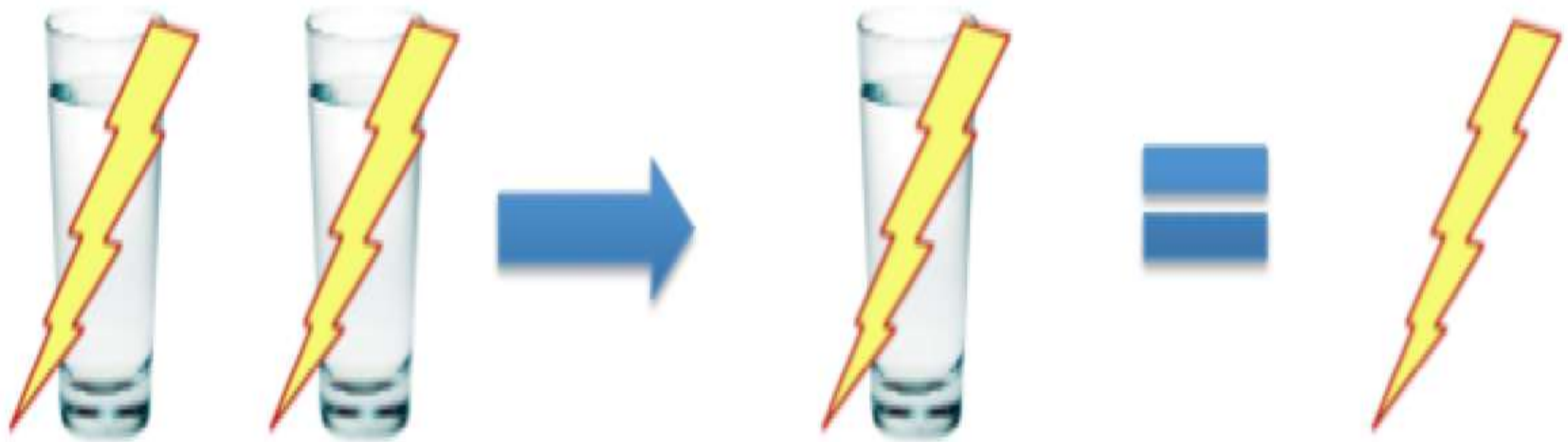


Embedded Energy in Water Systems

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Dr. House has a Bachelors, two Masters, and a Ph.D. in Engineering and Economics from University of California at Davis. He is a Certified Energy Manager (CEM) and a Certified Sustainable Development Professional (CSDP) with the Association of Energy Engineers. He taught engineering in Graduate School at U.C. Davis for a number of years and is the founder and Co-Director of Hydropower for the U.C Davis Energy Institute. He worked for the California Energy Commission for five years as a utility planner, and he was the chief utility planner for the California Public Utilities Commission for five years. In 1990 he went out into the consulting business, starting his own business (Water and Energy Consulting). He has been the Association of California Water Agencies (ACWA) energy consultant since 1992, representing 500 water agencies which are responsible for over 90 percent of the water delivered in California, and is the California Rural Water Association (CRWA) energy specialist, representing over 1,100 rural water and wastewater systems. Dr. House also works for the California Public Utilities Commission as an expert witness on transmission issues and is their water-energy expert, and for the California Energy Commission as a researcher. He is an investment management expert consultant in the water and energy areas for: Gerson Lehrman Group-GLG Scholar Program, eWork Markets, Price Waterhouse-Vantage Marketplace, Roundtable Group, and Standard & Poor's—Society of Industrial Leaders. He has been responsible for training and installation of over 25 small hydroelectric facilities in Southeast Asia. He is a member of the American Water Works Association (AWWA), American Society of Civil Engineers (ASCE), Sigma Xi- the National Research Honor Society, and Association of Energy Engineers (AEE).



What You Will Learn in This Class

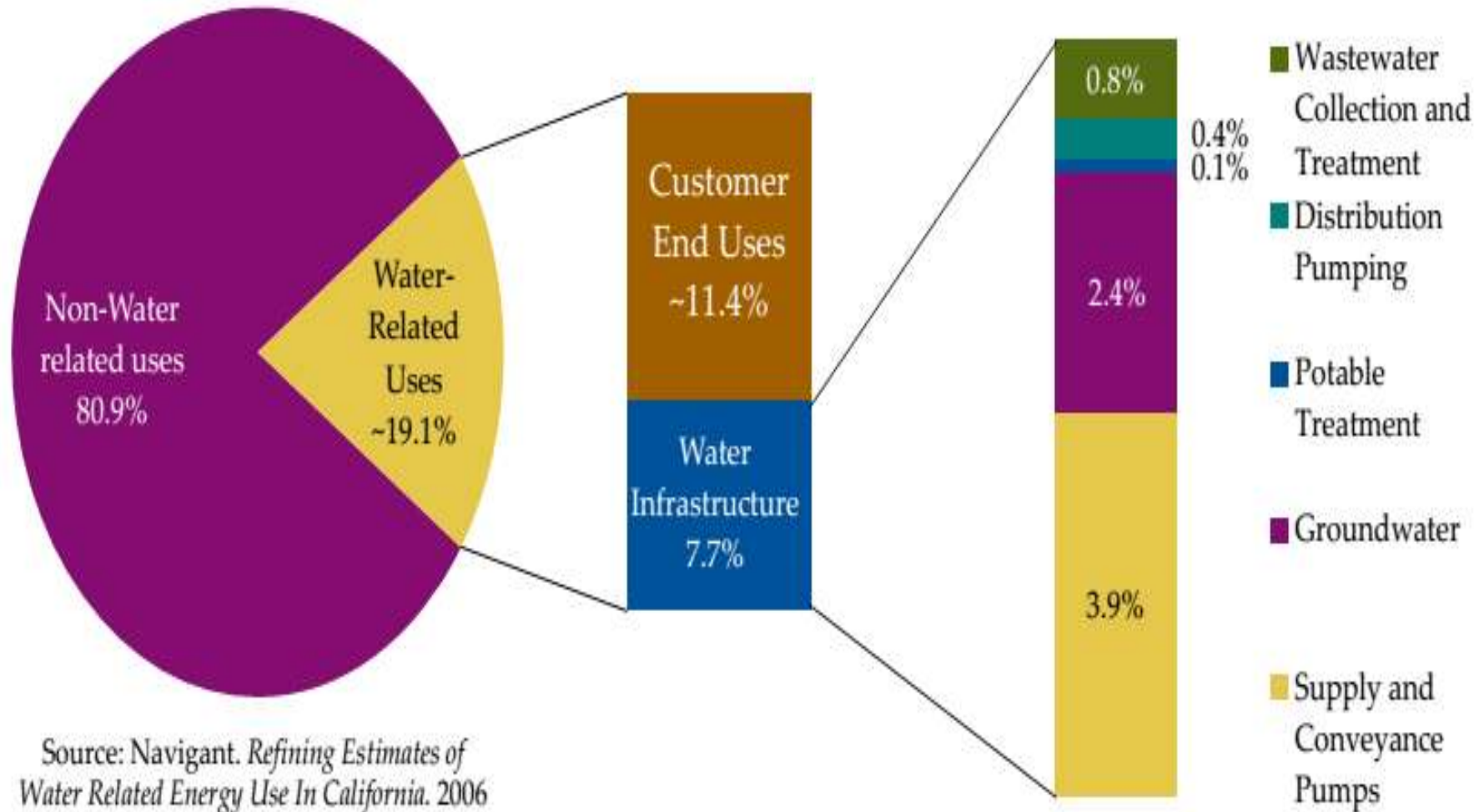
- What is embedded energy and energy intensity
- How to determine your system embedded energy
- How to use embedded energy values
- Some things to watch out for with embedded energy calculations and use

