



# EFFECTIVE USE OF RECYCLED WATER IN COOLING TOWERS WITH NEW GREEN TECHNOLOGY

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# Cooling Tower Issues

# Tower Operator Goals



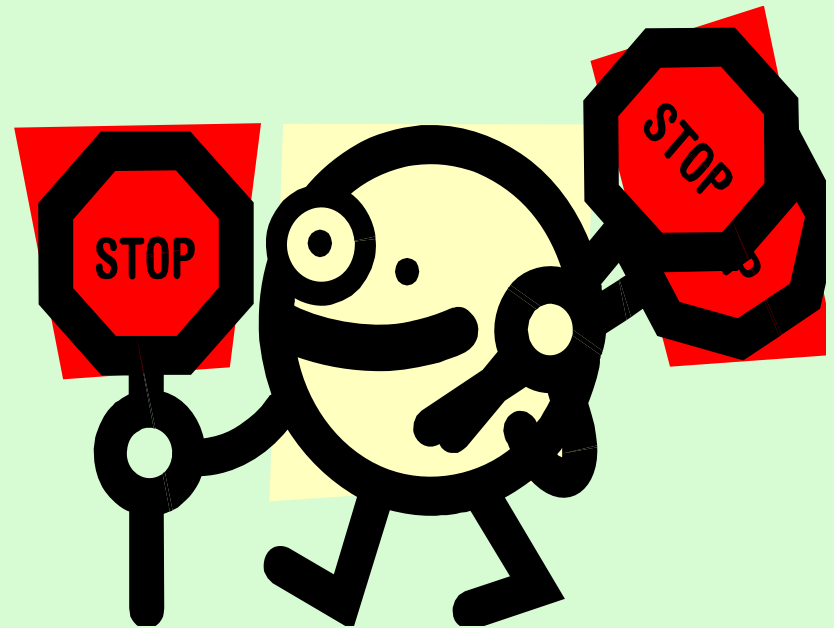
- **Reduce water & sewer costs**
- **Eliminate efficiency losses**
- **Forgiving / tolerant control**
- **Insured water supply**
- **No recycled water problems**
- **LEED credits**

# Tertiary Disinfected in Cooling Towers

**Traditional Treatment requires**

**significant chemical additives to:**

- **Inhibit corrosion**
- **Inhibit bio-growth**

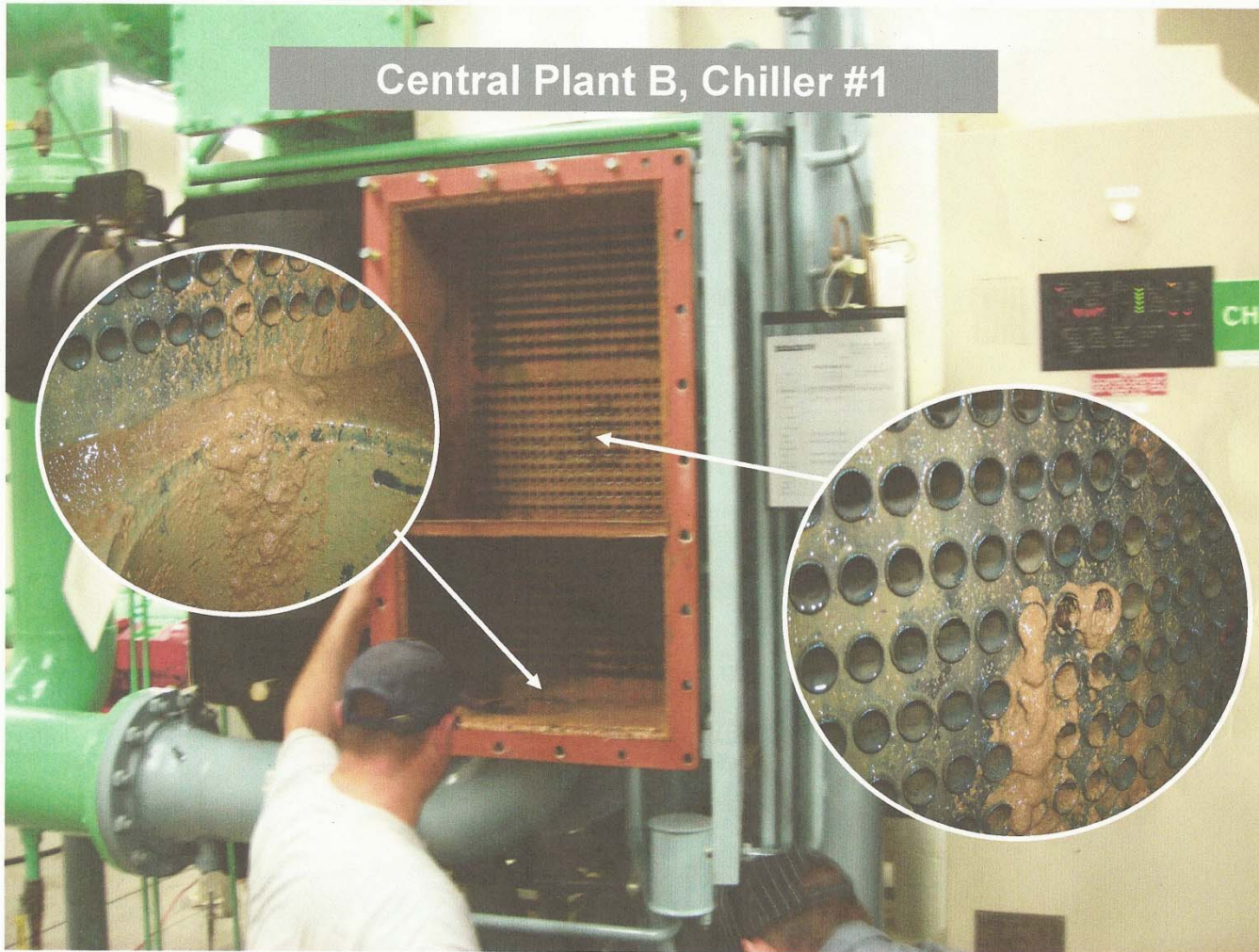


# Tertiary Disinfected in Cooling Towers

## Traditional Treatment results in:

- Lower cycles of concentration (about 1 COC) / higher water costs
- Reduced efficiency of cooling towers
- Higher chemical costs
- Higher cleaning costs





**Cooling towers become incubators for biogrowth.  
WBMWD and customer are researching traditional and  
non-traditional methods of addressing biogrowth.**

# WBMWD Customer Service

- **Become part of their team.**
- **Engage expert consulting firm to study problem.**
- **Develop analysis and action plan.**
- **Partner on solution.**
- **Continue follow-up.**



# Tertiary Disinfected in Cooling Towers

The solution to these issues came from another customer using a non-traditional treatment from:



**Water Conservation Technology  
International (WCTI)**



# New Green Technology to Sustain Water and Energy Resources



# Natural Green Chemistry (NGC)

**R&D Focus – patented technologies**

Pilot Studies & Field Proven over 5 years

Licensed for professional application

**US 6,929,749 / Scale Inhibition**

**US 6,949,193 / Scale Inhibition**

**US 6,998,092 / Corrosion Inhibition**

**US 7,122,148 / Corrosion Inhibition**

**US 7,517,493 / Corrosion Inhibition**

**EP 1704123 / Scale & Corrosion Inhibition**



# Why Recycled Water is a Challenge for use in Cooling Towers

- **Ammonia attacks copper / alloys**
- **Increased bio-fouling from nutrients**
- **More minerals, increased scale and corrosion**
- **Increased water wastage and sewer loading**
- **Increased chemical treatment costs (2-4X)**

# Energy Efficiency Losses From Low Solubility Mineral Deposits



# Hidden Cost of Efficiency Loss (Energy Cost with Scale or Fouling)

A/C Tons	CONDENSER SCALE / BIO-FOULED THICKNESS & COST / YR		
	LIGHT .001 FF (.012")	MODERATE .003 FF (.036")	HEAVY .005 FF (.060")
500	\$13,200	\$39,068	\$65,000
1000	\$25,932	\$78,136	\$129,532
2000	\$51,864	\$156,272	\$259,064

**Assumptions: (1) Operating 12 hr/day, 240 days/yr (2) One ton A/C uses 0.9 KWH (3) Power costs \$0.20/KWH**

# Natural Green Chemistry Meets Customer Goals

- Natural bio-static water – no biocide use
- Zero tower blowdown, 20-40% water savings
- Highly tolerant to upsets / self correcting
- Tolerates water quality and load variations
- Reduces treatment costs 50-75%
- Prevent and remove scale deposits



# 69% less Water - 25% less Energy

One year on zero bleed, 100 mg/L silica in makeup!

