ENERGY INTENSITY OF SANTA BARBARA'S WATER SYSTEM

LENA MOFFITT AND MIKE MOSLEY
SANTA BARBARA PUBLIC WORKS
MAY 2008

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ENERGY INTENSITY OF SANTA BARBARA'S WATER SYSTEM

LENA MOFFITT AND MIKE MOSLEY[1]
EXECUTIVE SUMMARY
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As California struggles to cope with significant water supply and energy infrastructure challenges, the relationship between these two sectors is increasingly being examined. The fact that two thirds of the California's precipitation falls in the north while two thirds of its population resides in the south has resulted in one of the most energy-intensive and mechanized water delivery systems in the world. Water related energy demands consume 19% of all of California's electricity and 30% of its natural gas[2]. The State Water Project, which pumps water from the Sacramento Delta to many southern Californian cities, is the state's single largest energy user. Energy is additionally consumed by each subsequent stage of local water systems, including potable water treatment, distribution, wastewater collection, and wastewater treatment. In this study, we considered the energy intensity of each of these steps in Santa Barbara's water system. With this information, we hope to assist water managers in equitably assessing the relative energy intensities of various sources of supply.

To begin, we calculated the energy embedded in each of Santa Barbara's three main sources of supply: surface water, ground water, and purchased water. Santa Barbara also has a reclaimed water production plant and ocean desalination plant, although the latter is not currently in use. **Surface water** in Santa Barbara comes from Lake Cachuma, the Gibraltar Reservoir, Devil's Canyon Creek, and seepage into Mission Tunnel. Because all of these sources require no pumping and are delivered into the city on a gravity-fed basis, we considered them to have **zero embedded energy** when they enter the city's water system at Cater Treatment Plant.

Groundwater, alternatively, is associated with considerable energy inputs, as it must be pumped from the ground. Accurately calculating the energy embedded in groundwater can be extremely complicated, as increasing amounts of power

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[1] Contact Lena Moffitt at lmoffitt@bren.ucsb.edu and Mike Mosley at mmosley@bren.ucsb.edu.
[2] California Energy Commission, "California's Water-Energy Relationship." November, 2005.

are needed as the water table drops and more energy is needed to remove a unit of water. Because Santa Barbara did not produce any groundwater between the years of 2001-2005 and minimal amounts were produced between 1995-2000, it was difficult to obtain useful historical data. Consequently, only the year 2007 was considered. Although months from this year when no groundwater was produced were dropped from the overall calculation, the groundwater system was not operating at full capacity. This may have resulted in an inflation of our calculation of the energy needed to produce one unit of groundwater; hypothetically, if some of the energy inputs of the groundwater system are fixed, increasing production could result in a *decrease* in the amount of energy *per unit produced.* That being said, we calculated that a unit of groundwater produced in 2007 (when about half of the system's potential 1,400 acre-feet was produced) consumed about **991 kWh/acre-ft.** At this point, groundwater is put directly into the distribution system, bypassing the energy inputs required for treatment.

Santa Barbara's purchased water is primarily **State Water Project Water.** Adding to research previously conducted by Bob Wilkinson of the Donald Bren School, we found that State Water Project Water, having been pumped from the Sacramento Delta, has **2919 kWh/acre-ft** embedded in each unit by the time it is delivered to Lake Cachuma, making it by far Santa Barbara's most energy-intensive current source. This water must then be treated at Cater Treatment Plant before it enters the distribution system, consuming even more energy. **Desalination,** although not currently employed, is estimated to require approximately **3750 kWh/acre-foot** of water produced[3].

All of Santa Barbara's water, with the exception of groundwater, is treated to potable levels at the Cater Treatment Plant. To calculate the energy consumed per unit water treated, we used the annual energy use for 2002 at Cater divided by the amount of potable water delivered. This resulted in a calculation of **220 kWh/acre-ft used for potable treatment.** This treated water, as well as ground water, is then delivered to customers via an extensive distribution system, powered and maintained by pumps and pressure relief valves. Overall, this **distribution system requires an additional 111 kWh/acre-ft** of water delivered to a Santa Barbara tap.