Embedded Energy

- **Embedded energy** is the sum of all the energy required to produce any goods or services, considered as if that energy was incorporated or 'embodied' in the product itself. The concept can be useful in determining the effectiveness of energy-producing or energy-saving devices and, because energy-inputs usually entail greenhouse gas emissions, in deciding whether a product contributes to greenhouse gasses. One fundamental purpose for measuring this quantity is to compare the amount of energy produced or saved by the product in question to the amount of energy consumed in producing it.

The Infamous 20%

California Statewide Electricity Use



Source: Study 1 and Study 2

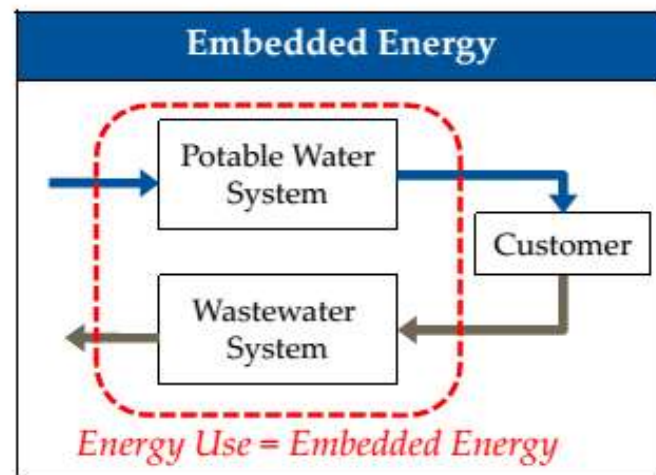
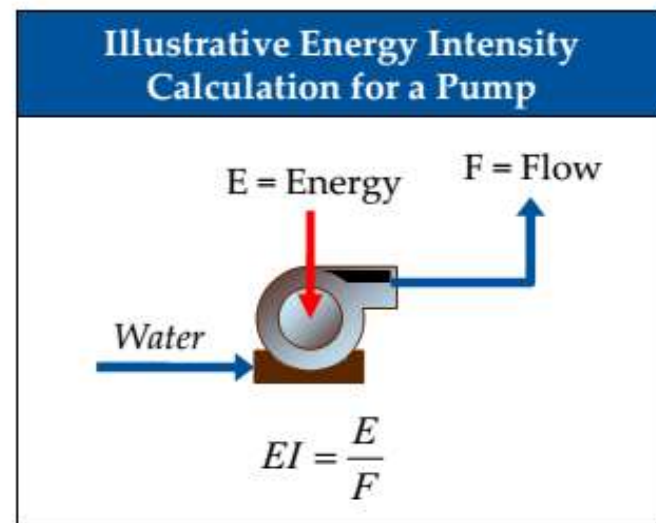
Energy Intensity and Embedded Energy are two terms that are key to understanding the Water-Energy nexus

» Energy Intensity (EI)

