackish/Ground Water)
66%
254,875,242
(Ocean/Recycled Water)
3%
9,802,377
(Ocean/Surface Water)
Surface Water
Ground Water
Recycled Water
Brackish Water/Ground Water
Ocean/Surface Water
Ocean/Recycled Water

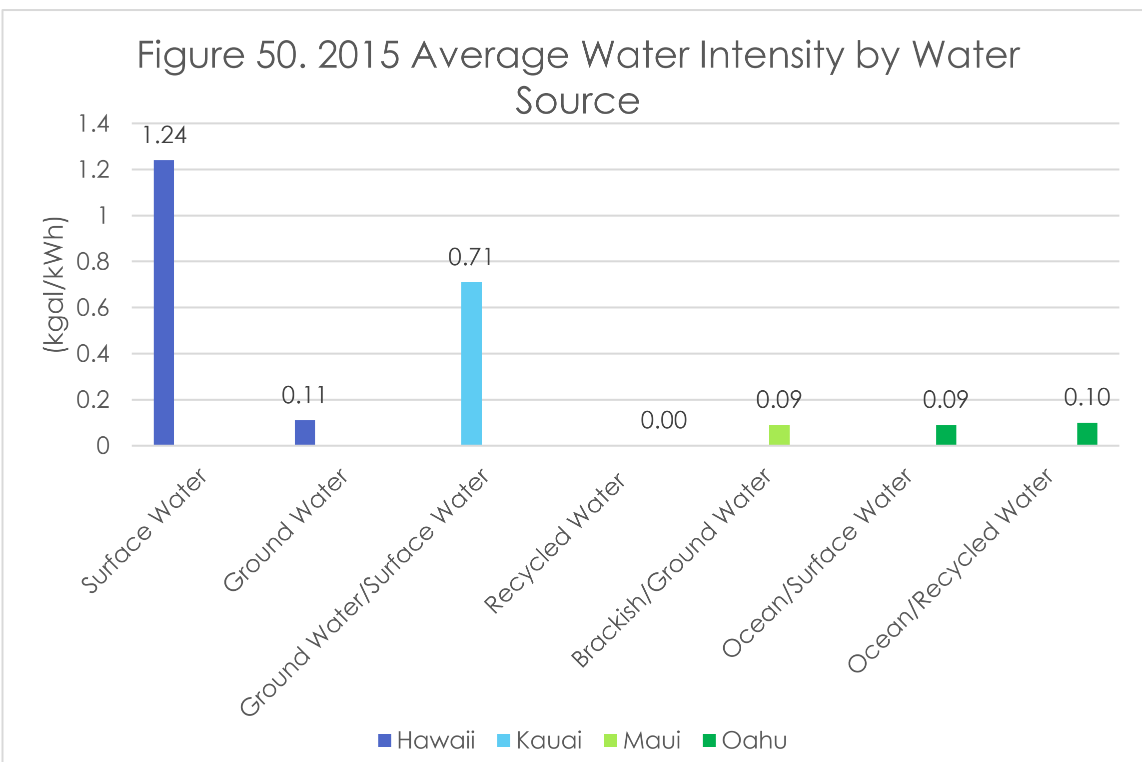


Figure 50. 2015 Average Water Intensity by Water Source
(kgal/kWh)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1.24
0.11
0.71
0.00
0.09
0.09
0.10
Surface Water
Ground Water
Ground Water/Surface Water
Recycled Water
Brackish/Ground Water
Ocean/Surface Water
Ocean/Recycled Water
Hawaii
Kauai
Maui
Oahu

c) Summary

As shown in Figures 48 and 50, less recycled water is required to produce the same amount of energy as ground water. Diversifying the source of water used for energy production can help conserve potable water and improve system efficiency. In addition, the purchase of recycled water can offset electricity costs associated with pumping ground water or brackish water used for cooling and production.

12) OPPORTUNITIES AND CONSTRAINTS FOR WATER & ENERGY MANAGEMENT

Energy consumption accounts for a large portion of a utility's operating budget. Energy management practices, or conservation measures, can help to decrease energy use and minimize operating costs.

Energy management opportunities for water and wastewater utilities can be classified into four main groups: optimizing system operations, renewable energy sources, demand response strategies, and best management practices. Table 22 provides examples for each type of opportunity.

Table 22. Energy Management Opportunities

Optimizing System Operations	Renewable Energy Sources	Demand Response Strategies	Best Management Practices
• Data monitoring and flow control • Leak detection • Calibration and/or replacement of flow meters • High efficiency Pumps and Motors	• Solar fields • Hydropower • Biogas • Thermal energy conversion • Other sources	• Shift demand to off peak hours • Backup generators	• Conduct annual facility energy assessments • Monitor real time energy consumption • Personnel education

a) Optimizing System Operations

If treatment requirements become more stringent for both the water and wastewater industries, utilities will be required to implement additional processes that will require more advanced technologies. Though advances in technology are producing more energy efficient equipment components, there will still be an increase in energy use due to additional treatment requirements. Optimizing the operation of the system can help to offset the energy demand of the system as a whole.

Data monitoring and flow control

Supervisory Control and Data Acquisition (SCADA) systems can be used to remotely monitor, gather and process data from water and wastewater systems. SCADA systems have the ability to monitor pump status, flows, pressures and storage levels from field devices and recommend optimal pumping operations for energy efficiency. SCADA can also be used to control peak demand, monitor ground water wells and control wastewater treatment processes. All data is collected in real time allowing operators to have complete oversight over their system.

Leak Detection

Unrealized water losses and storm water infiltration can contribute to water and wastewater system inefficiencies as systems are collecting and/or treating in excess of required water demands and generated wastewater flows. Since energy use is directly proportional to flows conveyed through the system, excess flows contribute to increased energy costs and lost revenue.