PERFORMANCE MEASUREMENTS	CHEMICAL TREATMENT	NGC
Tower Water Wasted	70%	1%
Fill / Exchanger	Visible Scale	Scale Dissolved
Avg. Planktonic Cts	$10^4 - 10^5$ CFU/ml	$10^0$ CFU/ml
Avg. Sessile Cts	$10^6$ CFU/cm <sup>2</sup>	$10^1$ CFU/cm <sup>2</sup>
Avg. Biocide Use	2.0 – 2.5 gpd	None
Exchanger Amp Load	34	25

# How Natural Chemistry Works

- The major surface water minerals are Ca, Mg, Na, Cl, SO<sub>4</sub>, alkalinity and silica
- Softening exchanges Na for Ca/Mg and eliminates the low solubility salts that scale
- Evaporation of water saturates silica, TDS, and alkalinity (pH) which catalyze polymerization of silica to amorphous silicates
- This form of silica is an outstanding corrosion inhibitor, and does not form deposits





# Natural Biostatic Water



- **Elevated pH and TDS are naturally biostatic to bacteria, spores and viruses**
- **Proteins & enzymes are denatured by high TDS**
- **Hydrolysis of peptide chains occurs as water pH is increased (used in wastewater treatment)**
- **Natural pH/TDS increase as water is evaporated and concentrates minerals with zero tower discharge**
- **Mitigates pathogenic bio-films and organisms (Legionella), even when static (no flow)**

# Recycled Water and Natural Green Chemistry



- **Replaces fresh water consumption**
- **Reduces embodied water-energy consumption (\$272 /AF in CA)**
- **Bio-static water ends “bio-bloom fouling”**
- **Mitigates ammonia-copper corrosion**

# Recycled Water and Natural Green Process

- **Non chemical program – uses natural silica and minerals in water**
- **Customer assured water supply**
- **Customer controls high efficiency filtering and softening**
- **Green (LEED) credits**



# High Efficiency design-build systems further reduce water and waste

- HES / HEF – high efficiency softeners / filters
- Low salt design (4#/CF) cuts salt use 30-50%
- Allows 98% evaporative use (over 100 COC)
- \$0.12 /1000 gallons vs \$3.00-\$12.00 /1000 bleed cost
- Tower waste reduced 20-40% (zero bleed)
- Economic (1-2% volume) TDS separation



# ROI – Typical S. CA Tower

<b>Tons Tower Capacity</b>	<b>Peak Flow GPM</b>	<b>Installed \$ Cost Estimate</b>	<b>MGY Water Saved *</b>	<b>\$ /yr Water Cost Saved*</b>	<b>ROI Months</b>
250	7	6000	1.2	7200	10
500	13	12000	2.4	14000	10
1000	25	18000	4.8	28800	8
1500	38	24000	7.8	46800	6
2000	50	30000	10	61200	6
3000	75	35000	15	90000	5
4000	100	50000	20	122400	5
5000	125	60000	24	144000	5
10000	250	175000**	49	288000	7
20000	500	300000**	99	576000	6

\*60% of design as average load \*\* Includes bulk salt handling system

# Recycled Case History

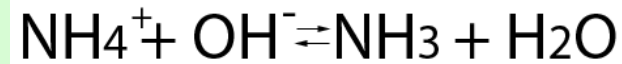
# Auto HQ / Recycled Water

- Five cooling towers, chillers/absorber, plate & frame exchanger
- HEF - HES Pre-treat System
- Recycled Water Quality
  - Ammonia = 38 mg/L
  - Turbidity = 3 ntu
- LEED Certification
- Saved 40 Million Gal/yr potable water
- Averted 15 Million Gal/yr to sewer



# Ammonia Strip by Natural Process

**In a waste stream, ammonium ions exist in equilibrium with ammonia.**



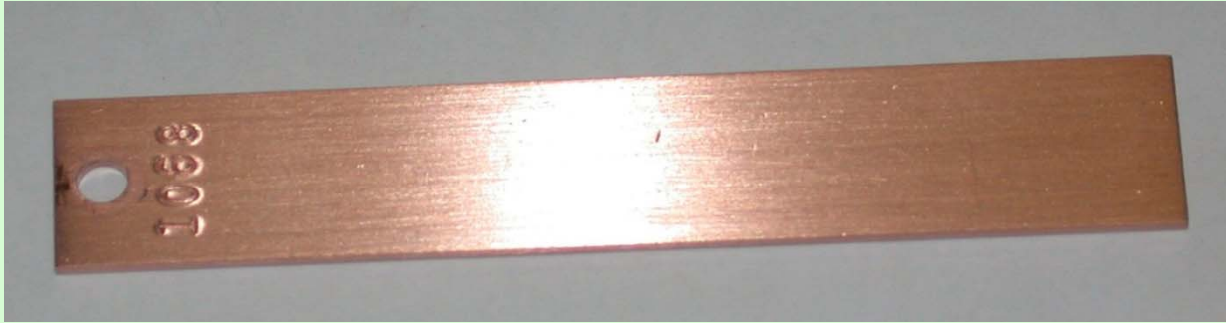
- **Below pH 7, the ammonia is soluble ammonium ions.**
- **Above pH 12, the ammonia is a dissolved gas.**
- **Between pH 7 - 12, both ammonium ions and dissolved gas**
- **Dissolved gas ratio increases with pH and temperature.**
- **Elevated pH and temperature remove ammonia from the water as the gas when water is scrubbed over a tower.**
- **Incremental removal as water added, odor is dissipated.**



# Recycled Study & Lessons Learned

- Ammonia was aggressive to brass makeup valves (untreated, failed in less than 12 months, replaced with stainless).
- Don't use copper pipe for restrooms!!
- Azoles - highly effective for copper / ammonia corrosion mitigation (NGC, patent pending).
- Biostatic tower chemistry mitigates ammonia, phosphate, bio-nutrient effects (and no odor).

# Coupon Weight Loss Results



**Copper coupon, exposed 99 days, 0.16 mpy corrosion rate (under mount bias).**



**Mild steel coupon exposed 99 days with 0.426 mpy corrosion rate (under mount bias).**

# Copper Corrosion (CMAS study)

## Chemical / ZBD Potable / ZBD Recycled

- Independent PHD real time on line study
- NGC treated water - a very minor increase from 0.04 to 0.09 mpy (potable to recycled)
- Well below acceptable copper standards
- NGC corrosion well below 0.3 mpy rate with prior tower bleed and chemical treatment
- Azoles use minimized (< 3%) by zero bleed

# Auto HQ Performance Summary

- **Two years on recycled water**
- **Ammonia strip, < 0.5 mg/L in tower water**
- **Over 80 COC (tower water concentrations)**
- **No scale**
- **No corrosion**
- **No bio-fouling**

# **A Sustainable Future**

# Water Use Reduction Trade-offs!



- Acid & chemicals can provide some tower discharge reduction, but increase TDS to sewers
- Acid / pH control upsets result in rapid scale and efficiency loss, or system corrosion damage
- Chemical or NCD water use reduction is limited
- WWTP / Recyclers must use RO / EDI (energy intensive) to reduce TDS when limits exceeded.
- NGC / zero bleed can avert this waste
- Unintended consequences of “CA softener bill”.

# Why Zero Tower Bleed?

- Reduce sewer volume loading (20-40%)
- Reduce largest sewer TDS contributor
- TDS limits useful water recycling for irrigation
- Avert energy intensive TDS removal (RO, EDI)
- Water wasted per 1000 ton tower ~ 75 families
- TDS per 1000 ton tower ~ 800 home softeners



# Zero Bleed Tower (Recycled Water)

## Reduce TDS Load to Sewer by 70-100%

**Lb /Yr TDS to Sewer per 1000 Ton Load  
From 13,140,000 GPY Evaporation  
And 21,379,000 GPY Makeup @ 2.5 COC**

	MU TDS	Tower COC	Tower TDS	Gal / Year BD	# / Year TDS to Sewer
Tower (low COC)	730	2.5	1,825	8,239,000	<b>125,604</b>
Zero Tower BD	730	75	54,750	0	<b>“0”</b>
HES Regen Waste	-	-	22,700	181,028	<b>33,146</b>
Brine Line, Haul, Evaporation Pond	-	-	-	181,028	<b>“0”</b>



# Shovel Ready Green ROI

- Design-build installs, 3-5 weeks
- 20-40% potable reduction, 98% with recycled
- Restore cooling efficiency / reduce energy use
- Reduce water-embodied energy consumption
- Immediate ROI via water & energy reductions
- Enables LEED points - 5 credit areas