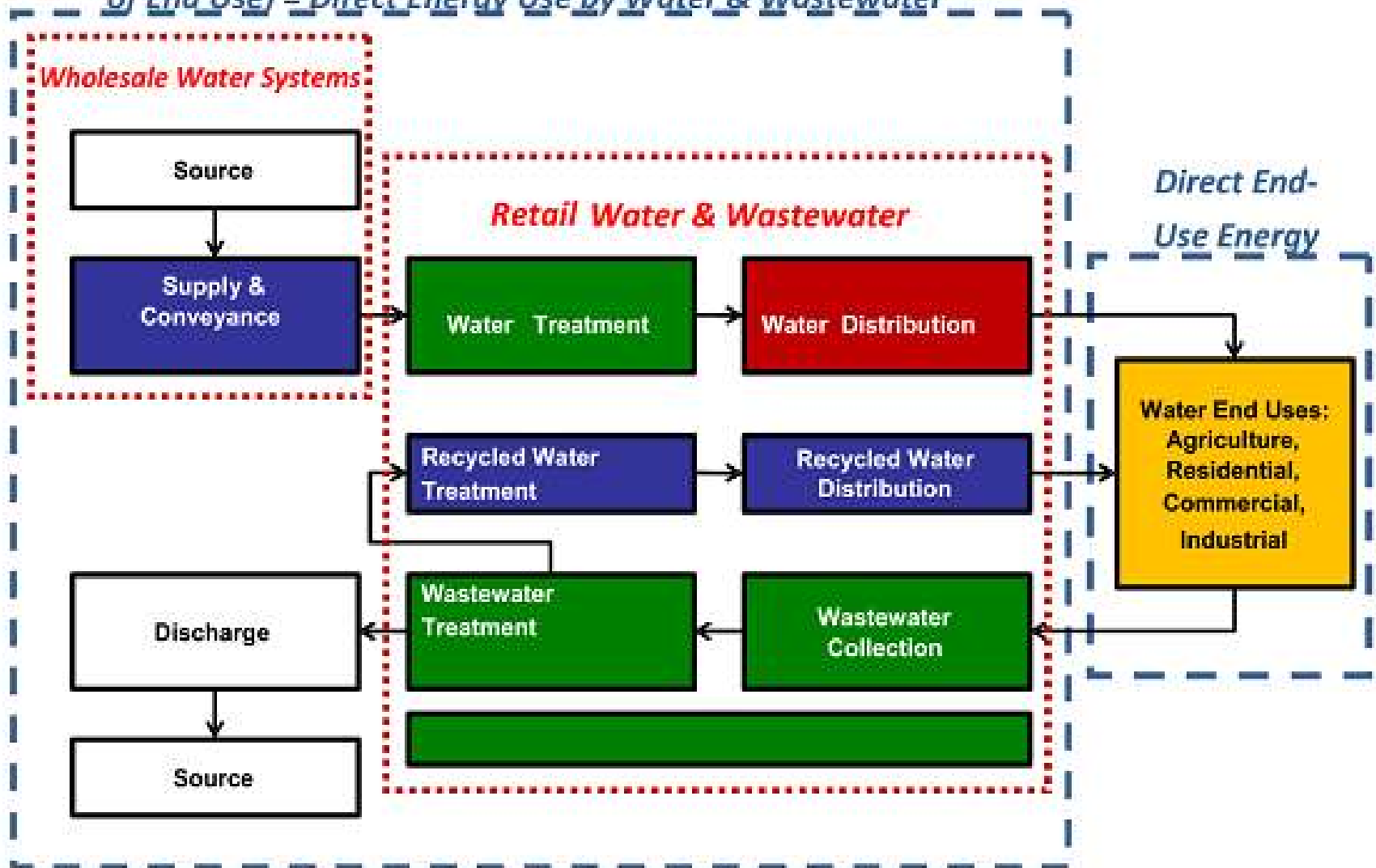
- The average amount of energy needed to transport or treat water or wastewater on a per unit basis (kilowatt hours per acre-foot of water [kWh/AF]).
- The energy intensity is associated with a particular facility and is similar to a measure of efficiency.
- The energy intensities of individual facilities within a water agency can be aggregated to represent the energy intensity of water supply.

» Energy Embedded in Water

- The amount of energy that is used to collect, convey, treat, and distribute water to end users, and the amount of energy that is used to collect and transport wastewater for treatment prior to safe discharge of the effluent.
- Captures the entire energy picture both upstream and downstream of an end use customer.
- Embedded energy is not associate with a particular facility but with the water itself.

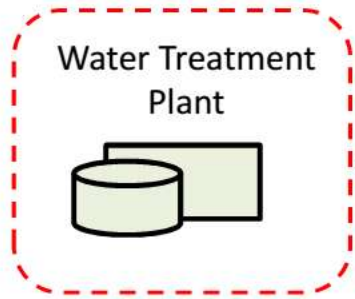


Indirect, or "Embedded" Energy (Upstream & Downstream of End Use) = Direct Energy Use by Water & Wastewater

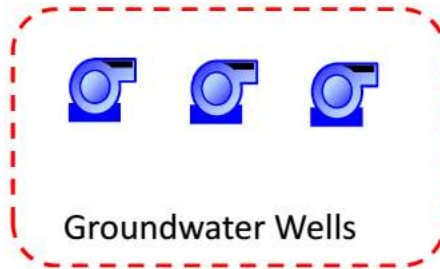
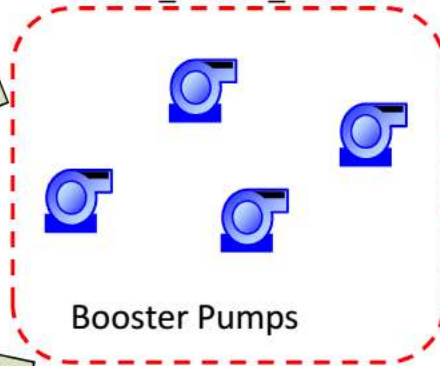


- Aggregating energy and water data for groups of facilities allows calculation of Energy Intensity by supply type.