Once Santa Barbara water customers have used this water, a significant portion of it is discarded as wastewater (although some is removed from the system as irrigation). We calculated that approximately **15 kWh/acre-ft is required to collect wastewater.** This waste is delivered to the El Estero Wastewater Treatment Plant, where **549 kWh/acre-ft is used to treat the wastewater.** This treated effluent is then delivered via gravity to the ocean.

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[3] Bob Wilkinson, Donald Bren School of the Environment, independent research in pending paper. Wilkinson@bren.ucsb.edu

Reclaimed water is used to irrigate landscapes and flush some public toilets in Santa Barbara. This water is reclaimed at the El Estero Wastewater Treatment Plant and given additional treatment before it is distributed to customers. Because the portion of El Estero energy used specifically to treat reclaimed water is not metered separately, we used an estimate that 15% of the plant's energy goes to the production of reclaimed water. This energy is primarily needed to pump the water to different stations at the plant. We calculated that generation of **reclaimed water requires 1066 kWh/acre-ft.** Additional energy is then needed to distribute this water to its use-point; we calculated that in Santa Barbara, **reclaimed water distribution requires 275 kWh/acre-ft.**

By adding the energy required at each stage of the water production and delivery process, water managers can gain an understanding of the overall energy embedded in each source, which can help inform their decisions about which sources to rely on. Considering water from each source, all the way to its discharge into the ocean may prove beneficial. Surface water, with no initial energy embedded (because it is a gravity-fed system), is the least energy intensive; surface water treated, delivered, collected, and re-treated has a total of 895 kWh/acre-ft of energy embedded in it by the time it reaches the ocean. Groundwater, which is not subject to Cater treatment but requiring significant energy for extraction, has approximately 1886 kWh/acre-ft embedded in it by the time it is discharged to the ocean, and State Water Project Water, with significant original energy considerations *and* requiring additional treatment, has 3816 kWh/acre-ft of energy embedded in each unit when it is discharged to the ocean. The energy needed to generate and distribute reclaimed water may seem high, but if we consider the total energy needed to obtain, treat, and deliver a *fresh* unit of water, it becomes more moderate. **Reclaimed water, treated and delivered to a sprinkler, ready to water a lawn, has 1340 kWh/acre-ft of energy embedded in it. A unit of fresh State Water Project Water, pumped from Sacramento, treated at Cater treatment plant, and distributed to that same sprinkler, has 3250 kWh/acre-ft of energy embedded in it.** In this comparison, reclaimed water seems like the obvious alternative.

Overall, we found that all sources of water for Santa Barbara contain significant amounts of embedded energy by the time they reach the tap, and even more by the time they are discharged to the ocean. Of the three, surface water is the least intensive, followed by groundwater, then purchased water in the form of State Water Project Water. All three of these are less energy intensive than ocean desalination. We also calculated the greenhouse gas production associated with the energy intake at each stake, and the result is not insignificant (see Appendix, "CO_2 Impacts"). For instance, an acre-foot of State Water treated and delivered to the tap has effectively caused the generation of 2690 lbs of CO_2. As California works to be a leader in combating climate change, this type of greenhouse gas

production will not go unnoticed, and provides yet another reason to invest in water-use efficiency and conservation.

We did encounter some limitations while conducting this project. Although we feel that our data are representative of the energy intensity of the various pieces of Santa Barbara's water system, all of the results would be made more robust by the consideration of more historical data. We only considered one year's worth of water production and energy consumption. Comparing this year with other years would help ensure this was an accurate representation of water and energy consumption in Santa Barbara.

APPENDIX 1. Spreadsheet of Data

	Type	kWh/acre-foot	Total Energy Used from 9/02-9/03 (kWh)	Total Water (ac-ft)
Sources	State Water Project into Cachuma	2919.00	----	---
	Groundwater	991.06	635016.00	640.75
	Surface Water	0.00	0.00	11434.00
reatment	Potable Treatment	219.87	2801771.00	12743.00
stribution	Potable Distribution	110.56	1408871.00	12743.00
astewater	Wastewater Collection	15.19	144586.00	9521.21
	Wastewater Treatment	549.36	5230478.40	9521.00
ecycled	Recycled Production	1065.99	784571.76	736.00
	Recycled Distribution	275.26	202589.00	736.00
TOTAL ENERGY IN SB WATER (AT TAP, and TO THE OCEAN)				
ource +	Treatment +	Distribution =	ENERGY INHERENT IN WATER AT YOUR TAP (kWh/ac-ft)	
2919.00	219.87	110.56	3249.43	
	At tap +	Wastewater collection & treatment =	ENERGY INHERENT AT END OF PIPE (kWh/ac-ft)	
	3249.43	564.55	3813.98	