No water system is completely free of leaks. Water losses can come from leaks in the system, water meter inaccuracies, data handling errors and unauthorized consumption. Efforts to limit water losses include leak detection and repair of pipes and reservoirs, and regular water audits. The DOH SDWB offers funding mechanisms and technical support to County water systems for water system improvements.

Under Act 169 Session Laws of Hawaii (SLH) 2016, Relating to Water Audits, the Commission is in the process of implementing a standardized water audit program and associated training for public utilities across the State. The program is based on the methods adopted by the American Water Works Association's Water Audit and Loss Control Programs, Manual of Water Supply Practices-M36, as amended. The program will help utilities understand the real and apparent water losses of their system, conserve water and energy and recover lost revenue. The program targets county run public water systems, large capacity public water systems (>1,000 population served), and public water systems located in designated water management areas.

In conjunction with leak detection programs, utilities should regularly replace aging pipes. Pipe breaks can result in significant water losses, upwards of hundreds of thousands of gallons. Regular replacement of pipes and reservoir lining can help mitigate the occurrence and severity of breaks, reducing system water losses.

In wastewater systems, inflow and infiltration from storm water during rain events can contribute to significant increases in wastewater influent. Storm water can enter the wastewater system via holes, joints and cracks in manholes and pipes. In the event of huge storm events, storm water can even surcharge pipes and manholes, resulting in wastewater spills. Closed circuit television inspections and smoke testing for pipes and manhole inspections can help to identify cracks, leaks or abnormalities in the system. Repair of those deficiencies can restrict wastewater treatment to the appropriate flows and eliminate incidences of excessive flows and wastewater overflows.

In the past, Counties used to operate a combined wastewater and storm water system, where storm water runoff was collected and treated by wastewater treatment plants. However, the Counties have since separated the two systems with storm water being discharged directly into the ocean with minimal treatment. While storm water systems have its own infrastructure, there are still some interconnections between the storm water system and the wastewater system. These interconnections should be removed to reduce the amount of water being treated and ensure that only wastewater is being treated.

Calibration and/or replacement of flow meters

In addition to leak detection, water utilities should calibrate and replace source and customer flow meters to ensure accurate meter readings and water balance calculations. Inaccuracies in customer water meter readings can result in significant revenue losses.

High efficiency pumps and motors

Pumps and motors are typically oversized for peak demand instead of average daily flows. This can result in pumps with low efficiencies, as the pumps are operating at average flows for the majority of the time. Using pumps that are sized to handle actual flow requirements can improve pump efficiencies and manage system demands. Supplemental pumps can be used to handle any additional flows. At the time of replacement, pumps and motors should be upgraded together as a whole to optimize overall performance.

Variable frequency drives (VFD) can also be used in water and wastewater systems to match the motor output speeds to load requirements and avoid running at full power at all times. VFD are ideal for large pump applications with variable flow rates. Although the upfront cost is high, the costs can be offset by savings in operating costs.

b) Renewable energy sources

To offset energy requirements, water and wastewater utilities can develop renewable energy sources to power individual equipment components. Within the existing system infrastructure, there are opportunities to recover energy from water delivery and wastewater treatment via conduit hydropower and biogas production.

Conduit hydropower uses turbines installed in conduits to capture the energy from water flowing in the pipeline. Ideal candidates for conduit hydropower include pipelines with high pressure differentials and high continuous flows. Packaged systems are being developed to simplify installation and siting requirements. While this system can utilize existing pipelines, the potential energy production is relatively small and can only produce a portion of the total energy needs.

Biogas is a byproduct of wastewater processing. Generated during anaerobic digestion, biogas is typically flared into the atmosphere. Recent studies have discovered that biogas can be collected and used for combined heat and power production. Biogas can be used to power treatment plants or be fed into the grid for other uses. In California, the Orange County Sanitation District uses biogas to produce electricity and renewable hydrogen for transportation fuel.

Water and wastewater utilities that have substantial lands or right-of-ways or have opportunities to partner with private land owners, near their operations, can develop large scale renewable energy systems to support their system. Potential sources of renewable energy for utility use are solar, wind, hydropower and thermal energy conversion. Systems that are primarily dependent on renewable energy should be connected to the grid or backup generators in the event that not enough renewable energy is generated.

Energy produced in excess of system requirements may be sold to other entities or electrical providers through power purchase agreements. However, power purchase agreements have been difficult to obtain as the proposed purchase rate per kWh is often lower than the cost to produce a single unit. Although these utilities are offsetting a portion of their operational costs by selling their excess energy, they are still operating at an overall loss. Coupled with huge upfront capital costs, constructing large renewable energy systems may not be financially feasible or desirable for utilities and private developers. To incentivize the development of large scale renewable energy systems, utilities should work with the public utilities commission to determine fair purchase rates.

In an effort to promote the construction of renewable energy systems, the legislature recently approved Act 173 SLH 2016, Relating to Hydroelectric Power, which authorizes the construction of small hydropower facilities in agricultural zoned districts under the HRS Section 205-2. Wind farms, biofuel processing facilities and solar farms are already authorized uses in agricultural districts.

c) Demand Response Strategies

Demand response strategies can be used to mitigate the energy use of water and wastewater systems during peak energy demand periods. While these strategies may not reduce energy use, they can provide significant cost savings and manage system demands. Water and wastewater systems are good candidates for demand response strategies as these systems typically contain significant amounts of storage.

Examples of demand response strategies include:

- Operating mixers, aerators and energy intensive treatment systems during off peak hours,
- Filling water reservoirs during off peak hours and only pumping as necessary during peak hours to meet water demands
- Scheduling pumping for high lift pump stations during off peak hours to minimize costs
- Allowing pumps to use power from a backup generator when ground water pumping during critical peak periods cannot be deferred.