$$EI = \frac{\text{Total_Plant_Energy_Use}}{\text{Total_Water_Treated}}$$

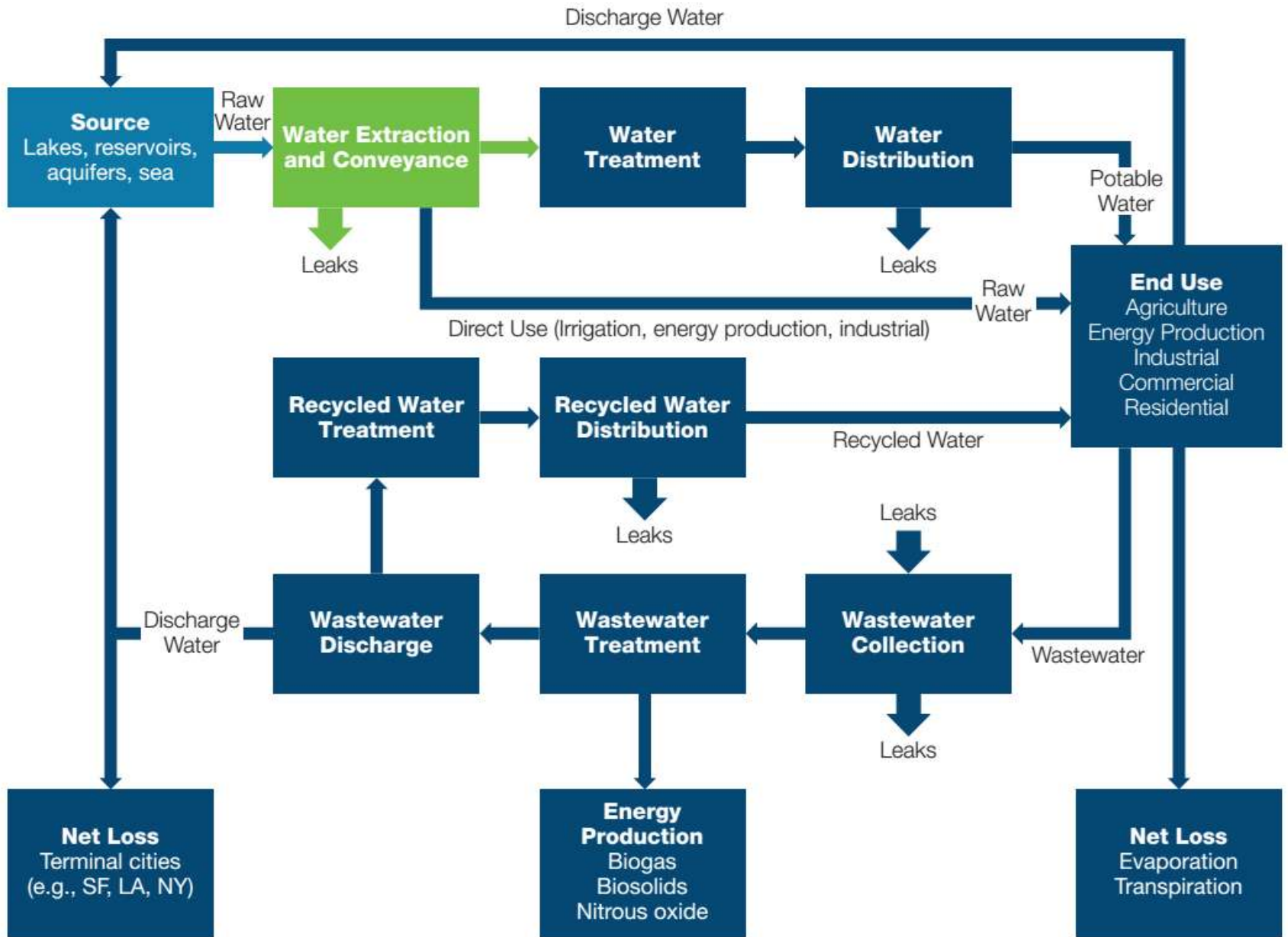


$$EI = \frac{\text{Total_Booster_Pump_Energy_Use}}{\text{Total_Water_Delivered}}$$



$$EI = \frac{\text{Total_Groundwater_Pump_Energy_Use}}{\text{Total_Groundwater_Pumped}}$$

$$EI = \frac{\text{Total_Plant_Energy_Use}}{\text{Total_Wastewater_Treated}}$$



Source: Adapted from Wilkinson, 2000

Step 1: Get Electric Billing Data for all Accounts

PG&E account	Annual KWH Usage				
	2010	2011	2012	2013	2014
<u>Production</u>					
lift station	15,664	15,870	18,380	16,310	14,681
WELL #14	448,211	454,088	525,935	466,694	420,080
WELL #18	415,674	421,124	487,755	432,815	389,585
COUNTRY CLUB TANK SITE	1,046	1,059	1,227	1,089	980
COLLEGE FAIRFAX TANK SITE	2,330	2,361	2,734	2,426	2,184
WELL #19	573,473	580,992	672,918	597,122	537,480
BIG BERTHA PUMP STATION	362,511	367,265	425,374	377,460	339,759
EAST NILES TANK SITE	80,638	81,695	94,621	83,963	75,577
MORNING DRIVE TANK SITE	214,161	216,970	251,299	222,993	200,720
CORNER TANK PUMP STATION	155,115	157,149	182,014	161,512	145,380
WELL #20	391,875	397,014	459,830	408,035	367,280
WILSON RD PUMP STATION	375,505	380,429	440,621	390,990	351,937
Well #21	925,930	938,071	1,086,494	964,114	867,816
PEPPER DR.TANK SIGHT	0	0	0	0	0
LIFT STATION	11,641	11,793	13,659	12,121	10,910
Kern Citrus Pump Station	651,967	660,516	765,024	678,853	611,048
<u>Treatment</u>					
TREATMENT SITE	356,598	361,274	418,435	371,304	334,217
BRECKENRIDGE FILTRATION PLANT	42,321	42,876	49,660	44,066	39,665
<u>Ancillary</u>					
SL# 17313	536	543	628	558	502
OFFICE	46,879	47,494	55,009	48,812	43,937
SHOP	12,753	12,921	14,965	13,279	11,953
SYSTEM	5,084,330	5,151,000	5,966,000	5,294,000	4,765,225

Step 2. Get Water Production Data

<i>Million Gallons per Year</i>						
	<u>2010</u>	<u>2011</u>	<u>2012</u>	<u>2013</u>	<u>2014</u>	5 year average
<u>Annual Water Production</u>	3,730.1	3,846.5	4,188.6	4,222.7	4,106.0	4,018.8
					Low	3,730.1
					High	4,222.7

Step 3. Determine System Embedded Energy: Divide Energy Use by Water Produced to Get Embedded Energy