Total Energy (kWh/ac-ft) for State Water Project Deliveries to Santa Barbara at Cachuma

Total (kWh/ac-ft)						
2919.00	= 2826	+ 93				

Energy used to deliver State Water past Polonio to Cachuma
Source: CCWA, Laura Matthews, ljm@ccwa.com

Energy used to deliver State Water to Polonio
Source: Bob Wilkinson, wilkinson@bren.ucsb.edu

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CCWA Data on the energy used to deliver State Water from Polonio to Santa Barbara County

CCWA Account	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06
Energy Diss. Valve Vault	1649	1970	1524	1474	1483	866	975	833	885	753	967	969
Rectifier at 1175 Branch Mill Rd	67	47	43	44	47	44	45	46	45	43	47	43
Lopenz Turnout	268	286	279	251	159	159	144	146	158	153	165	160
Tank #7	564	440	503	420	493	509	417	343	428	411	410	339
Buelton Turnout	94	84	103	86	88	92	94	83	91	88	85	88
Isoaltion Valve #3	91	76	87	84	89	117	80	66	71	84	84	84
Buelton Office Suite A	1272	1109	0	1132	1462	1804	2337	3262	2703	2256	1275	1128
Buelton Office Suite B	5314	6030	5773	5539	5835	5679	5402	5528	5470	5626	5078	5578
Rectifier DWR 0424 Creston, CA	67	73	66	64	49	72	69	64	72	65	73	65
Tank #2	1651	1791	1591	1744	1490	1763	2123	1690	1736	1440	1495	1424
Rectifier at 749 Burton Mesa Rd	93	87	60	57	60	73	94	92	91	89	79	61
Rectifier at 4892 Hapgood Rd	53	59	56	51	58	55	57	55	55	55	49	60
Rectifier at 2898 Hwy 246, Lompoc	20	22	21	14	0	0	2	0	4	1	2	9
Rectifier at 100 Cimarron Way, Nipomo	57	52	58	55	51	57	55	50	58	53	51	58
Rectifier DWR 0419-Sta Margarita	36	39	38	42	39	37	40	38	36	39	39	36
Rectifier at 2222 Black Rd, S.M.	259	131	148	255	118	188	116	158	146	108	133	192
Rectifier 2000 Santa Maria River	159	253	246	230	249	239	248	252	234	245	229	234
Rectifier DWR 0422 Chalome	11	9	10	13	16	17	15	16	15	16	4	0
Rectifier DWR 0423 R/W Shandon	0	0	0	0	0	0	0	0	0	0	0	0
Isolation Valve #4	116	108	114	87	85	94	92	76	75	34	83	121
Solvang Turnout	35	35	31	33	34	32	56	37	34	32	33	35
Pump Station, Santa Ynez	51666	29633	0	3824	3350	3135	67799	9838	72190	34781	40423	49914
Polonio Pass WTP	95400	99000	94200	92400	81600	90000	85200	834000	88800	72000	75000	90600
Rectifier 6729 Orcutt Rd, San Luis	0	0	0	0	0	0	0	0	0	0	0	0
Rectifier 100 Fox Hollow Road, SLO	33	38	32	34	36	33	34	34	34	32	37	33
TOTAL (kWh)	158975	141372	104983	107933	96891	105065	165494	856707	173431	118404	125841	151231
Month Average for 2006-2007 (kWh)	133590	129295	148471	183775.5	194895.5	334175	327616.5	614855	274718.5	244711.5	158216.5	207173.5
Year TOT (kWh)	2951493.5											
Acre Feet	31,697											
kWh/acft	**93**											

Source: CCWA, Laura Matthews, ljm@ccwa.com

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CCWA Data on the energy used to deliver State Water from Polonio to Santa Barbara County