Individual systems should be analyzed to determine which strategies are most appropriate given the demands and storage capacity of the system.

Backup pumps

Due to the energy rate structure, utilities are often forced to pay high electrical costs to operate backup pumps for short periods of time during routine maintenance inspections. The backup pumps are required in the event that one of the primary pumps fail. The pumps are operated periodically (exercised) to ensure that it can run in the event of an emergency.

To curtail high electrical costs, because they are only operated for short periods of time, backup pumps can be powered by backup diesel generators or renewable energy sources during maintenance inspections. The pump should also be connected to the main power supply and controlled by SCADA in the event that it needs to be fully operational for an extended period of time.

d) Best Management Practices

Best management practices can be implemented to raise awareness of a facility’s energy use. Practices include conducting annual facility energy assessments, monitoring real time energy consumption and personnel education/training. By conducting annual facility energy assessments and monitoring real time energy consumption, utilities are able to identify and monitor the consumption of individual system components and consumption trends.

Identifying equipment inefficiencies and energy consumption trends can help utilities optimize their system and develop effective demand response strategies. Educating in house staff on energy conservation practices can help reduce energy use associated with the day to day operations of the system.

13) OPPORTUNITIES FOR WATER MANAGEMENT FOR ENERGY UTILITIES

As discussed, water is required for energy production. Managing the amount of water used by electrical utilities can help to reduce overall water consumption by utilities. Opportunities for managing water use include diversifying the water source, utilizing closed looping cooling systems, conducting regular facility water audit assessments and using renewable energy sources.

a) Water Supply Diversification

Power plants in Hawaii rely on surface water, ground water, recycled water and/or brackish water for electricity production. Limiting the quantity of fresh water or restricting the type of water used for energy production to recycled water and brackish water, where feasible, can help minimize the use of potable water. Since less recycled water is required to produce a unit of energy, energy production will not be negatively affected by the use of recycled water. Instead, the use of recycled water may improve efficiency and lower costs associated with pumping water from other sources.

b) Closed Looping Cooling System

Utilizing closed looping cooling systems can reduce the amount of water required for cooling. Closed looping cooling systems use minimal amounts of water as it reuses the water throughout the system. Water is only withdrawn if any water used for cooling is lost through evaporation. In addition to using less water, closed looping cooling systems use less energy than once through systems as less water is required to be pumped from the source through the system.

c) Utility Water Audit Assessments

Facility water audit assessments can help identify areas of water inefficiencies within the system or facility and provide recommendations for conserving water during system operations. Addressing these inefficiencies can help reduce overall water use and operating costs. Funding for these improvements may be available through grants and loans.

d) Renewable Energy

Some renewable energy systems do not require water for energy production (e.g. wind and solar). Utilities seeking to diversify their energy portfolio and reduce their water use and costs may consider the implementation of these renewable energy systems. Different types of renewable energy systems should be evaluated to determine which system provides the most benefit for the utility’s needs.

14) FINDINGS AND RECOMMENDATIONS

a) Findings

Water and energy play integral roles in the production of each resource. Energy is required for the production of potable water and vice versa. Neither one can be produced without the other.

Understanding this water-energy relationship is crucial for developing effective water conservation programs and policies. To understand water and energy use, this study surveyed the largest consumers and producers of water and energy - utilities.

As part of this study, water and energy consumption data for 2014 and 2015 was obtained from 39 public and private utilities throughout the State. To quantify the water energy relationship, energy intensity, or the amount of energy required to collect, treat and distribute 1,000 gallons of water, was calculated for each individual system or facility. Likewise, for electrical systems which consume water for energy production, water intensity, or the amount of water needed to produce a unit of energy, was calculated for each facility. Marginal cost was used to visually represent the cost of water use or production to the utility. Table 23 summarizes the energy intensities and marginal costs for water, wastewater and recycled water industries in 2014 and 2015. Table 24 summarizes the water use by electrical utilities in 2014 and 2015. Cost information for electrical utilities is not available. The findings presented herein are based on the data collected from the 39 participating utilities and may not accurately represent the industry as a whole.

Table 23. 2014 and 2015 Water and Energy Use

Year[1]	**Industry**	**Energy Intensity (kWh/kgal)/**		**Marginal Cost ($/kgal)**	
		Range	Average	Range	Average
2014	Water	0.0 – 24.6	4.4	$0.06 - $9.22	$1.66
2015	Water	0.0 – 23.9	5.1	$0.03 - $7.50	$1.70
2014	Wastewater	2.1 – 23.5	7.2	$0.49 - $8.66	$2.54
2015	Wastewater	3.1 – 24.2	12.1	$0.91 – 6.98	$3.87
2015	Recycled Water	0.1 – 6.3	3.5	-	-

[1] The number of participating utilities varied for each year; therefore, data for 2014 and 2015 cannot be compared against each other as the number of utilities or participating utilities may not be the same.

Table 24. 2014 and 2015 Electrical Water Use

Year[1]	Water Intensity (kgal/kWh)	
	Range	Average
2014	0.00 – 1.09	0.15
2015	0.00 – 1.45	0.35

In general, energy use for the collection, treatment, distribution and disposal for each industry varies from system to system, depending on system characteristics. Table 25 summarizes some of the primary drivers that factor into the energy and water use of a system.