	<i>kWh/MG</i>					
	<u>2010</u>	<u>2011</u>	<u>2012</u>	<u>2013</u>	<u>2014</u>	5 year average
System Embedded Energy	1,363	1,339	1,424	1,254	1,161	1,307
Treatment	107	105	112	98	91	103
Pumping - Distribution	1,240	1,218	1,296	1,141	1,056	1,190
Ancillary	16	16	17	15	14	15
					Low	1,161
					High	1,424

Step 4. Evaluate Water/Energy Savings Measures

<u>Audit Date</u>	<u>Location</u>	<u>Volume of Water Loss (GPM)</u>	<u>Volume of Water Loss (GPY)</u>	<u>Current status</u>	<u>Date fixed</u>	<u>Description of Fix</u>	<u>Cost of Fixing Leak (\$)</u>	<u>kWh Saved Per Year</u>	<u>Retail Value of Electricity (\$/Yr)</u>
1/12/2015	6" AC (Asbestos Cement) pipe	1	525,840					687	\$137

Comments: lot of small leaks at O-rings, several valve leaks of about 0.5gpm
 note- kWh saved includes only treatment and supply/distribution electricity

Uses of Embedded Energy Values

- Benchmark your water system
- Evaluate energy use within your system
- Evaluate water conservation measures
- Evaluate energy efficiency measures
- Address policy issues
- Partner with electric utilities on water conservation

Table EW-1: Embedded Energy in the Water Cycle

Water Cycle Segments	Range of Embedded Energy (kilowatt hours/million gallons)		
	Low	High	Typical Southern California Urban Water System
Supply and Conveyance	0	14,000	8,900
Treatment	100	16,000	100
Distribution	700	1,200	1,200
Wastewater Collection and Treatment	1,100	4,600	2,500
Wastewater Discharge	0	400	n/a
Recycled Water Treatment and Distribution	400	1,200	n/a

Source: California Energy Commission, California's Water-Energy Relationship, final staff report, 2005.

Embedded Energy in Water Systems: PG&E Territory

	Supply (kWh/MG)	Treatment (kWh/MG)	Distribution (kWh/MG)	Wastewater (kWh/MG)
California American Water, Monterey (1)	1,319	390	1,375	6,223
California American Water, Monterey (2)	2,681			4,739
City of Fresno (1)	1,264			1,724
City of Santa Cruz (1)	1,034	325	393	1,593
City of Santa Rosa (1)	2,384	6	512	4,541
City of Watsonville (1)	1,608			2,129
East Bay Municipal Utility District (1)	163	110	924	1,448
East Bay Municipal Utility District (2)	310	220	510	NA
North Marin Water District (1)	2,433			NA
San Jose Water Company (1)	1,912	129	592	2,074
San Jose Water Company (2)	1,778	469	944	NA
Santa Clara Valley Water District (1)	2,304	359	982	2,074
Sonoma County Water Agency (1)	2,890			3,544
Sonoma Valley area (1)	1,859	6	1,921	4,299
Northern California (CEC) (1)	2,117	110	1,270	1,912
Pacific Institute Model (1)	798	169	1,212	1,350
Contra Costa Water District (2)	1,159	1,060	1,058	NA
Marin Municipal Water District (2)	276	296	617	1,619
Monterey Regional Water Pollution Control Agency (2)	NA	NA	266	1,537
Natomas Mutual Water Company (2)	3	NA	NA	NA
Semi-tropic Water Storage District (2)	963	NA	NA	NA