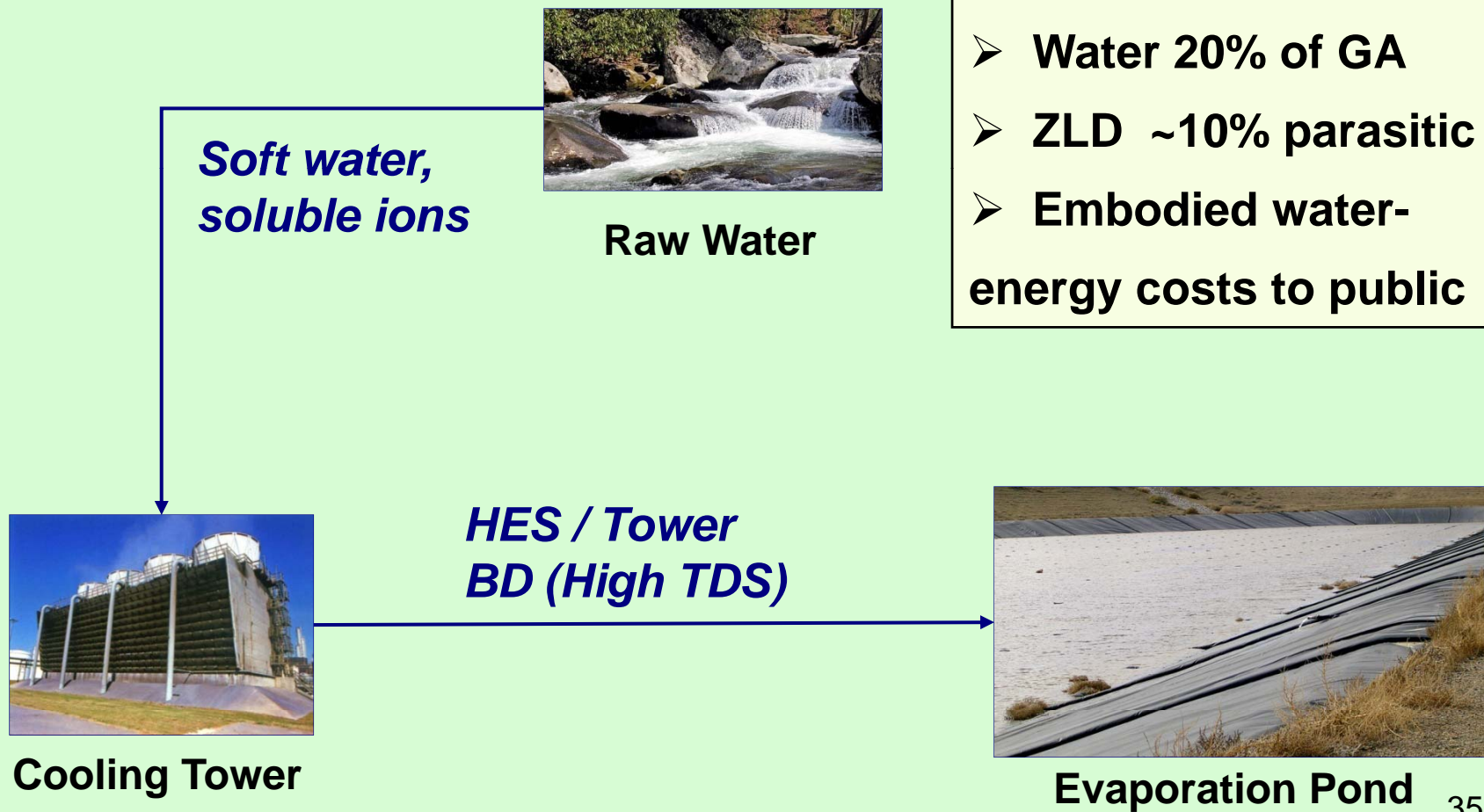


# Public / Private Infrastructure Partners



- Over 400,000 cooling towers in the US
- Cooling tower evaporation energy is free!
- Evaporate recycled water into biosphere
- Avert cost of further treatment & discharge
- 95-98% waste reduction, economic options
- Brine lines, bulk haul co-op, evap-pond
- Reduce high strength waste (TDS) to sewer
- Avert TDS removal costs for RO / EDI

# Power Plants – huge opportunity for Recycled water / conservation



- Use 47% of water
- Water 20% of GA
- ZLD ~10% parasitic
- Embodied water-energy costs to public

# WIN – WIN / Sustainable Future



- Improve cooling system energy efficiency
- Conserve limited fresh water supply.
- Beneficial use / disposal of recycled water.
- Reduce embodied water-energy consumed
- Reduce sewer volume and TDS loads
- Eliminate toxic & persistent chemical discharge.
- “Shower to Tower” / Green infrastructure

# Current Recycled, High Silica, High Hardness Water Projects

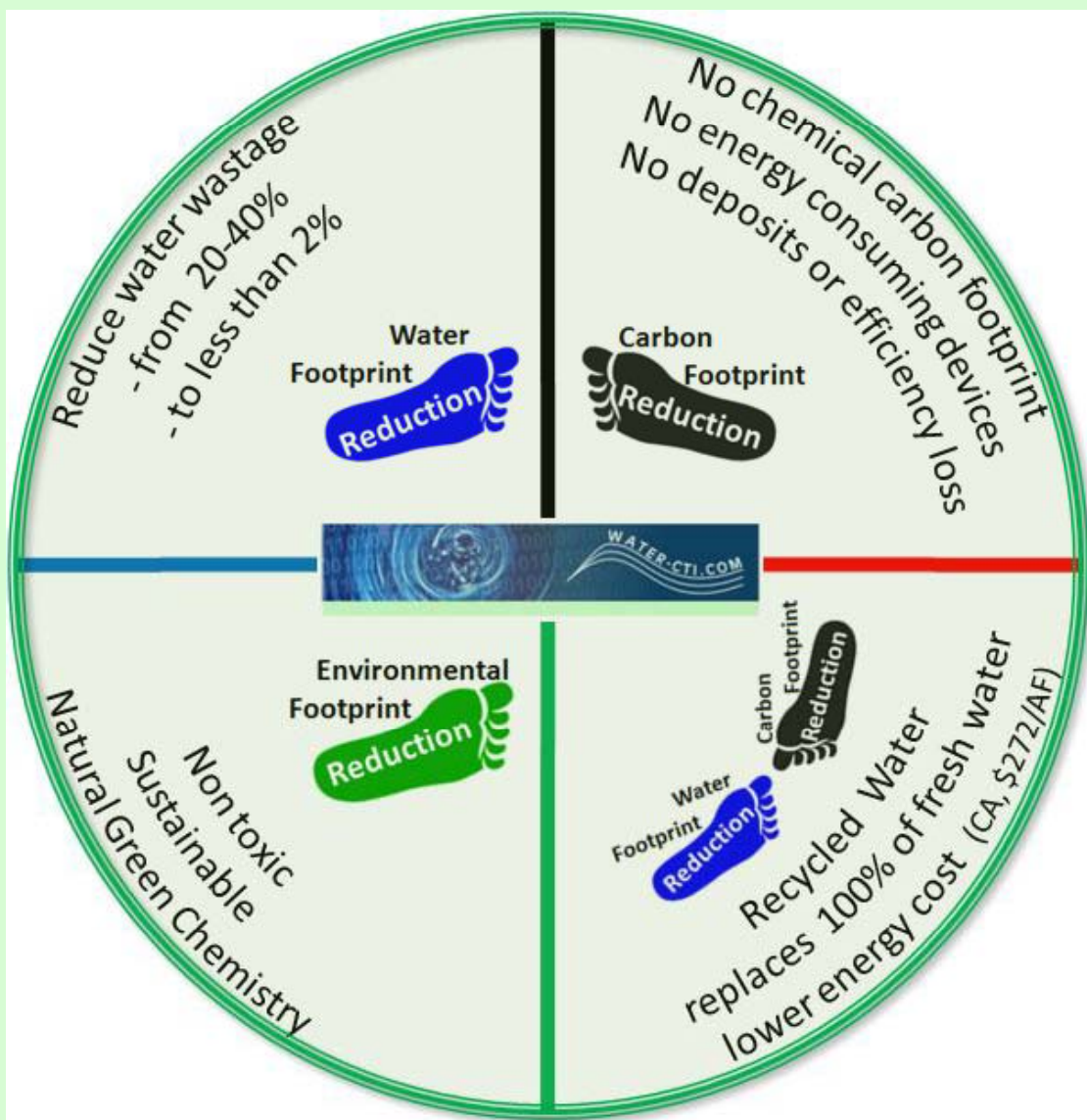
- **Recycled - Honda, CSUDH, LAX, Northrop, Equinix, LMU**
- **Boeing, Pratt Whitney, Lockheed**
- **Largest US Data Centers – recycled waste water / 35-70 silica**
- **Power Generation Plants – zero discharge**

# Summary: Recycled Water in Cooling Towers



- **100% potable reduction with recycled water**
- **Reduce sewer volume load (20-40%)**
- **Reduce TDS and toxics to sewer**
- **Energy / water efficient, quick ROI**
- **50% to 75% less cost than current treatments**
- **Green Infrastructure for a sustainable future**

# Recycled Water and Natural Green Chemistry can reduce these Footprints



**Questions?**



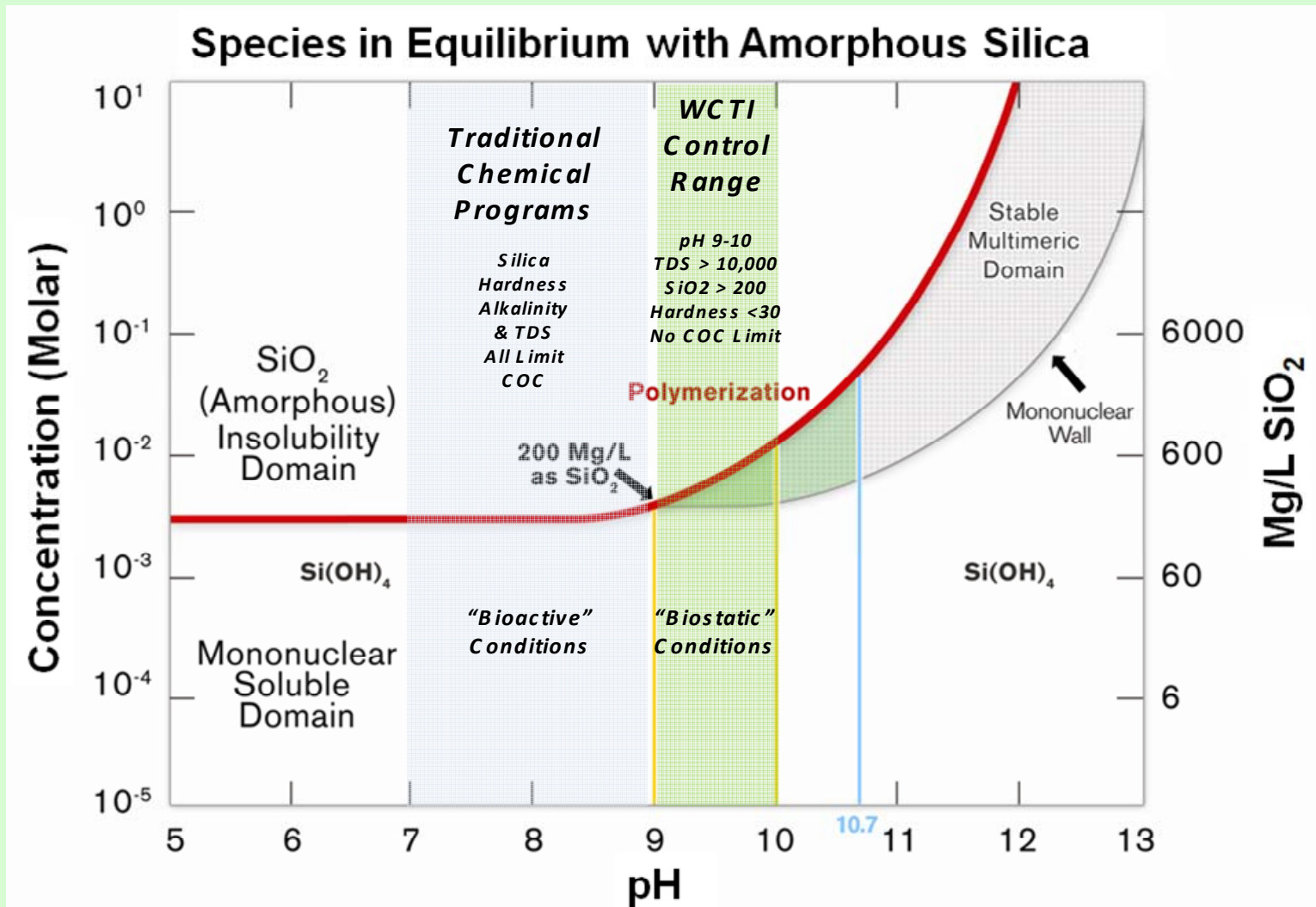
# Addendum – Research

# Highly Soluble Sodium Salts Eliminate Scale Limitations

(Solubility of Ion pairs as sodium salts @ 30° C)