CCWA Account	Jan-07	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08
Energy Diss. Valve Vault	774	671	649	746	722	820	846	1407	941	670	593	469	534
Rectifier at 1175 Branch Mill Rd	47	47	49	56	59	58	55	60	57	55	48	46	44
Lopenz Turnout	99	78	78	75	87	83	85	80	90	81	88	91	83
Tank #7	489	392	415	383	289	159	95	161	82	112	77	225	76
Buelton Turnout	96	85	88	91	87	89	69	63	63	86	84	88	94
Isoaltion Valve #3	99	84	313	84	89	311	88	65	73	235	84	93	286
Buelton Office Suite A	1141	1632	1394	1412	1600	1689	2215	2439	2708	2030	1740	1712	1496
Buelton Office Suite B	5794	5655	5973	5884	5918	5532	5734	5938	5691	5965	5938	6589	6744
Rectifier DWR 0424 Creston, CA	68	70	63	66	61	70	66	64	76	71	80	69	73
Tank #2	1223	1299	1386	1384	1447	1242	946	859	912	895	933	903	847
Rectifier at 749 Burton Mesa Rd	57	62	58	91	94	91	91	95	92	81	55	61	58
Rectifier at 4892 Hapgood Rd	53	60	52	52	56	55	56	58	55	54	52	58	53
Rectifier at 2898 Hwy 246, Lompoc	8	17	7	4	5	3	8	8	12	17	18	16	11
Rectifier at 100 Cimarron Way, Nipomo	55	54	56	52	54	59	52	52	58	53	52	60	53
Rectifier DWR 0419-Sta Margarita	41	40	37	39	40	36	42	35	37	46	45	44	40
Rectifier at 2222 Black Rd, S.M.	129	167	168	216	160	110	110	117	105	106	116	158	99
Rectifier 2000 Santa Maria River	215	217	235	245	247	236	226	251	226	189	219	228	201
Rectifier DWR 0422 Chalome	0	0	0	0	0	1	0	1	0	0	1	0	4
Rectifier DWR 0423 R/W Shandon	0	0	0	0	0	0	0	0	0	0	0	0	0
Isolation Valve #4	152	110	355	92	114	317	73	24	136	73	76	134	120
Solvang Turnout	32	31	36	31	34	35	34	31	37	32	32	36	33
Pump Station, Santa Ynez	4600	6811	100714	161582	205502	467452	394811	284355	278715	288730	104021	161402	117948
Polonio Pass WTP	93000	99600	79800	87000	76200	84800	84000	76800	85800	71400	76200	90600	87600
Rectifier 6729 Orcutt Rd, San Luis	0	0	0	0	0	0	0	0	0	0	0	0	0
Rectifier 100 Fox Hollow Road, SLO	33	36	33	33	35	37	37	40	40	38	40	34	35
	108205	117218	191959	259618	292900	563285	489739	373003	376006	371019	190592	263116	216532

Groundwater Summary Data (2002-2003)

ENERGY

Edison Accounts Associated with Groundwater	Name	Energy (kWh) (Production Months, April-Sept 2007)
3001564851	**Alameda Well,** 1400 Santa Barbara St	151776.00
3000596328	**Hope Well**, 35 S Hope Ave	117492.00
3000771261	**Los Robles Well**, 4101 Via Diego	194652.00
3001375478	**San Roque Well,** 165 Canon Dr	171096.00
	TOTAL	**635016.00**

Source: Santa Barbara Edison bills 02-03 provided by Bill McTomney, Bmctomney@santabarbaraca.gov

WATER

	Production	Acre-Feet/yr (produced from Apr-Sept 2007)
	Alameda Well, 1400 Santa Barbara St	177.73
	Hope Well, 35 S Hope Ave	164.11
	Los Robles Well, 4101 Via Diego	126.67
	San Roque Well, 165 Canon Dr	172.24
	TOTAL	**640.75**

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Source: Water Production Data, 02-03 provided by Bill Ferguson, Bferguson@santabarbaraca.gov

Surface Water Summary Data (2002-2003)

ENERGY		
Edison Accounts Associated with Surface Water	**Name**	**Energy (kWh) (Sept 02-Sept 03)**
none	all gravity fed	0
	TOTAL	**0**

Source: Santa Barbara Edison bills 02-03 provided by Bill McTomney, Bmctomney@santabarbaraca.gov
Reservoir and pump names and functions provided by Rocky Peebles, Rpeebles@santabarbaraca.gov

WATER	
Production	**Acre-Feet/yr**
Cachuma (less State Water delivery)	6590
Mission Tunnel	1065
Devil's Canyon	31
Gibralter	3748
TOTAL	**11434**