Statewide Energy Intensity Range of Observed Infrastructure

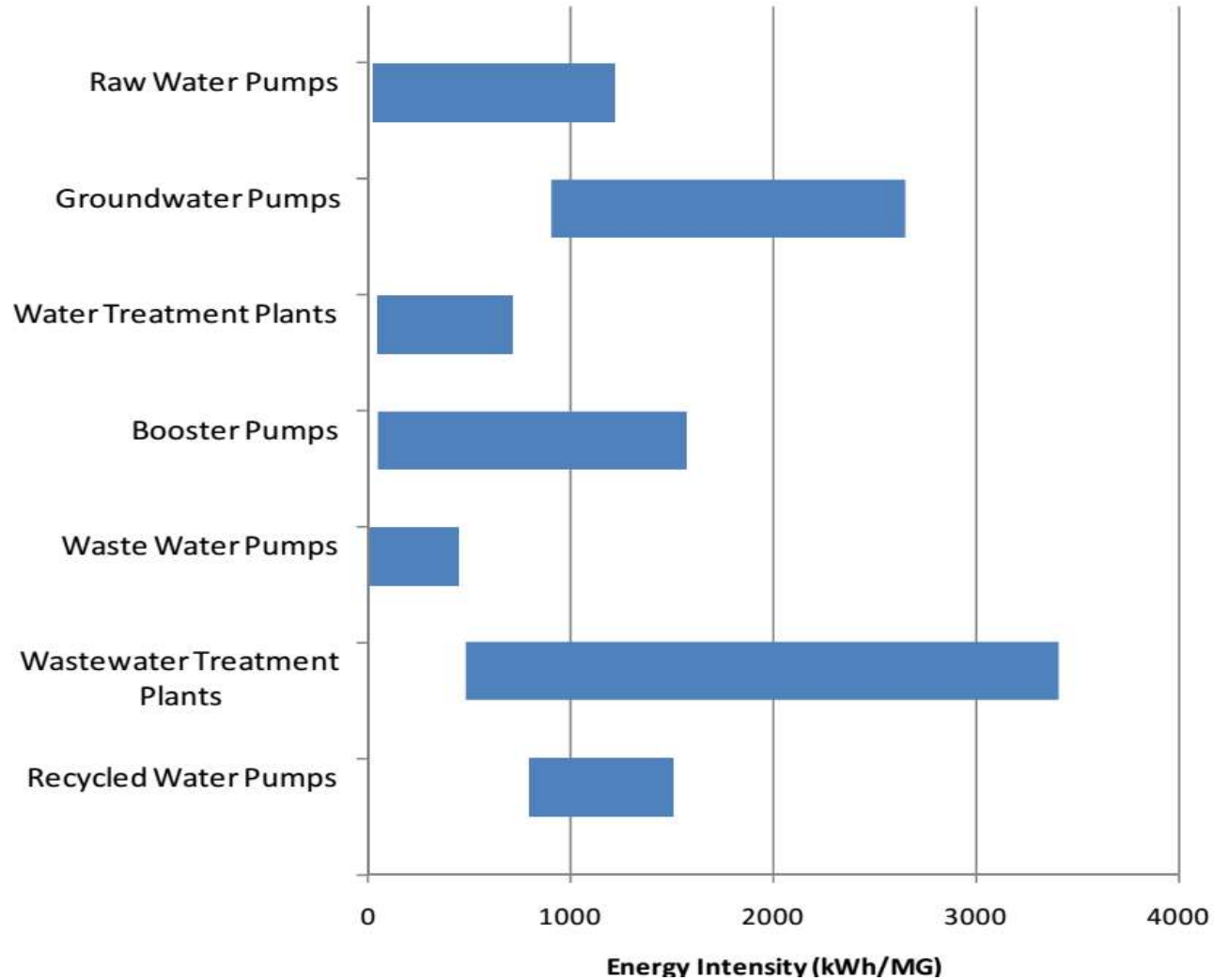


Table 6 - Water-Energy Measures, Costs and Savings Potential

End Use	Measure	Incremental Cost Range*	Percent Water Savings**	Percent Energy Savings**
Irrigation	Efficient irrigation sprinkler heads	\$5 to \$7 per head	20%	Varies
	Smart/weather-based irrigation controls	\$120 to \$350 per controller	6% to 25%	Varies
	Xeriscaping	\$1 to \$3 per square foot	100%	Varies
Toilets/Urinals	Low flow toilets	\$50 per toilet	20%	Varies
	Dual flush toilets	\$50 per toilet	33%	Varies
	Low flow urinals	\$25 to \$100 per urinal	87%	Varies
	Zero-water urinals	\$90 per urinal	100%	Varies
	Sink to toilet gray water system	\$200 to \$600 per system	27%	Varies
Faucets/Showers	Low flow showerheads	\$5 per showerhead	40%	Varies
	Low flow faucet aerators	\$5 per aerator	40%	Varies
	Shower timers	\$5 to \$15 per timer	0% to 35%	Varies
	Shower timers with automatic cutoff	\$90 per timer	35%	Varies
	Drain water heat recovery	\$300 to \$500 per system	N/A	30% to 40%
Appliances	Residential high efficiency dishwasher	\$150 to \$300 per dishwasher	42%	23%
	Residential high efficiency clothes washer	\$200 to \$600 per clothes washer	35%	48%
	Residential high efficiency water heater	\$100 to \$1000 per water heater	N/A	10% to 50%
	Commercial high efficiency dishwasher	\$0 to \$1000 per dishwasher	15% to 50%	10% to 50%
	Solar water heating	Varies based on size	0%	40% to 60%
	Institutional laundry equipment (high efficiency tunnel washers, ozone, wastewater recycling)	Varies based on size	15% to 50%	10% to 50%
	Commercial high efficiency water heater	Varies based on size	N/A	10% to 50%
Comprehensive	On-site rainwater harvesting	\$2 to \$8 per gallon of storage capacity	Varies based on size	Varies based on size
	On-site grey water reuse	Varies based on size	Up to 30% in Residential, 10% in Commercial	Varies based on size
	On-site water recycling (6,000 to 35,000 gallons per day capacity)	\$40 to \$100 per gallon of daily capacity	Varies based on size	Varies based on size
	Community scale storm water recharge	Varies based on size	Varies based on size	Varies based on size
	City-scale water recycling (1 MGD or larger)	\$4 to \$7 per gallon daily capacity	Varies based on size	Varies based on size

*Incremental cost is the cost difference between a standard unit and a high efficiency (low flow) unit.