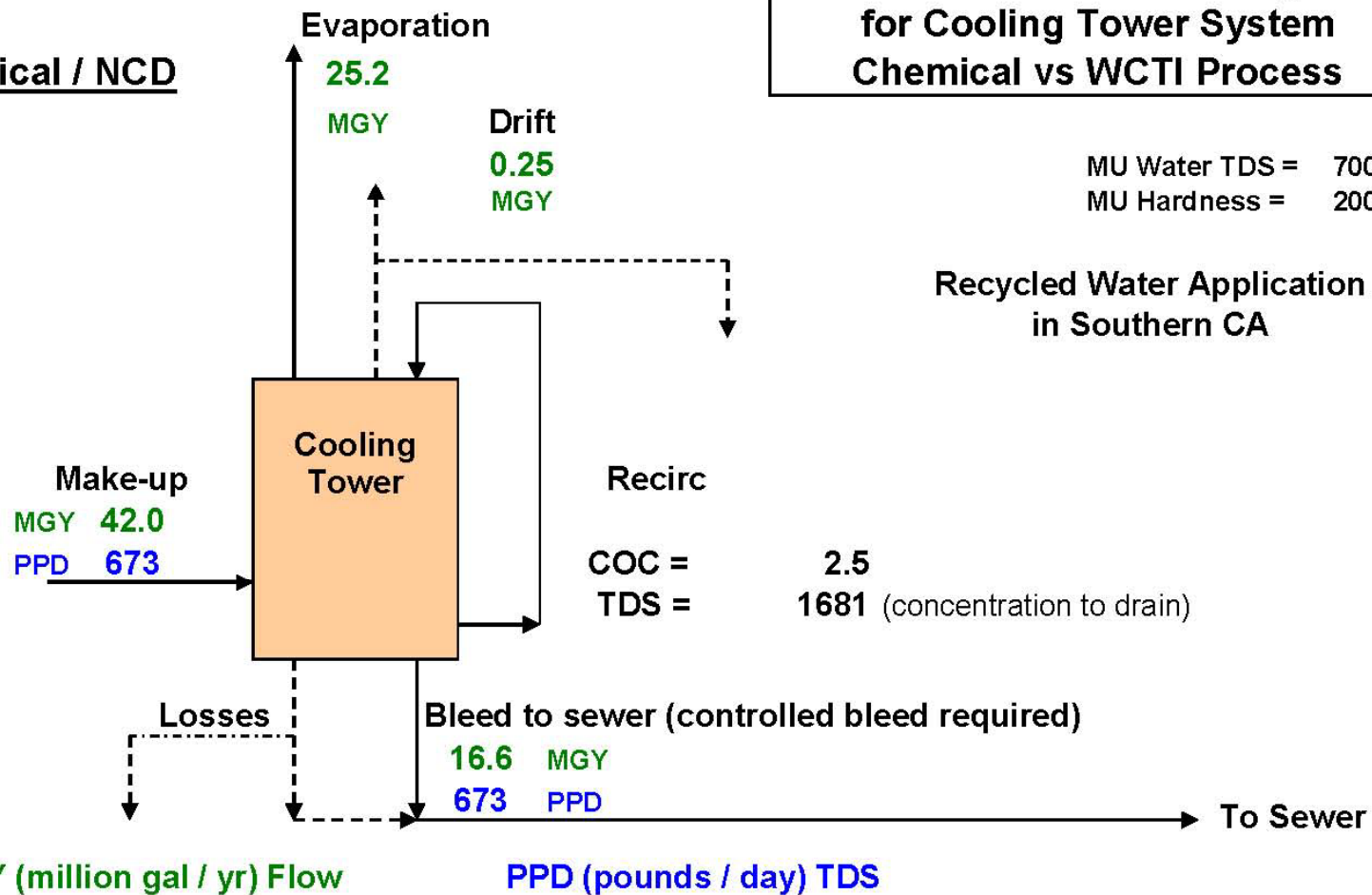
- Sodium Chloride (36% ~ 360,000 mg/L)
  - Sodium Carbonate (16% ~ 160,000 mg/L)
  - Sodium Sulfate (48% ~ 480,000 mg/L)
  - Sodium Ortho-Phosphate (26% ~ 260,000 mg/L)
- Non-common ion effect also increases solubility  
(increased calcium solubility in seawater)

# Silica Concentration / pH Dependent Relationship

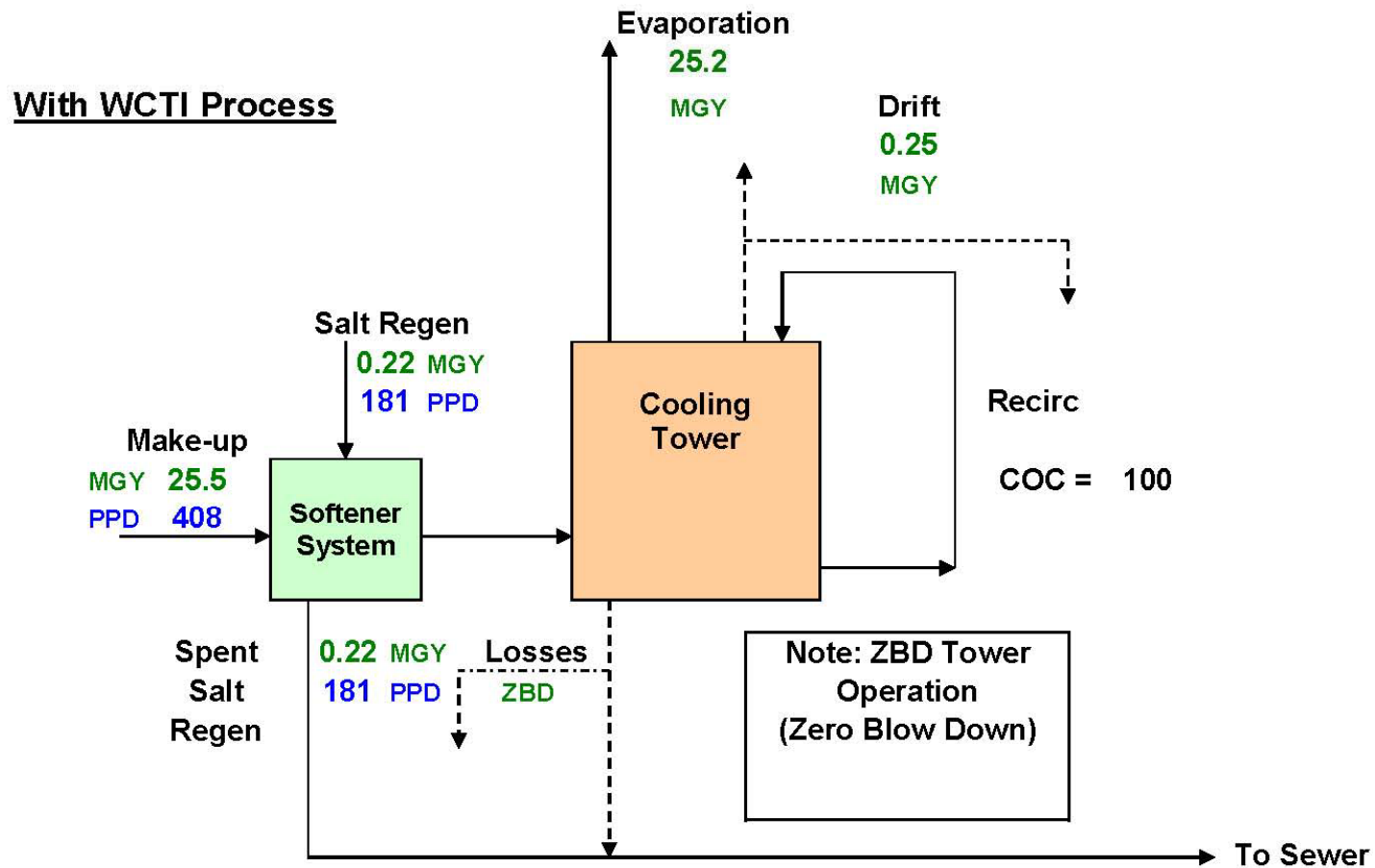


# Tower TDS – Chemical / Low COC

Chemical / NCD



# Tower TDS – Zero Blowdown



Reduced Make-up Vol. =	16.6 MGY	39.4 %	[42 - 25.5 = 16.5]	2.5 COC to ZBD
Reduced TDS to sewer =	492 PPD	73.09 %	[673 - 181 = 492]	Tower BD vs HES