Table 25. Primary Drivers of Energy and Water Use

Water	• Pumping: well depth, elevation, distance, volume, pressure • Volume treated • Source: ground water, surface water, brackish, ocean • Treatment technology
Wastewater	• Pumping • Volume collected and treated • Level of treatment: primary, secondary, tertiary • Treatment technology: activated sludge, UV disinfection
Recycled Water	• Pumping - distribution • Volume collected and treated • Level of treatment: R-1, R-2, R-3, R-O • Treatment technology: trickling sand filter, UV disinfection • Effluent distribution
Electrical	• Volume of electricity generated • Type of electricity production: fossil fuels, renewable energy

Related to drivers of energy and water use, the following trends were observed in participating utilities throughout the State:

- Less energy is required to treat smaller volumes of water, wastewater and recycled water
- Municipal water systems have lower energy intensities and marginal costs than private water systems
- The amount of energy required to pump ground water is dependent on the depth of the well. More energy is required to pump water from greater depths
- Brackish water mixed with recycled water is the most commonly used source of water for non-renewable energy production.
- Less recycled water and ground water is required to produce the same amount of energy as surface water or brackish water.

Since water and energy use is interdependent, reducing water use can reduce the amount of energy needed to collect, treat and distribute water. This can contribute to savings in operating costs. Water use can be managed through conservation efforts, optimizing system operations and implementing demand response strategies.

b) Water & Energy Conservation Strategies

In order to protect Hawaii's current and future fresh water resources, it is important to develop and implement water conversation strategies and programs targeted at both utilities and end users. Recommended water conservation strategies include:

- Increased public education and awareness for water conservation
  Due to the high cost of electricity, most consumers practice or implement energy efficient practices and systems. As a result, there is tremendous emphasis placed on decentralized renewable energy systems and the use of energy efficient appliances. Meanwhile, because water is relatively inexpensive, there is little financial incentive for consumers to reduce their water use. Other than in periods of drought and water restrictions, there is little to no driving factor for consumers to conserve water. Water conservation efforts should be as prevalent as energy conservation.

  Many public utilities have public education and conservation programs in place to help customers identify ways to use less water. Public education should emphasize the importance and imminence of protecting the State's limited supply of fresh water resources. Understanding the need for conservation is imperative for getting customers to practice water conservation. In addition, education on the fees imbedded in the water bill can help customers understand the cost of water.

  In addition to public education, emphasis should be placed on reducing the water use of large consumers in an effort to decrease overall water use. Working closely with these customers to understand their system operations can help to identify opportunities for water conversation. Potential opportunities include the use of drip irrigation systems, recycled water for irrigation, upgrading the plumbing system in older buildings and low flow fixtures. Utilities should also identify and work with customers with significant water overuse in comparison to similarly characterized customers or their allowed water allocation, to identify ways to reduce their water use.

- Water conservation rate schedule
  Increasing water rates may prompt consumers to conserve water, in an effort to reduce their water bill. Water utilities should take into consideration the

potential of reduced revenue from water conservation efforts, when evaluating rate schedules.

- Encouraging the use of recycled water in urban settings
  Recycled water is slowly becoming an accepted, alternative source for landscape irrigation water for golf courses and schools. Recycled water can also be used for carwashes, construction, industrial uses and toilet and urinal flushing.

  Each county currently operates its own water reuse program. However, there are only a handful of recycled water facilities on each island. Although recycled water facilities can consume more energy than water systems, the reuse of wastewater decreases overall water consumption, lessening the demand on fresh water resources.

  Since recycled water is treated wastewater, there may still be some misconceptions by the public that recycled water may not be safe for use. Without understanding how wastewater is treated for public safety, the public may oppose and protest the use of recycled water. For this reason it is imperative that utilities develop and implement robust public education programs to address the public's health concerns regarding the safety and cleanliness of using recycled water. Without public support, it will be difficult to get customers to accept the use of recycled water.

- Implementation of water and energy audit programs
  Regular auditing of the system can help utilities identify equipment inefficiencies and areas of lost revenue (i.e. real and apparent losses), as well as provide a thorough understanding of their system operations. Better understanding of their system operations can help purveyors identify unusual spikes and activity in their systems faster, leading to increased system efficiency and faster recovery of lost revenue. If conducted by a third party, utilities should designate in house personnel familiar with the system to oversee the program.

- Development of a water use policy for appropriate water use
  Utilities should develop policies for the appropriate use of potable water. As water is a precious resource, the Commission has adopted a policy of "highest and best use", where the quality of the water supply should be matched to the quality of water needed, and the highest quality water should be allocated for the highest uses. However, potable water can be used for non-potable purposes if there are no practical non-potable alternatives, until such time that an alternative non-potable source becomes available. Non

potable uses such as irrigation and water features should explore and utilize alternative sources of water including recycled water, rainfall reuse or gray water.

Gray water is untreated wastewater discharged from showers, hand washing sinks and washing machines. Since gray water cannot come into contact with black water (wastewater discharged from toilets and kitchens), two separate wastewater piping systems are required to separate the two. Gray water systems are regulated by DOH to ensure the safety of public health. Although gray water has fewer bacterial contaminants than black water, there are still application restrictions.

- Increased collaboration between industries and government agencies
  As water and energy use is interdependent, it is important to understand and acknowledge that water conservation is a multi-industry effort and a single industry cannot independently effect water conservation strategies with widespread results. Inter-utility coordination is necessary for developing effective and mutually beneficial conservation initiatives and programs. Lack of communication could result in policies that while benefitting the issuing agency could either negatively impact other agencies or miss greater opportunities. The Hawaii Water Plan provides an opportunity for utilities to coordinate with the state's future water use. Increased utility coordination with energy management plans can further help to identify areas of potential conflicts and opportunities for integration.