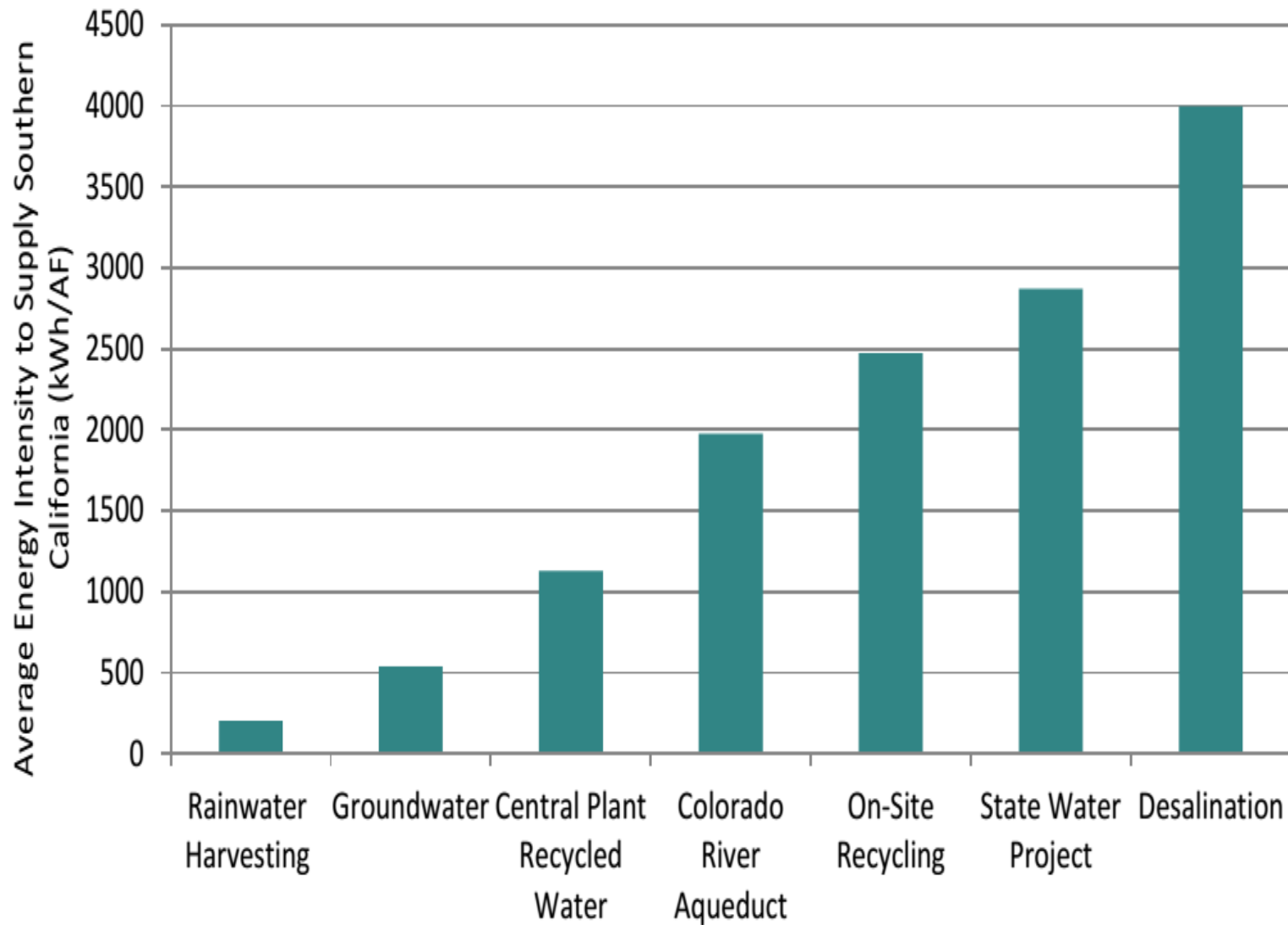


Table 2: Total Water System Embodied Energy and Carbon Dioxide Emissions

Water System Element	Energy Intensity (kWh/gal)	House Demand (gal/day)	Energy Consumption/Day (kWh/day)	Energy Consumption/Day (kWh/year)	Carbon Conversion Factor lbs CO ₂ /kWh (kg CO ₂ /kWh)	CO ₂ Emissions per year lbs CO ₂ /year (kg CO ₂ /year)
Water Treatment	0.001406	350	0.4921	179.62	1.16 (0.53)	208 (94)
Wastewater Treatment	0.001911	350	0.66885	244.13	1.16 (0.53)	283 (128)
Water Distribution (Pumping)	0.000764 [1] 0.001500 [2]	350	0.2674 [1] 0.5250 [2]	97.60 [1] 191.63 [2]	1.16 (0.53)	113 (51) [1] 222 (101) [2]
Wastewater Collection	0.0001960 [1] 0.0009796 [2]	350	0.06860 [1] 0.34286 [2]	25.04 [1] 125.14 [2]	1.16 (0.53)	29 (13) [1] 145 (66) [2]
					Total	634 (288) [1] 859 (390) [2]

Table 3: Residential End-Use Energy & Carbon Footprint Estimates for Virginia

Appliance	Use Assumptions	kWh/use	kWh/year	CO ₂ Emissions per year lbs CO ₂ /year (kg CO ₂ /year)
Microwave Oven	96 times per year	0.945 kWh per use (based on 1.39 kWh for full power and 0.5 kWh for defrosting)	90.72	105 (48)
Washing Machine	187 washes per year	EU energy label A-rated gives an average consumption at 40°C using a 2kg load to be 0.63 kWh	117.81	137 (62)
Electric Tumble Dryer	148 uses per year	2.50 kWh per cycle	370	105 (48)
Electric Oven	135.1 uses per year	1.56 kWh per use	210.756	244 (111)
Dishwasher at 65°C	135 uses per year	1.44 kWh per use	194.4	226 (103)
Fridge-Freezer A spec	24 hours a day	408 kWh per year	408	473 (215)
Personal computer	365 days a year	270 w x 2 hrs per use	197.1	229 (104)
Standard Light Bulb; assume 15 bulbs	4 hours a day	100 W	2,190	2,540 (1,152)

Assumptions for energy use were extracted from Carbon Footprint (2009)

Water-Energy Pilots



California Energy Commission: 19% of state electricity production is for water-related uses, recommends water savings included in electric utility EE portfolios

California Public Utilities Commission (CPUC) requests 4 largest investor owned energy utilities (IOEUs) to develop Pilot programs to investigate potential embedded energy savings. Specifically:

- IOEUs must partner with water provider
- Programs should be jointly funded
- Programs must quantify embedded energy in water to calculate potential energy savings

California Water-Energy Pilot Program

Table 1. California Water Energy Pilot Programs.

Large Commercial Customer – Audits and Incentives: Offered water audits to large commercial, industrial, and institutional customers to recommend water efficiency improvements and offered financial incentives to help offset the cost of improvements. Types of eligible improvements included: ozone laundry systems, winery and food processing changes, detention facility toilet and shower upgrades, and recycled water retrofit projects.

Large Customer Incentives: Provided capital funding to install water conservation measures at sites that had received prior water audits and where the customer had not yet acted to implement the identified measures.

Commercial Customer – pH Controllers and Irrigation: Provided systems pH controllers for cooling towers and Weather Based Irrigation Controllers (WBICs) to commercial customers with chilled water HVAC and/or large landscape irrigation systems.

High-Efficiency Toilets – Single Family: Direct install of high efficiency toilets (HETs) to low-income customers living in single-family residences.

High-Efficiency Toilets – Multi-Family: Direct install of high efficiency toilets to low-income customers living in multi-family residences.

Emerging Technologies – Water Systems: Integration of real-time electricity consumption data from water pumping into existing water system SCADA systems.