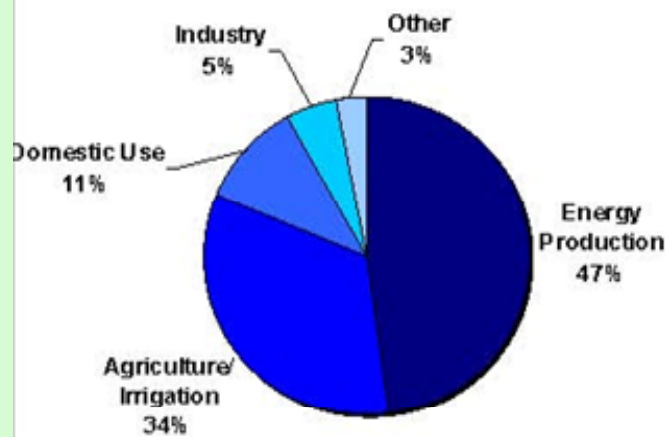
# Reduce Energy Dependence

- Prevent and remove scale deposits
- Prevent and remove bio-fouling deposits
- No scale in high temperature exchangers
- maintain equipment efficiency (standards)
- Replace potable (100%) with recycled water
- Embodied water-energy use reduction
- Reduce chemical/transport carbon footprint

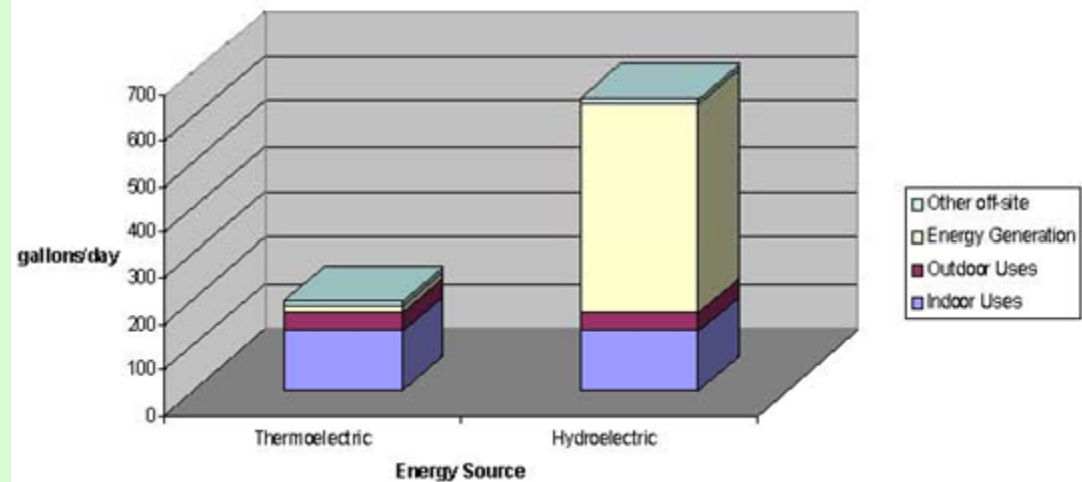


# End use and Water-Energy Connection

U.S. Water Use, 2000 (USGS)



Residential Water Uses (2 person household)



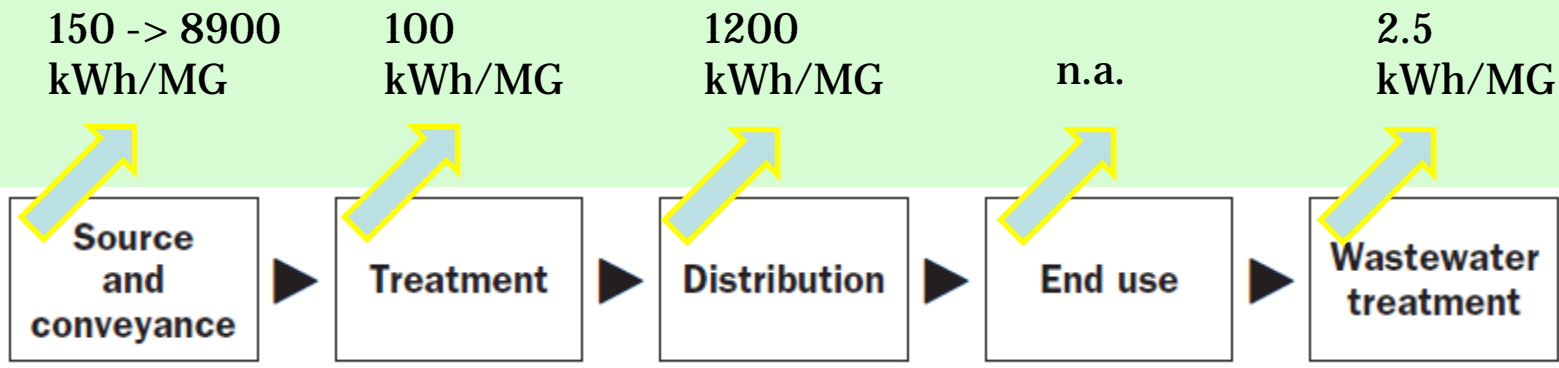
US Commercial buildings consume about 11% of the total water supply (but greater % of treated potable). Energy production (power) consumes almost four times as much water. Thus buildings that save energy also save embodied water.

Source: ARUP; Water Conservation Showcase 2009

# Embodied Energy in Water

Offsite Energy in water consumed in a typical Southern California household is equivalent to 1/3 of household energy demands

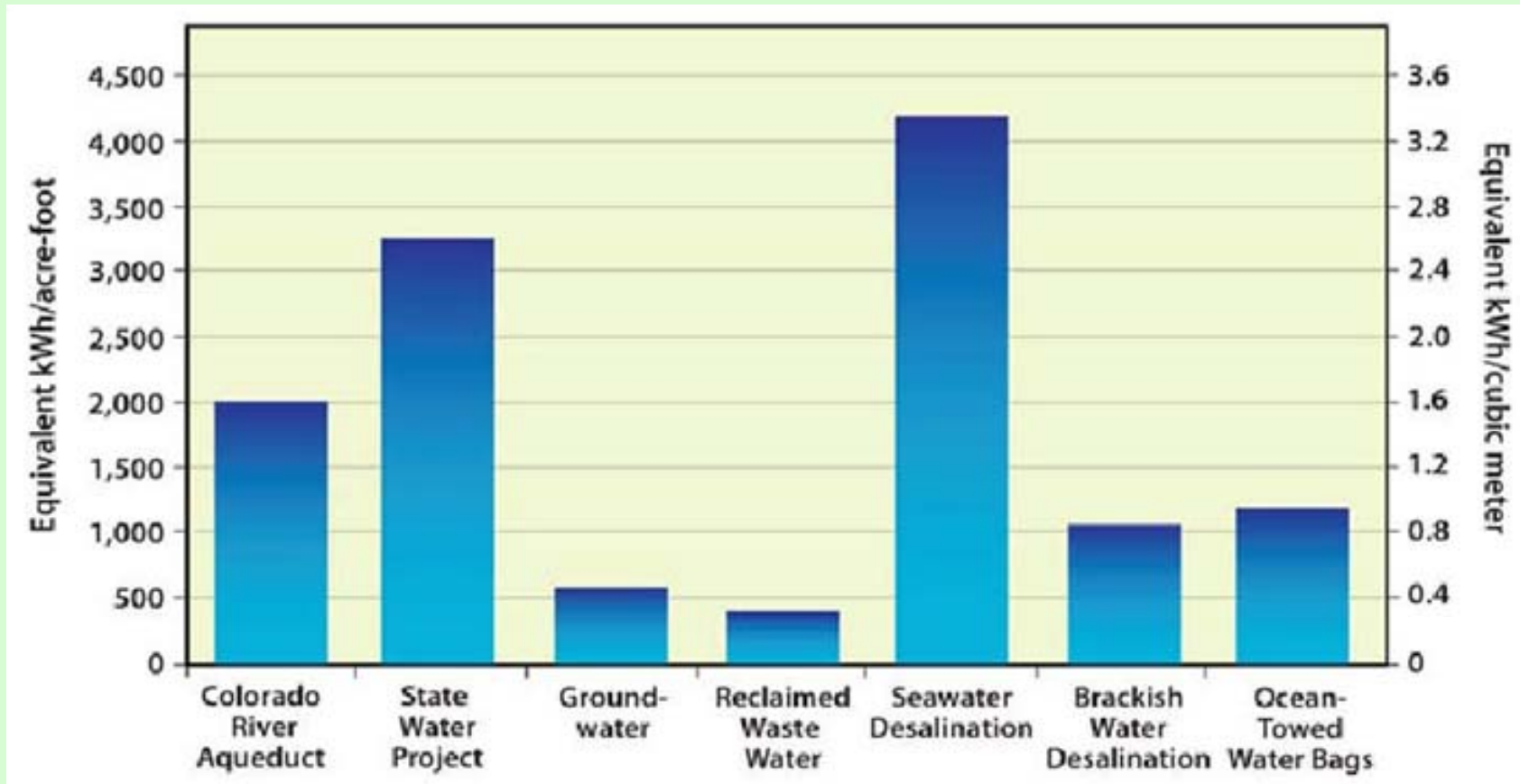
1 MGD = 12.7 MWh in Southern California  
= 4.0 MWh in Southern California



Can water efficiency be a **more effective energy and carbon strategy** than traditional energy efficiency and renewable energy technologies?