Source: Water Production Data, 02-03 provided by Bill Ferguson, Bferguson@santabarbaraca.gov

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Treatment Summary Data (2002-2003)

ENERGY

Edison Accounts Associated with Potable Water Treatment	Name	Energy (kWh) (Sept 02-Sept 03)
3001375552	Cater Treatment Plant	2801771
	TOTAL	**2801771**

Source: Santa Barbara Edison bills 02-03 provided by Bill McT
Bmctomney@santabarbaraca.gov

WATER

Production	Acre-Feet/yr
All Potable (less groundwater)	12,743
TOTAL	**12,743**

Source: Water Production Data, 02-03 provided by
Bill Ferguson, Bferguson@santabarbaraca.gov

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Distribution Summary Data (2002-2003)

ENERGY

Edison Accounts Associated with Potable Water Distribution	Name	Energy (kWh) (Sept 02-Sept 03)
3001375426	El Cielito Pump Station, 2411 Stanwood Dr	21709
3000498561	Pump station, 460 Northridge Rd	128
3001375540	El Cielito Pump Station, 2410 Sstanwood Dr	482139
3001375544	Sheffield Pump Station, 1 Foothill Dr	456566
3001375545	Rocky Nook Pump Station, 2491 Foothill Dr	2230
3001375553	Pump station, 310 Northridge Rd	16031
3001375515	Pump station, Calle Caleras/Cliff Dr	68319
3022532386	Cater S Coast Pump, 1150 San Roque Rd	156000
3001375548	Tunnel Reservoir Pump Station, End Tunnel Rd	21336
3001375543	El Cielito Reservoir Pump Station, 2117 Mount Cavalry Rd	37440
3001375524	East Reservoir Pump Station, 55 Crestview Ln	60984
3001375525	ndito Reservoir Pump Station, SKYLINE WY/FLRA VS PMP	61295
3000783093	Reservoir, 1030 La Vista Rd	2586
3001375529	La Mesa Reservoir	1922
3001375532	Reservoir #2, 1 Laguna St	1123
3001375536	Vic Trace Reservoir, 1631 La Coronilla	1835
3001978393	Reservoir #1, 144 Cedar Ln	1980
3028107223	Hope Reservoir Pump, 824 Centinela St	13480
3001375535	PRV	949
3010382902	PRV	819
	TOTAL	**1408871**

Source: Santa Barbara Edison bills 02-03 provided by Bill McTomney, Bmctomney@santabarbaraca.gov
Pump names and funtions provided by Rocky Peebles, Rpeebles@santabarbaraca.gov

WATER

Production	Acre-Feet/yr
All delivered potable water	12,743
TOTAL	**12,743**

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Source: Water Production Data, 02-03 provided by
Bill Ferguson, Bferguson@santabarbaraca.gov

Distribution Summary Data (2002-2003)

ENERGY

Edison Accounts Associated with Potable Water Distribution	Name	Energy (kWh) (Sept 02-Sept 03)
3001375426	El Cielito Pump Station, 2411 Stanwood Dr	21709
3000498561	Pump station, 460 Northridge Rd	128
3001375540	El Cielito Pump Station, 2410 Sstanwood Dr	482139
3001375544	Sheffield Pump Station, 1 Foothill Dr	456566
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3001375553	Pump station, 310 Northridge Rd	16031
3001375515	Pump station, Calle Caleras/Cliff Dr	68319
3022532386	Cater S Coast Pump, 1150 San Roque Rd	156000
3001375548	Tunnel Reservoir Pump Station, End Tunnel Rd	21336
3001375543	El Cielito Reservoir Pump Station, 2117 Mount Cavalry Rd	37440
3001375524	East Reservoir Pump Station, 55 Crestview Ln	60984
3001375525	ndito Reservoir Pump Station, SKYLINE WY/FLRA VS PMP	61295
3000783093	Reservoir, 1030 La Vista Rd	2586
3001375529	La Mesa Reservoir	1922
3001375532	Reservoir #2, 1 Laguna St	1123
3001375536	Vic Trace Reservoir, 1631 La Coronilla	1835
3001978393	Reservoir #1, 144 Cedar Ln	1980
3028107223	Hope Reservoir Pump, 824 Centinela St	13480
3001375535	PRV	949
3010382902	PRV	819
	TOTAL	**1408871**