Leak Detection – Water Systems: Detailed water audits that complied with International Water Association and American Water Works Association protocols were completed for three water agencies. There was also an active leak detection effort for each water agency and the water agencies repaired all of the found leaks.

Landscape: Converted conventional irrigation controllers into controllers that utilize daily evapotranspiration (ET_o) and weather information to automatically and dynamically control the amount of water used for irrigation.

Recycled Water Program: Expanded recycled water use by providing capital funding for planned retrofit projects that switched from a potable water source to a recycled water source.

Results of the Pilots

- Water System Leak Detection program offered the greatest energy savings potential (at relatively low cost) among all the Pilots.
- Detention facility projects that installed efficient toilets, urinals and toilet flush timers in detention facilities generated high energy savings in a relatively untapped market.
- Recycled water retrofit projects can offer large potable water savings, but additional research is needed to determine the embedded energy in recycled water treatment (which offsets energy savings from potable water).
- For the other pilots, the program costs are likely to exceed the energy benefits.
- Additional research is needed on actual program spending, measure lifetimes, and potential changes in end-user energy. Program cost-effectiveness could be increased by reducing energy program funding levels and/or targeting programs to the most energy intensive water systems water savings.



“Beyond Cost Effectiveness”

Energy Efficiency Savings must be Measured & Verified

- Requirement: demonstrate real savings at the end of a program: for water efficiency this will mean embedded energy savings
- Without energy intensity of supplier, wholesaler and retailer, water savings by customers cannot be translated into energy savings



W-E Follow-up



- Leak Detection. The CPUC ordered the IOEUs in the state to fund trial water system leak detection programs for evaluation. These are currently being evaluated.
- Embedded Energy Determination and Reporting. The California Department of Water Resources, as part of their 2015 Guidebook for Urban Water Management Plans (UWMPs), has requested that the states' water agencies voluntarily include energy intensity information in their plan submittals.
- Water-energy Calculator. The CPUC has developed a water-energy calculator model, available on the CPUC website:
<http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/Water-Energy+Nexus+Programs.htm>
that water systems can use for evaluating electric utility investments in water conservation programs.

Another Tool – The EPA Energy Use Assessment Tool

- Free of charge, downloadable tool based in Excel that can be used by small and medium water and wastewater systems. The tool can be found at: http://water.epa.gov/infrastructure/sustain/energy_use.cfm
- EPA's self assessment checklists available at: <http://www.epa.gov/region9/waterinfrastructure/audit.html>
- Data required
 - All plant utility data (use and cost information) by month (minimum of 12 months) for up to 5 years of analysis- Collect from utility bills such as electric, natural gas, water/sewer, fuel oil, alternative energy, and other utilities
 - Non -process information (by building)
 - List of lighting fixtures
 - HVAC equipment
 - Drinking water and/or Wastewater treatment plant information
 - Monthly treatment/discharge volumes
 - Pump and motor nameplate data (horsepower, efficiency rating, full load amp rating)
 - Average motor operating amperage
 - Process energy demand and energy consumption

Some Observations



- Determining embedded energy in water isn't as simple as it looks. The amount of energy embedded in water depends upon, among other things:
 - the source(s) of water
 - the treatment processes
 - the amount of lost water
 - the efficiency of system infrastructure
 - the energy to include in the determination: self generation, non IOEU energy
 - The year the analysis is done
- Program development for joint programs is challenging. Water systems are familiar with developing water conservation programs. When an energy utility becomes involved this becomes more challenging:
 - determining electric utility contribution
 - who the program applies to
 - verification of energy savings
 - consistency of energy savings

EBMUD Energy Use (kWh/MG)



Water System	Normal Year	Dry Year
Supply/Conveyance	177	1,423
Treatment	156	1,610
Distribution	917	917
TOTAL	1,250	3,950

- Dry Year Scenario: Includes Mokelumne supply, supplemental water supply, desalination, groundwater and recycled water
- Gravity Water Customers (55%)= ~ 400 kWh / MG
- Pumped Water Customers (45%) ~ 2000 kWh/ MG

Why Water Savings Programs Are Better Than Energy Savings



- *Less overhead*
 - Energy projects are typically run by the electric utilities. Water efficiency programs typically deliver much more of the dollars spent in the actual on-the-ground projects.
- *Water efficiency savings more permanent*
 - Energy efficiency tends to be much more transitory, due to the substitution (Snackwell) effect. As population in California doubled during the last 30 years, electricity use has doubled, whereas water use has stayed the same.
- *Water efficiency saves both water and energy, energy efficiency savings save only energy*
 - Between 3-5% of all the electricity used in the U.S. is used to treat and distribute water (in California the number is over 7%). That means every time you save water you also are saving the energy that was previously used to treat and distribute that water.
 - When you save energy (with a more efficient refrigerator) you only save energy, no water. Water savings gives you double bang for your buck.

Conclusions from the Pilots

- Saving water saves energy. Anytime that you save water, particularly in urban environments, you will also save the energy - that energy that was used to obtain, treat, and distribute that water, as well as any energy required to collect and treat the wastewater.
- Partnerships between electric utilities and water systems can benefit both. Joint programs can allow combined water and energy audits, increased incentives for water conservation technologies, and reduced energy use in the water sector. The electric utility can claim energy credits as part of its energy efficiency portfolio, and the water system gets the water savings.
- Investments in water systems are likely to offer the greatest water and verified energy savings. The California pilots found that water system leak detection was the best program from a verified water and energy savings perspective of any of the pilots. Other programs that improve the efficiency of the water system (e.g., increased pump or treatment efficiency) will also provide verifiable energy savings.



Conclusions and Recommendations

- Embedded energy is a useful tool:
 - Benchmark your water system
 - Evaluate energy use within your system
 - Evaluate water conservation measures
 - Evaluate energy efficiency measures
 - Address policy issues
 - Partner with electric utilities on water conservation
- Embedded energy value can be used to justify system improvements, energy efficiency measures, and water conservation programs that may not be justified on water savings alone



SAVING WATER SAVES ENERGY