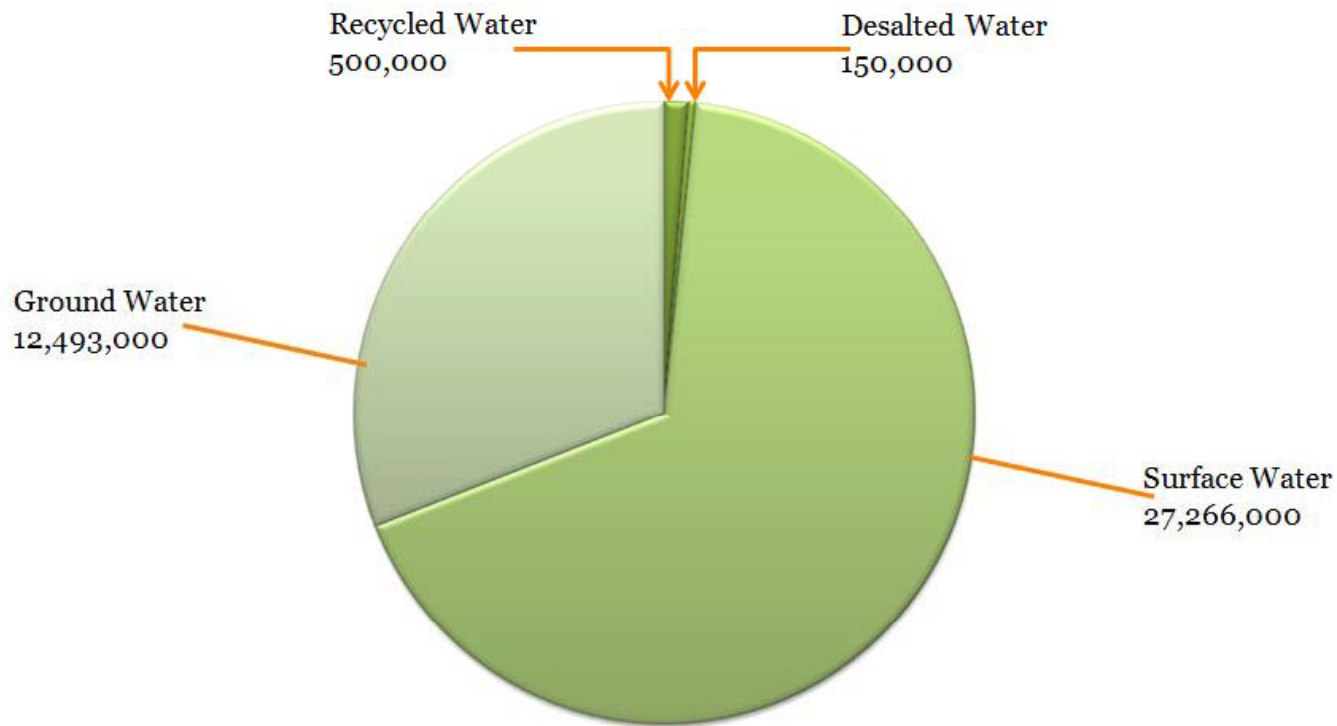
# Energy intensity of Water Sources San Diego, CA



Source: Pacific Institute, Wolf et al., 2004

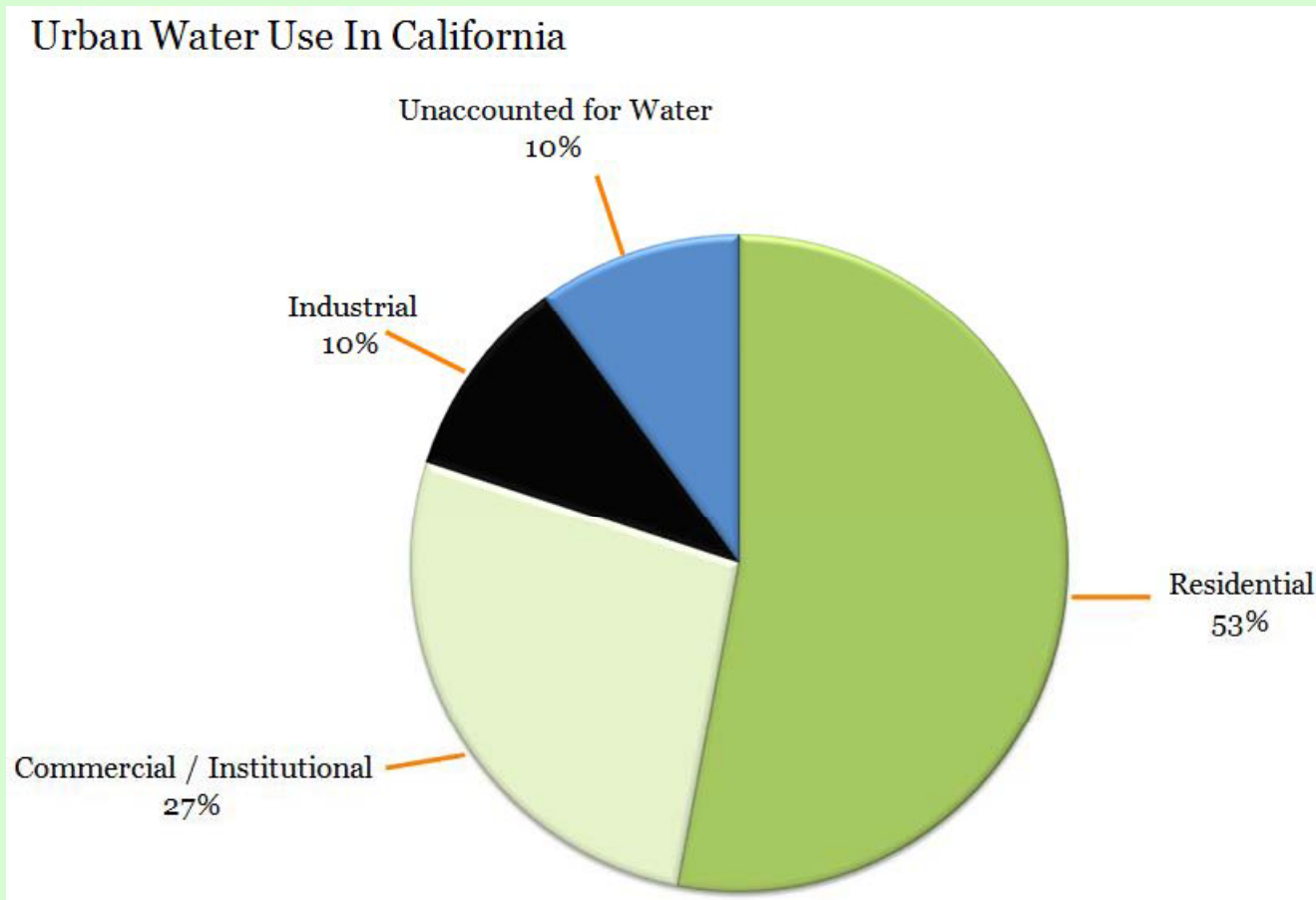
# 40 million AF /yr Water, < 2% recycled

Primary Sources of Water In California in Acre-Feet per year



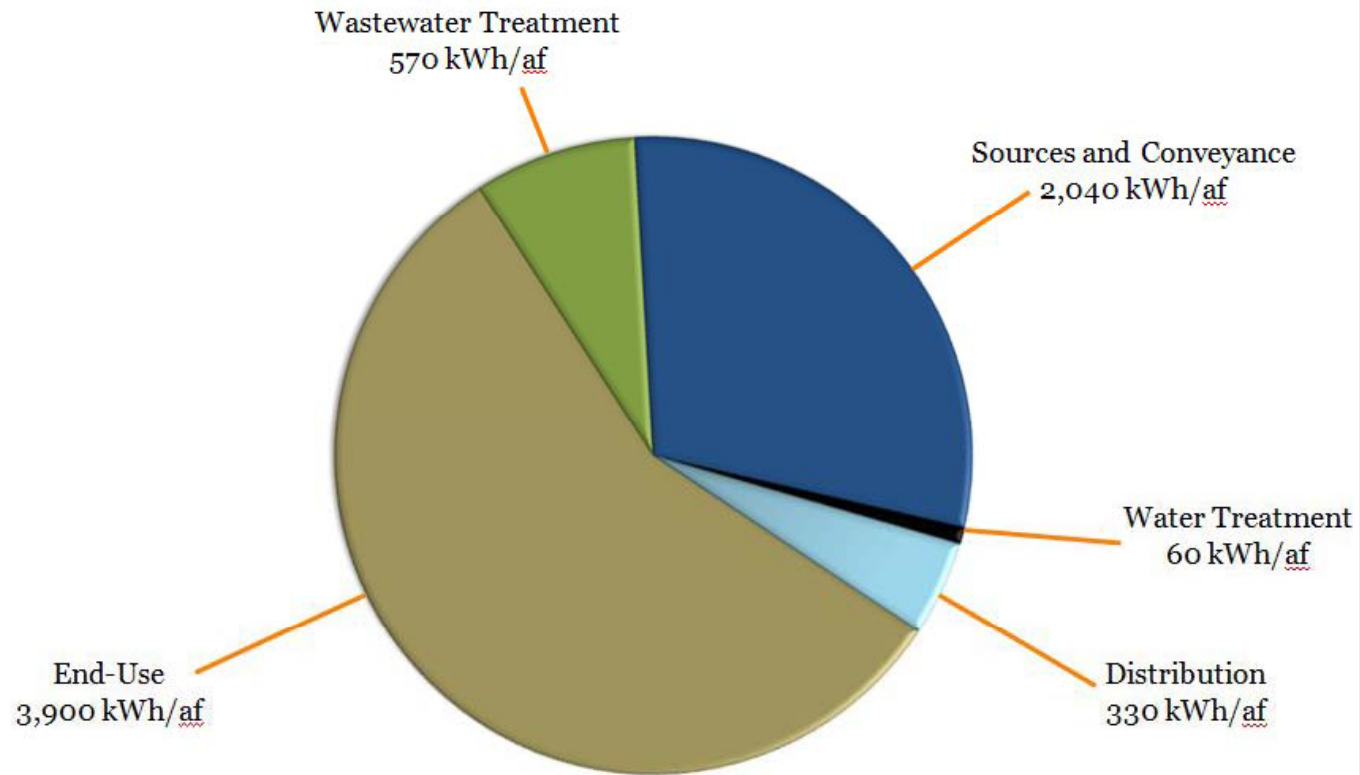
Source: "Energy Down The Drain", NRDC / Pacific Inst. 2004