- Identify opportunities to recharge ground water aquifers
  In addition to reducing water use, recharging the ground water aquifers will also protect the State's fresh water resources. Recharging ground water aquifers will allow well levels to replenish and increase the amount of water available for use. Higher levels of ground water will reduce the amount of energy needed to collect the water. Recharge mimics the natural water cycle, returning needed resources back to the environment.

c) Recommendations

- Explore the means to promote the coordination of individual water and energy conservation efforts and policies
- Provide incentives for utilities to develop joint infrastructure improvements focused on water and energy efficiency
- Require new developments with large projected water demands to meet minimum water and energy efficiency requirements

- Utilities should develop an audit program to monitor the efficiency of the system and designate a program coordinator to implement water and energy conservation initiatives.
- Develop methodologies for evaluating tradeoffs in water and energy use
- Provide incentives and fair rate structures for utilities to develop large scale renewable energy systems that can generate excess energy for the grid
- Establish pilot programs to track the impact of different conservation methods on energy intensity
- Expand the sample size and continue to characterize the energy intensity for utilities across the State to provide a comprehensive overview of water and energy use
- Develop methodologies for selecting and implementing cost effective conservation technologies and programs
- The price to purchase alternative sources of water and energy should be set to encourage use. Subsidies could be provided to allow for competitive pricing.
- Utilities and state water planners should develop public education programs targeting end use water efficiency and explaining the water energy nexus in Hawaii
- The county public works departments should identify areas of storm water inflow into wastewater systems and increase the integrity of their pipelines
- Require tracking and reporting of surface water requirements for hydroelectric facilities to determine the system's impact on fresh water sources
- Identify opportunities for decentralized systems to reduce energy use from pumping operations
- Allocate financial and human resources to exploring, piloting and integrating innovative technologies into water utilities

d) Future Studies

This study is intended to provide an overview of water and energy use of the various utilities throughout Hawaii and is in no means an in-depth analysis of the intricacies of each system component. Should detailed system information be desired, additional studies limited to a specific system or group of systems should be conducted for the particulars. Examples of more detailed studies include understanding the use for each type of treatment process and impacts of the varying elevations of system components on energy use.

The following are suggestions for additional studies to further understand water and energy use in Hawaii:

Agricultural Use

Hawaii is historically known for its agriculture. Early Native Hawaiians built intricate ditch systems to transport stream water for taro cultivation and domestic needs. With the advent of the sugar industry, elaborate ditch and tunnel systems were constructed to divert water from windward streams to the drier leeward plains where large contiguous acreages were planted in sugarcane. Many of these irrigation systems are still used today.

Although the majority of these systems are gravity fed and do not use energy, because agriculture is a significant aspect of Hawaii's economy, future studies concentrating on agricultural water energy use should be conducted to understand the water energy relationship from an agricultural perspective. Understanding this relationship will help to identify the tradeoff between using water resources for potable water, energy use and food production.

In addition, should surface water sources continue to diminish, alternative sources for irrigation will be required. Identifying the demand of these irrigation systems will be critical for identifying viable irrigation sources. The Agricultural Water Use and Development Plan, a component of the Hawaii Water Plan that is prepared by the State Department of Agriculture, provides estimates of existing and future demand for selected irrigation systems. Another forecasting tool, the Irrigation Water Requirement Estimation Decision Support System (IWREDSS), has been developed by the Commission in collaboration with the University of Hawaii, College of Tropical Agriculture and Human Resources, to estimate water duty. Using these two tools together, based on the location of their farm, farmers can determine which crops can be solely dependent on ambient rainfall for irrigation needs.

Renewable Energy

Last year Hawaii enacted its clean energy initiative which mandates that all of the State's electricity come from renewable sources no later than 2045. As the State prepares to achieve this goal, it is important to ensure that the proposed renewable sources are also sustainable and that 100% renewable energy can be maintained. The US Department of Energy (DOE) in partnership with the Hawaii Natural Energy Institute recently completed a Programmatic Environmental Impact Study (PEIS) to analyze the potential environmental impacts of various renewable energies. The study outlines the impacts of the various technologies to water resource and provides guidance for selecting the appropriate technologies. The study, combined with further examination of the performance of existing renewable energy systems in Hawaii, can help to determine which technologies would be the most suitable for implementation by specific utilities. Permitting requirements for each island with respect to different renewable energy systems are presented in the Guide to Renewable Energy Facility Permits in the State of Hawaii, version 3, dated 2015 prepared by the Hawaii State Energy Office. Knowledge of the water intensities associated with the various technologies and water sources can help utilities make informed decisions on potential renewable sources with regard to water use.

15) LIMITATIONS

This study is intended to provide an overview of the water energy relationship within utility companies throughout the State of Hawaii. Limitations in the data presented in the study include:

Limited participation

A total of 137 utility companies were contacted for voluntary participation in the study. Of those, approximately 47 percent of the utility companies responded to the survey with only 28 percent participating in the study. The majority of the respondents were municipal and governmental agencies which, while greatly contributing to water and energy use amongst utility providers, cannot definitely characterize use throughout the State by itself as it only accounts for a portion of the total use.

For example, with the rise of renewable energy projects and systems, the amount of water used to produce energy is decreasing. Though renewable energies may attribute to only a fraction of energy production in comparison to fossil fuels, it is an important component of Hawaii's energy portfolio, which cannot be overlooked. Likewise, data from private companies would help to provide a more comprehensive overview of water and energy use throughout the State. Better understanding the water energy nexus will aid in developing water conservation measures specific to Hawaii's utility portfolio.

Energy Rate Schedule

In additional to energy consumption charges, utility providers are subject to a fuel charge and demand charge as part of their electricity bill. While the fuel charge is based on the kWh use within the billing cycle, the demand charge is based on the highest peak kW during any 15-minute period within an eleven month period. Under this structure, utilities are required to pay monthly demand charges even if the system is only operated periodically. This is the case with backup pumps that need to be tested for short periods of time for maintenance purposes. The demand charge can often result in a significant portion of the energy bill.