Source: Santa Barbara Edison bills 02-03 provided by Bill McTomney, Bmctomney@santabarbaraca.gov
Pump names and funtions provided by Rocky Peebles, Rpeebles@santabarbaraca.gov

WATER

Production	Acre-Feet/yr
All delivered potable water	12,743
TOTAL	**12,743**

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Source: Water Production Data, 02-03 provided by
Bill Ferguson, Bferguson@santabarbaraca.gov

Treatment Summary Data (2002-2003)

ENERGY

Edison Accounts Associated with Wastewater Treatment	Name	Energy (kWh) (Sept 02-Sept 03)	Date
El Estero Wastewater Treatment Plant	2274164482	618864	Feb-08
		448944	Jan-08
		501528	Dec-07
		597840	Nov-07
		516552	Oct-06
		484920	Sep-07
		614568	Aug-05
		459024	Jul-06
		490104	Jun-05
		474792	Apr-06
		527664	Mar-05
		418704	Feb-06
	TOTAL	6153504	
	Total less energy used for recycled production	**5230478.4**	

Source: Santa Barbara Edison bills 02-03 provided by Bill McTomney
Bmctomney@santabarbaraca.gov
Monthly energy is the highest amount used for that month over the last three years to reflect energy consumed without CoGeneration

WATER

Production	Acre-Feet/yr
8.5 million gallons/day	9,521
TOTAL	**9,521**

Estimation based on wastewater website
8.5 millions gallons/day x 365 days/ year x 325,851.429 gallons/ac-ft

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Treatment Summary Data (2002-2003)

ENERGY

Edison Accounts Associated with Recycled Water Production	Name	Energy (kWh) (Sept 02-Sept 03)
None	15% El Estero Energy	923025.6
	TOTAL	**923025.6**

Source: Santa Barbara Edison bills 02-03 provided by Bill McTomney
Bmctomney@santabarbaraca.gov

WATER

Production	Acre-Feet/yr
Estimation from website	736
TOTAL	**736**

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Estimation based on Santa Barbara wastewater website

Treatment Summary Data (2002-2003)

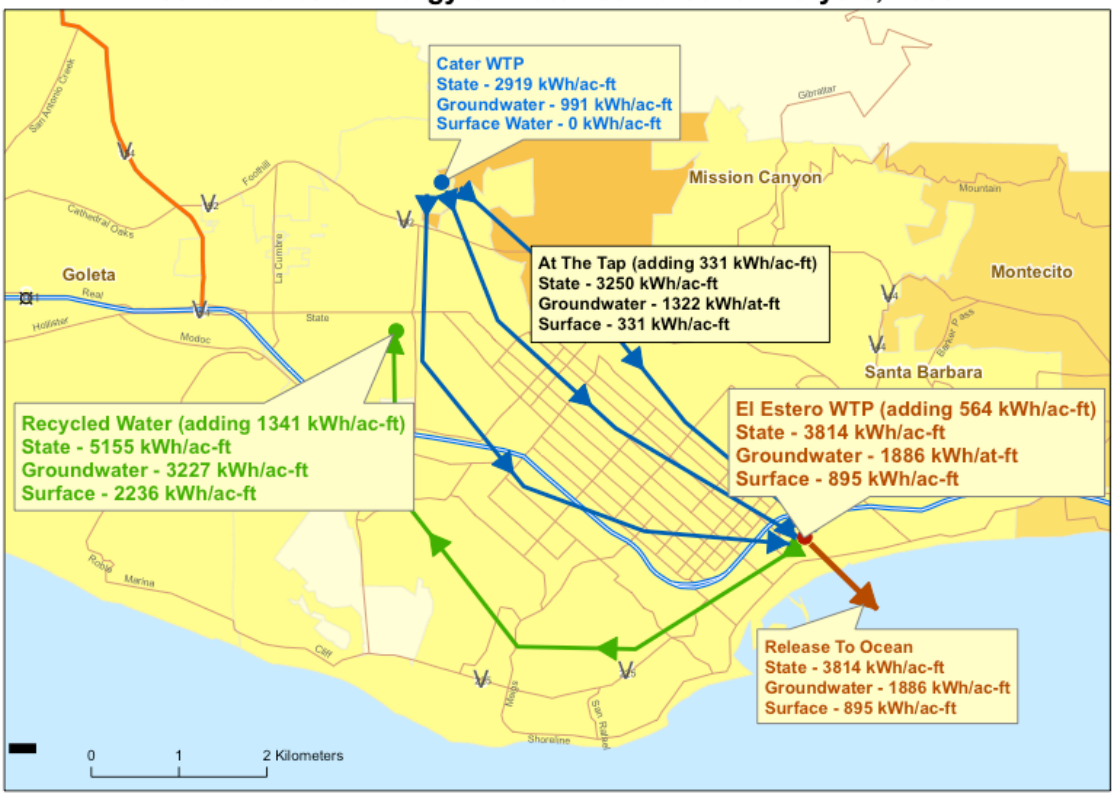
ENERGY		
Edison Accounts Associated with Recycled Water Distribution	**Name**	**Energy (kWh) (Sept 02-Sept 03)**
3003752132	Recycled Pump Station, 3500 McCaw Ave	202589
	TOTAL	**202589**
Source: Santa Barbara Edison bills 02-03 provided by Bill McTomney, Bmctomney@santabarbaraca.gov		
Name of function of pump provided by Rocky Peebles, Rpeebles@santabarbaraca.gov		
WATER		
Production	**Acre-Feet/yr**	
Estimation from website	736	
TOTAL	**736**	
Click to return HOME	Estimation based on SB wastewater website	