# Commercial-Institutional and Industrial water total rivals Urban Residential water use



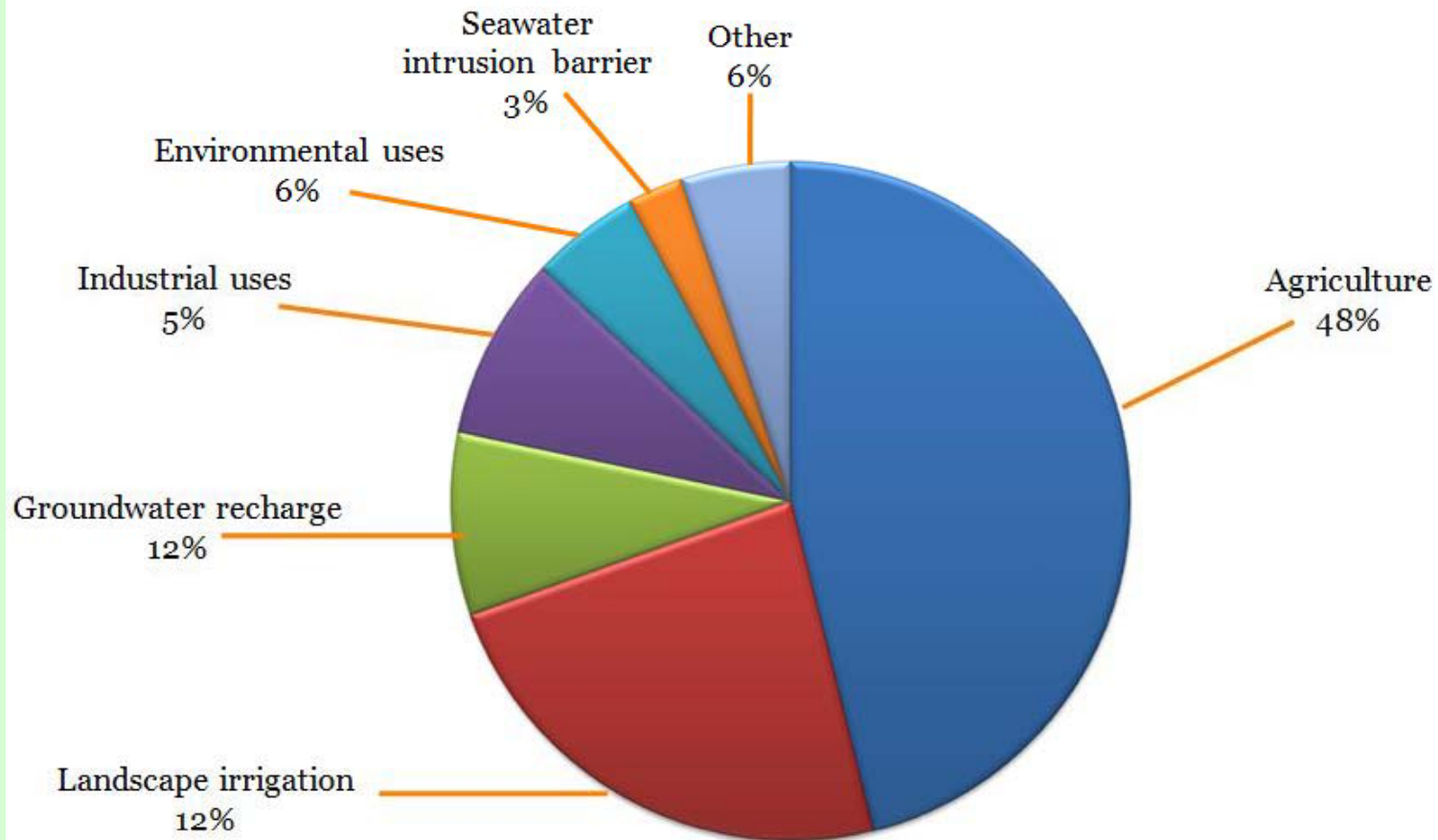
# Embodied water-energy use rivals total end use consumption by the public

Intensity Components of Water in San Diego County



# Less than 2% recycled, 5% use by Industrial; Cooling towers can be largest non-irrigation use

Recycled Water Use In California in 2000



# CALIFORNIA's Commercial-Institutional water reduction potential with zero tower bleed: ~ 16,500 AF per year

Building Type	System Type	Equivalent Full Load Hours	Tons	Ton-Hours of Operation Per Year	Annual Water Used at 3 cycles (Acre-Feet)	Annual Water Used Zero Bleed (Acre Feet)	Water Use Reduction Zero Bleed (Acre Feet)	Water Use by WCTI Process (Acre Feet)
Office	Centrifugal, Helicopter	1,310	1,318,446	1,727,691,481	14,313	9,590	4,723	96
Education	Centrifugal, Helicopter	1,344	645,197	867,144,660	7,184	4,813	2,371	48
Healthcare	Centrifugal, Helicopter	4,368	364,677	1,592,907,039	13,197	8,842	4,355	88
Mercantile	Centrifugal, Helicopter	2,184	308,572	673,922,209	5,583	3,741	1,842	37
Lodging	Centrifugal, Helicopter	1,835	168,312	308,778,903	2,558	1,714	844	17
			<b>2,636,892</b>	<b>5,170,444,292</b>	<b>42,835</b>	<b>28,699</b>	<b>14,136</b>	<b>287</b>
Office	Absorption	1,310	85,897	112,559,691	933	625	308	6
Education	Absorption	1,344	42,035	56,494,771	468	314	154	3
Healthcare	Absorption	4,368	23,759	103,778,438	860	576	284	6
Mercantile	Absorption	2,184	20,104	43,906,262	364	244	120	2
Lodging	Absorption	1,835	10,966	20,117,051	167	112	55	1
			<b>182,761</b>	<b>336,856,213</b>	<b>2,792</b>	<b>1,871</b>	<b>921</b>	<b>19</b>
Office	WSHP	1,310	413,352	541,491,120	4,486	3,006	1,480	30
Lodging	WSHP	1,835	45,928	84,277,880	698	468	230	5
			<b>459,280</b>	<b>625,769,000</b>	<b>5,184</b>	<b>3,473</b>	<b>1,711</b>	<b>35</b>
Office	SCVAV	1,310	2,300	30,130,000	250	168	83	2
<b>Totals</b>					<b>51,061</b>	<b>34,211</b>	<b>16,850</b>	<b>342</b>

Source: PBMP, Riesenberger / Koeller & Company, 2006

# Water, Energy, and TDS reduction targets for a Sustainable California



- 47% non potable use for power generation
- ~15% of potable for C&I towers (52,000 AF)
- ~ 5% of potable wasted by C&I towers (16,500 AF)
- Eliminate ~10-40% TDS load to sewers (from towers)
- Energy efficient cooling & standards (scale free)
- Reduce embodied water-energy with recycled water

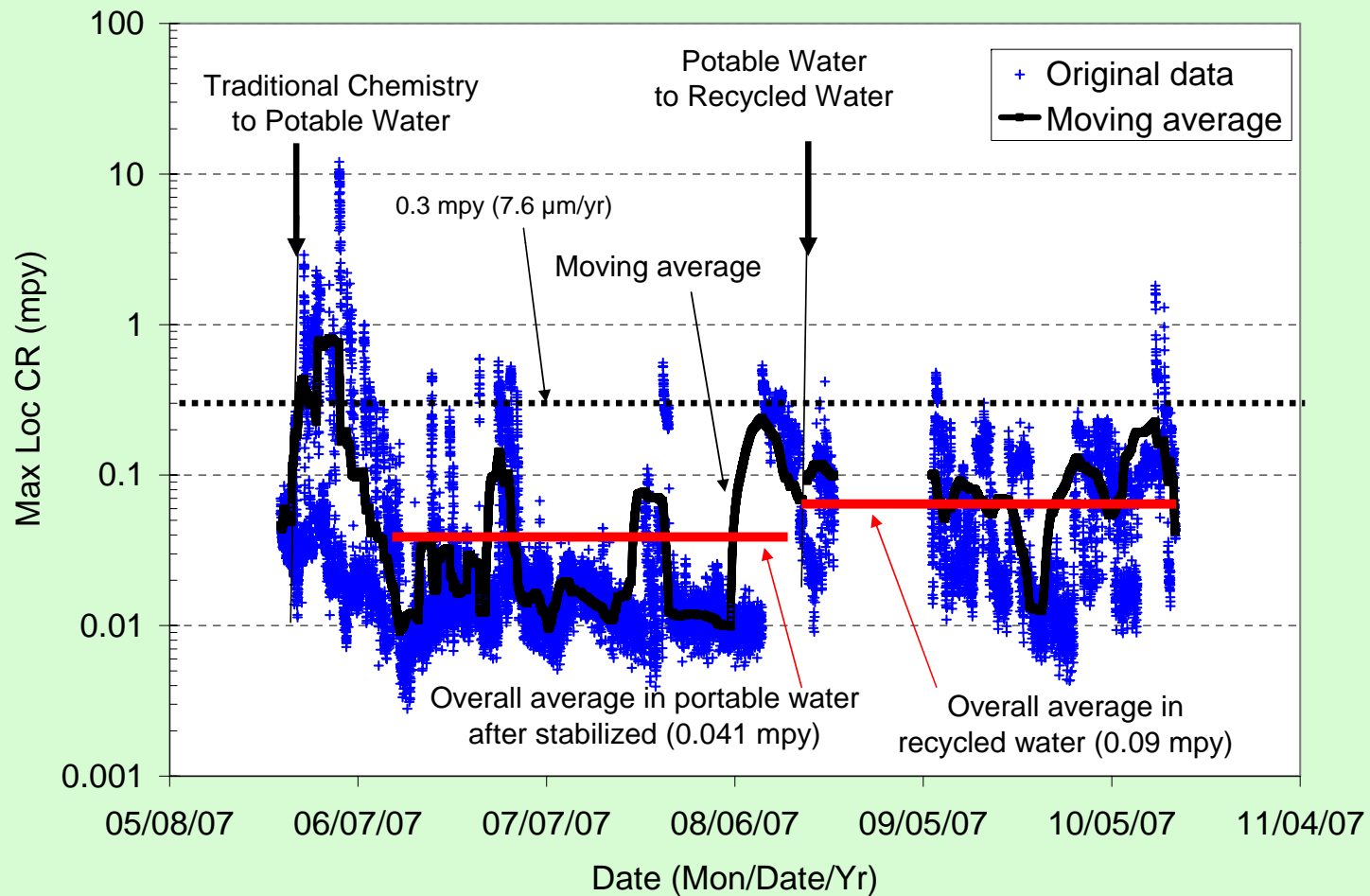
# Can water-energy reduction produce more Green ROI than renewable energy?