Without having information on the fuel charge and demand charge, it is difficult to determine the true cost of the energy consumed. As a result, the electrical data presented in this study represents the cost to the utility.

16) WATER AND ENERGY EFFICIENCY RESOURCES

The following programs and funding mechanisms provide information and resources for implementing water and energy efficiency practices. There are a number of different water and energy efficiency and funding programs available to utilities; the programs listed herein is by no means comprehensive and is instead meant to provide a starting point for further research.

Hawaii Energy

hawaiienergy.com

Hawaii Energy is a conservation and efficiency program administered by Leidos Engineering, LLC under contract with the PUC, for the Hawaii, Honolulu and Maui counties. The goal of the program is to educate, motivate and incentivize residents and businesses to adopt energy conservation behaviors and efficiency measures. As part of the program, Hawaii Energy offers several energy conservation services including education and training for residents, businesses and trade allies; cash rebates and incentives for energy efficient equipment for homes and businesses; and energy assessments and management plans for distribution, collection, conveyance and treatment facilities.

Hawaii Energy's Water and Wastewater Energy Management Best Practices Handbook provides an overview of energy efficient best management practices and outlines the potential impacts on productivity, economic benefit and potential energy savings.

Energy Excelerator

energyexcelerator.com

Energy Excelerator is non-profit cleantech business accelerator program formed by the Pacific International Center for High Technology Research (PICHTR). Funding for the program is provided by the U.S. Department of Defense, U.S. Department of Energy, the State of Hawaii, and private investors. Energy Excelerator partners with innovative companies, to provide grant funding and networking opportunities with investors, corporations and strategic partners. The program has partnered with over forty companies, with missions revolving around the energy grid, efficiency, financing, transportation, agriculture and water. Utilities can partner with businesses associated with Energy Excelerator to implement new water and energy efficient technologies.

Partnering companies targeting water efficiency include WaterSmart and GOmeter. WaterSmart is a software application that seeks to reduce water use through customer engagement and education. The software generates customer water use and efficiency reports to help customers understand their water use. The software can also detect potential leaks and provide water saving recommendations. As part of Energy

Excelerator's demonstration program, WaterSmart is working with water utilities in Honolulu and Hawaii Island to improve water use efficiency and customer engagement.

GOmeter converts traditional water meters into smart water meters through the installation of a camera based device. The device tracks water use throughout the day allowing residents and business to identify water usage patterns, leaks and appliance malfunction.

Energy Savings Performance Program

https://energy.gov/eere/slsc/energy-savings-performance-contracting

Energy Savings Performance Contracting (ESPC) allows government agencies to enter into a long term partnership with an energy service company (ESCO) to facilitate and accelerate water and energy conservation measures and increase operational efficiency. The partnership allows the agency to pay for the improvements without tapping into capital budgets. Under the ESPC process, the ESCO conducts an energy audit of the agency's facilities and recommends potential energy conservation measures. Selected improvements can be financed through a municipal tax-exempt lease purchase agreement, internal financing or bonds.

The City and County of Honolulu, Board of Water Supply (BWS) currently has a 20 year ESPC with NORESCO LLC to reduce the BWS' annual electrical usage by 8 million kWh. Proposed energy conservation measures include the installation of photovoltaic systems, energy efficient pumps, lighting, air conditioning and power factor correction equipment.

Water Research Foundation

http://www.waterrf.org/Pages/Index3.aspx

The Water Research Foundation is a not-for-profit research cooperative that funds and manages research for drinking water, wastewater, stormwater and reuse. The website provides valuable information, resources and tools for a range of topics affecting utilities including distribution system management, energy management, water supply diversification and utility management.

Water Audit Program

Under Act 169 SLH 2016, the Commission is required to develop and implement a standardized water audit program and provide associated training to counties and public water utilities. The program is based on the methods adopted by the American Water Works Association's (AWWA) Water Audit and Loss Control Programs – M36, as amended.

In 2015, the Commission began a targeted pilot program to train 15 PUC regulated public water systems on the AWWA water audit method. Beginning July 1, 2018, county owned public water systems will be required to submit annual water audits to the Commission. All remaining public water systems serving a population of 1,000 or more and public water systems in water management areas will be required to submit annual water audits to the Commission beginning July 1, 2020.

DOH SDWB Drinking Water State Revolving Funds

health.hawaii.gov/sdwb/drinking-water-state-revolving-fund/

Established in 1997, the State of Hawaii, Drinking Water State Revolving Fund program provides low interest loans to the County's water department for construction of drinking water infrastructure projects. Since implementation, DOH has funded over 60 projects totaling over $184 million dollars. Examples of projects eligible for loans include water treatment facilities, transmission and distribution of water, storage capacity development, development of new drinking water sources, and green projects. While the program currently limits funding to the County water departments, the DOH is planning to expand the program to include funding mechanisms and technical support to small, private water systems for water system improvements in the future.

US Department of Agriculture (USDA) Rural Development Loan & Grant Programs

https://rd.usda.gov/program-services/program-services-utilities

U.S. Department of Agriculture (USDA) Rural Development provides loan and grant funding for clean and reliable drinking water systems, sanitary sewage and solid waste disposal and storm water drainage for eligible rural areas. Eligible areas are defined as rural areas and towns with fewer than 10,000 people. Specific loans and grants may have additional requirements to qualify as an eligible area. Applicants are limited to State and local government entities, private non-profits and federally recognized Tribes. Funds may be used to construct, enlarge, extend or improve rural systems.