Type	kWh/acre-foot	lbs CO2/acre-foot produced
State Water Project into Cachuma	2919.00	2414.01
Groundwater	991.06	819.60
Surface Water	0.00	0.00
Potable Treatment	219.87	181.83
Potable Distribution	110.56	91.43
Wastewater Collection	15.19	12.56
Wastewater Treatment	549.36	454.32
Recycled Production	1065.99	881.58
Recycled Distribution	275.26	227.64

Source: Evan Johnson, Donald Bren School of the Environment, evjohnson@bren.ucs
Based on 0.827 lbs CO2/kWh for SoCalEdison's energy mix

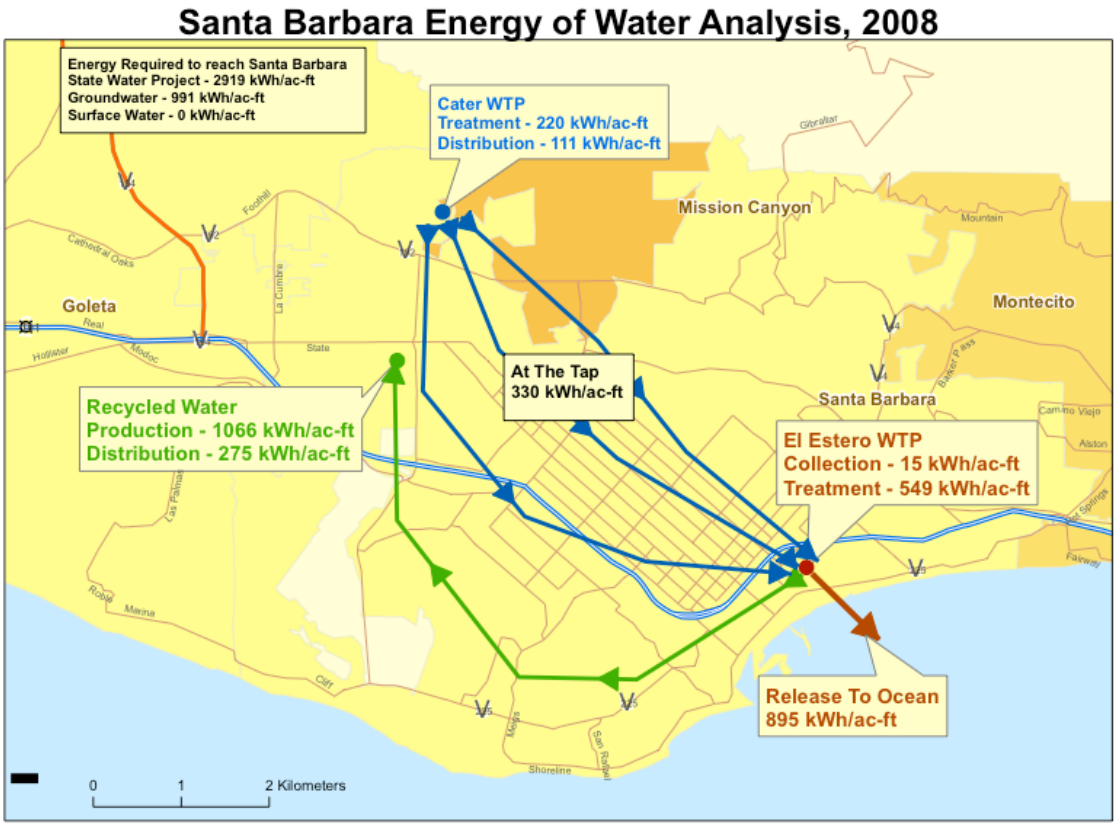
APPENDIX 2. Cumulative Analysis MAP

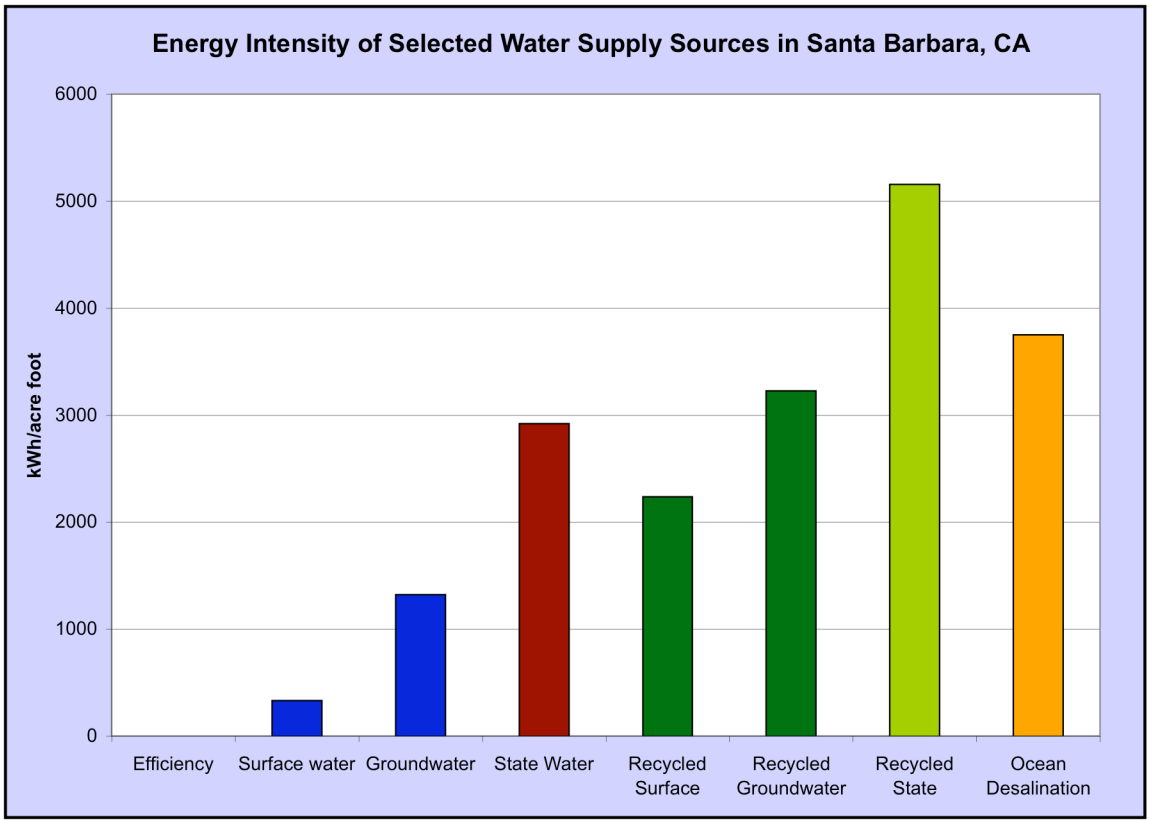
Santa Barbara Energy of Water Cumulative Analysis, 2008



Source: Santa Barbara City Public Works Dept

APPENDIX 3. Energy of Water by Step



Source: Santa Barbara City Public Works Dept

APPENDIX 4. Relative Energy of Sources Bar Chart