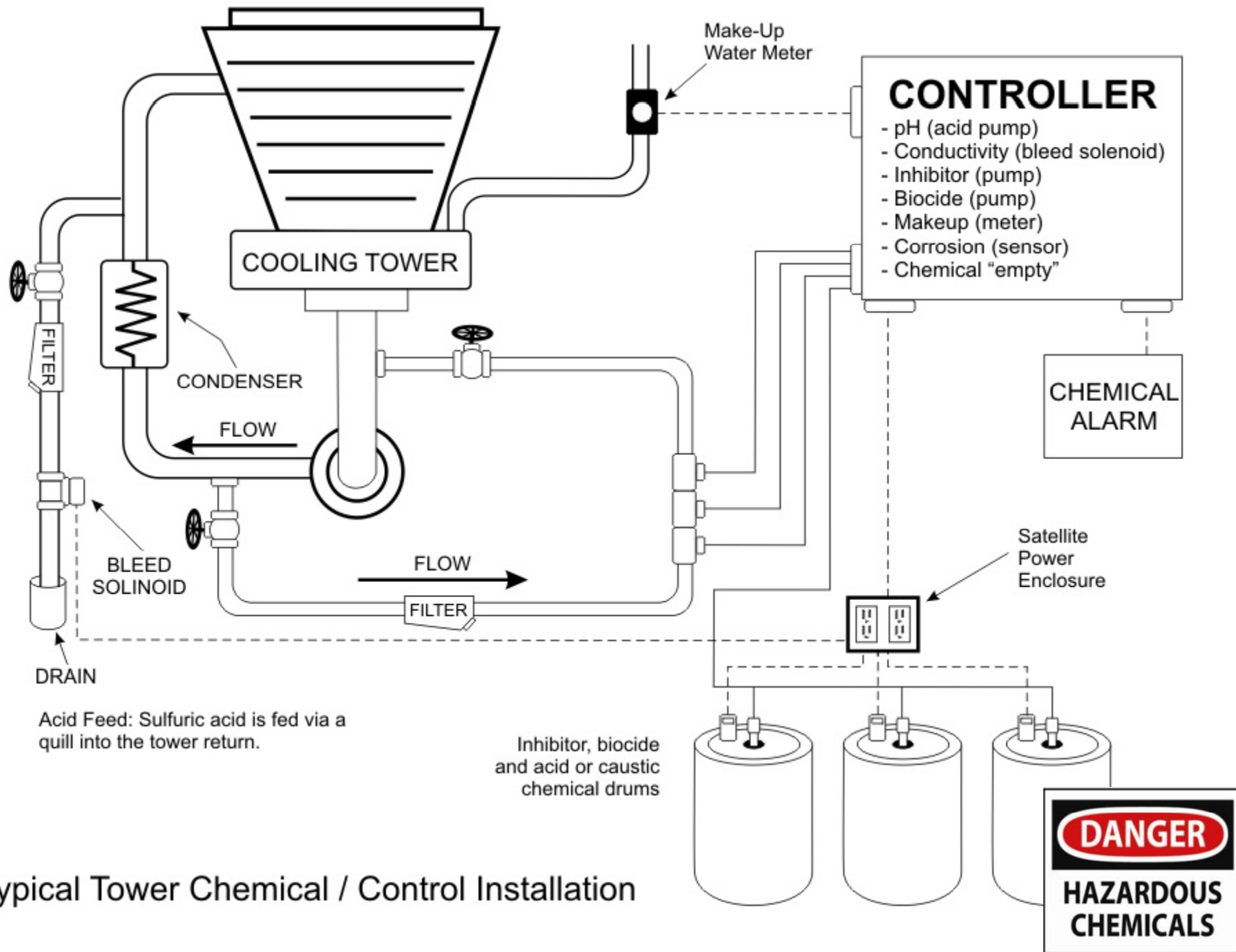
- There are over 400,000 cooling towers and evaporative condensers in the US
- A 10 gpm average tower water wastage per system totals 4 million gallons per minute of water and embodied energy down the drain
- If 30% of tower exchangers operate inefficient from deposition, restoration could save more energy than used by millions of US families



# Localized Copper Corrosion (CMAS study)

## Chemical vs ZBD Potable vs ZBD Recycled



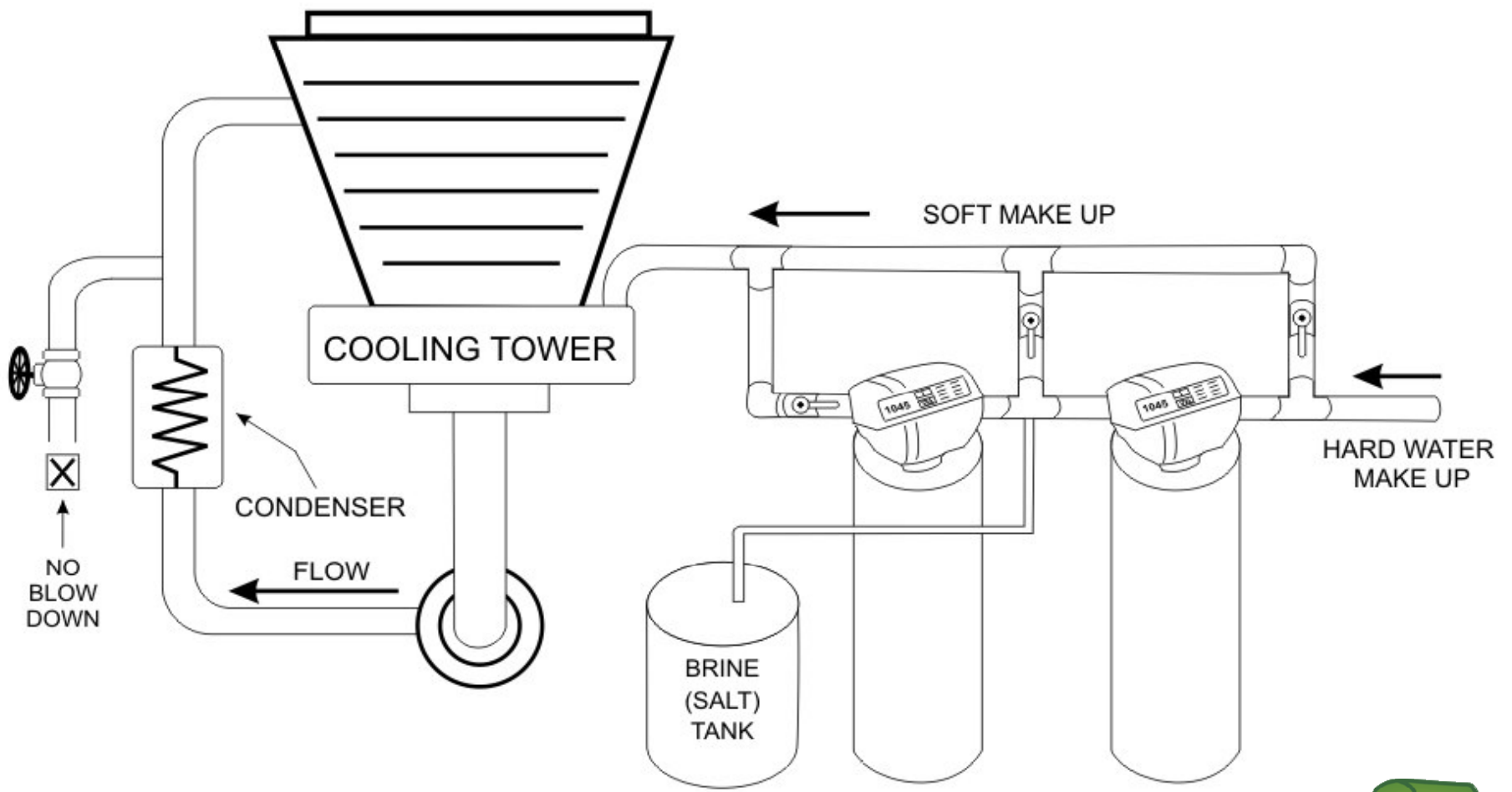


Acid Feed: Sulfuric acid is fed via a quill into the tower return.

Inhibitor, biocide and acid or caustic chemical drums

Typical Tower Chemical / Control Installation





Typical ZLD Installation

Preconditioning Tanks  
(Softening)