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APPENDIX A: SAMPLE SURVEY FORMS

Company Name ______________________

Water System Name	Facility Street Address	City, Island	Potable/Non-Potable	Number of Customers/Service Connections					Estimated Population Serviced	Estimated Cumulative Length of Pipeline	Booster Pumps	Map Attached of Water System Service Area (Yes or No)
	(Address/Coordinates/TMK)			Residential	Commerical	Industrial	Other (Describe type)	Total		(All sizes, excluding laterals)	(Yes or No)	
								0				

Company Name 0

If water use data for each process is not avaliable, please provide total water usage and energy production

*Please provide monthly data -- if available -- on next tab labeled "Monthly Data". Otherwise please enter annual data (January 1 - December 1) for 2014 and 2015 on this table

Water System Name	Water Source (Utility company, ground water, salt water [≥17,000 mg/l chloride], brackish water [250 to 16,999 mg/l chloride], surface, etc.)	Name/Location of Water Source (If location, provide address, coordinates, or TMK)	Volume of Water Treated (MG)*	Volume of Water Pumped (MG)*	Volume of Water Distributed (MG)*	Type of Energy Used (Gas, Oil, Coal, Renewable Energy, Purchased Electricity, etc. For renewable energy, please describe type. For purchased electricity, indicate utility provider)	Energy Used (kW)*	Electricity Cost*	Operating Month/Year (If providing annual data, indicate 2014 or 2015)

Company Name 0

Water Source	Date (M/YY)	Volume of Water Treated (MG)	Volume of Water Pumped (MG)	Volume of Water Distributed (MG)	Energy Used (kW)	Electricity Cost

Company Name ______________________________

Wastewater System Name	Data Classification	Facility Street Address	City, Island	Number of Customers/Service Connections					Estimated Population Serviced
	(Basin, Subbasin, Treatment Plant, Tributary, Pump Station, Other)	(Address/Coordinates/TMK)		Residential	Commerical	Industrial	Other (Describe type)	Total	
								0	

Company Name 0

Estimated Cumulative Length of Pipeline (All sizes, excluding laterals)		Lift or Pump Stations	Injection Wells	Map Attached of Water System Service Area (Yes or No)
Gravity Pipe	Force Main	(Yes or No)	(Yes or No)	

Company Name 0 0

If water use data for each process is not avaliable, please provide total water usage and energy production

*Please provide monthly data -- if available -- on next tab labeled "Monthly Data". Otherwise please enter annual data (January 1 - December 1) for 2014 and 2015 on this table

Wastewater System Name	**Level of Treatment**	**Volume of Wastewater Received (MG)***	**Volume of Wastewater Treated (MG)***	**Volume of Wastewater Disposed (MG)***	**Method of Disposal**	**Type of Energy Used**	**Energy Used (kW)***	**Electricity Cost***	**Operating Month/Year**
	(Primary, Secondary, Tertiary)				(ocean outfall, recycling, injection well, etc.)	(Gas, Oil, Coal, Renewable Energy, Purchased Electricity, etc. For renewable energy, please describe type. For purchased electricity, indicate utility provider)			(If providing annual data, indicate 2014 or 2015)

Company Name 0

Wastewater System Name	Date (M/YY)	Volume of Wastewater Received (MG)*	Volume of Wastewater Treated (MG)*	Volume of Wastewater Disposed (MG)*	Energy Used (kW)	Electricity Cost

Company Name ______________________

Recycled Water Facility Name	Facility Street Address (Address/Coordinates/TMK)	City, Island	Number of Customers/Service Connections					Estimated Cumulative Length of Pipeline (All sizes, excluding laterals)	Lift or Pump Stations (Yes or No)	Map Attached of Water System Service Area (Yes or No)
			Residential	Commerical	Industrial	Other (Describe type)	Total			
							0			

Company Name 0

If water use data for each process is not avaliable, please provide total water usage and energy production

*Please provide monthly data -- if available -- on next tab labeled "Monthly Data". Otherwise please enter annual data (January 1 - December 1) for 2014 and 2015 on this table

Recycled Water Facility Name	Type of Recycled Water Produced	Wastewater Source	Volume of Wastewater Received (MG)*	Volume of Wastewater Treated (MG)*	Volume of Recycled Water Distributed (MG)*	Type of Energy Used	Energy Used (kW)*	Electricity Cost*	Operating Month/Year
	(R-O, R-1, R-2, R-3)					(Gas, Oil, Coal, Renewable Energy, Purchased Electricity, etc. For renewable energy, please describe type. For purchased electricity, indicate utility provider)			(If providing annual data, indicate 2014 or 2015)

Company Name 0

Wastewater Source	Date (M/YY)	Volume of Wastewater Received (MG)*	Volume of Wastewater Treated (MG)*	Volume of Recycled Water Distributed (MG)*	Energy Used (kW)	Electricity Cost

Company Name ______________________

Facility Name	Facility Street Address (Address/Coordinates/TMK)	City, Island	Energy Source (used for energy production) (Gas, Oil, Coal, Renewable Energy, Other, etc. If renewable energy or other, please describe type)	Number of Customers/Service Connections: Residential	Commerical	Industrial	Other (Please describe)	Total	Estimated Population Serviced	Is water used for energy production? (Yes or No)
								0		

Company Name 0

If water use data for each process is not avaliable, please provide total water usage and energy production

*Please provide monthly data -- if available -- on next tab labeled "Monthly Data". Otherwise please enter annual data (January 1 - December 1) for 2014 and 2015 on this table

Facility Name	Energy Source (used for energy production)	Water Source (associated with Energy Production)	Name/Location of Water Source	Process Description	Volume Water Used (MG)*	Water Cost*	Operating Month/Year	Energy Produced (kW)*
	(Gas, Oil, Coal, Renewable Energy, Other, etc. If renewable energy or other, please describe type)	(Utility company, ground water, salt water [≥17,000 mg/l chloride], brackish water [250 to 16,999 mg/l chloride], surface, etc.)	(If location, provide address or coordinates)	(Extraction, Cooling, Production, Distribution, etc.)			(If providing annual data, indicate 2014 or 2015)	

Company Name 0

Water Source (associated with Energy Production)	**Date (M/YY)**	**Process Description** (Extraction, Cooling, Production, Distribution, etc.)	**Volume Water Used (MG)**	**Water Cost**	**Energy Produced (kW)**	**Electricity Cost**

APPENDIX B: LIST OF UTILITIES

As part of this study, 137 government agencies and private utility purveyors were contacted to provide information regarding their system operations. The information gathered from the participating utilities allowed the Commission to better understand the water and energy relationship in the State of Hawaii. The following utilities were contacted as part of this study:

WATER

- Hawaii Island
    - County of Hawaii, Department of Water Supply
    - Hawaii Water Service Company
    - Hawaiian Beaches Water Company, Inc.
    - Hawaiian Shores Association
    - Kaupulehu Water Company
    - Keopu Water Association
    - Kohala Ranch Water Company
    - Mauna Loa Macadamia Nut
    - Napuu Water Inc.
    - Pepeekeo Water Association, Inc.
    - S.M. Investment Partners
    - South Kohala Water Corporation
    - State of Hawaii
        - Department of Hawaiian Homelands
        - Department of Health
        - Department of Public Safety
    - Waiki Ranch Homeowners Association

- Kauai
    - Aqua Engineers
    - Department of Water, County of Kauai
    - Grove Farm Company, Inc.
    - Kealia Water Company Holdings, LLC
    - Moloaa Water Distribution Company, LLC
    - Princeville Utilities Company, Inc.
    - State of Hawaii, Department of Hawaiian Homelands

- Lanai
    - Lanai Water Company, Inc.

- Maui
    - A&B Properties
    - County of Maui, Department of Water Supply
    - Consolidated Baseyard Association
    - Bio-Logical Capital
    - Hawaii Water Service Company
    - Kahakuloa Acres Water Company
    - Kula Nani Estates Community Association
    - Maunaolu Plant Homeowners Association
    - Pural Water Specialty Company
    - Ohanui Corporation
    - West Kuiaha Meadows Homeowners Association
    - West Maui Land Company

- Molokai
    - County of Maui, Department of Water Supply
    - State of Hawaii, Department of Hawaiian Homelands
    - Waiola O Molokai, Inc./ Molokai Public Utilities
    - Kawela Homeowners Association

- Oahu
    - City and County of Honolulu, Board of Water Supply
    - Dole Food Co., Inc.
    - Gill Ewa Lands, LLC
    - Hawaii County Club LLC
    - Hawaii Nature Center
    - Hawaii Reserves, Inc.
    - Kahuku Water Association, Inc.
    - Kamehameha Schools
    - Kipapa Acres CPR Water System
    - Kunia Village Title Holding Corporation
    - Kyo-ya Company, Ltd.
    - Naval Facilities Engineering Command, Hawaii
    - North Shore Water Company, LLC
    - Poamoho Water Association, Inc.
    - Punahou School
    - Queen’s Medical Center
    - St. Stephen Diocesan Center
    - State of Hawaii
        - Department of Business, Economic Development and Tourism, Hawaii Housing Finance & Development Corporation
        - Department of Public Safety

    - Department of Transportation
  - United States
    - Department of the Army Directorate of Public Works
    - Marine Corp

WASTEWATER/ RECYCLED WATER

- Hawaii
  - Cellana
  - County of Hawaii, Department of Environmental Management
  - Hawaii Water Service Company, Inc.
  - Kohanaiki Shores, LLC
  - S.M. Investment Partners
  - South Kohala Water Corporation
  - State of Hawaii, Department of Transportation
  - Waimea Wastewater Company, Inc.

- Kauai
  - Department of Environmental Management, County of Kauai
  - HOH Utilities, LLC
  - Kawailoa Development, LLP
  - Kukui'ula South Shore Community Services
  - Princeville Utilities Company, Inc.

- Lanai
  - County of Maui, Department of Environmental Management
  - Pulama Lanai

- Maui
  - ATC Makena WWTP Services Corporation
  - County of Maui, Department of Environmental Management

- Molokai
  - County of Maui, Department of Environmental Management
  - Molokai Ranch Ltd

- Oahu
  - Aqua Engineers
  - City and County of Honolulu
    - Board of Water Supply
    - Department of Environmental Services
  - Hawaii Agriculture Research Center

        - Hawaii American Water
        - Pural Water Specialty Company, Inc.
        - State of Hawaii, Department of Public Safety
        - United States
            - Army Directorate of Public Works
            - Marine Corp

ENERGY

- Hawaii
    - BHE Renewable
    - County of Hawaii, Department of Water Supply
    - Hamakua Energy Partners
    - Hawaiian Electric Light Company
    - Ormat Technologies, Inc.
    - Puna Geothermal

- Kauai
    - A&B Properties/McBryde Sugar Company
    - Agribusiness Development Corporation
    - Gay and Robinson
    - Green Energy Kauai
    - Kauai Island Utility Cooperative
    - Kekaha Agricultural Association
    - Pacific West Energy LLC

- Lanai
    - Lanai Sustainability Research

- Maui
    - Hawaii Commercial & Sugar Company
    - Makila Land Company, LLC
    - Maui Electric Company

- Molokai
    - Maui Electric Company

- Oahu
    - City and County of Honolulu, Department of Environmental Services
    - Covanta Honolulu
    - AES Hawaii
    - Chevron

- Hawaiian Electric Company
- Hawaii Independent Energy
- Kalaeloa Partners