Influence of Spatial Heterogeneity on the Environmental and Economic Performances of Enhanced Water Supply Scenarios

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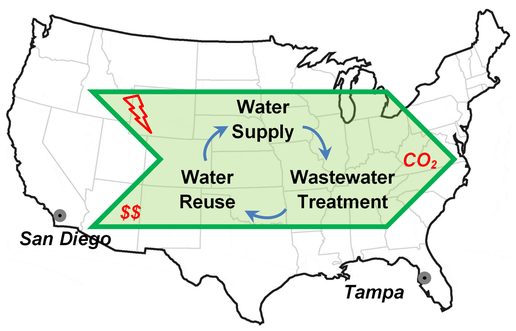
Introduction



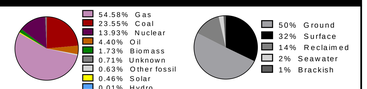
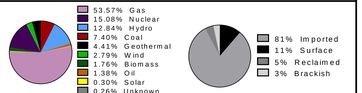
Increased water demand and scarce freshwater resources have forced communities to seek non-traditional water sources. These challenges are exacerbated in coastal communities where population growth rates and densities in the US are the highest.

To understand the current management dilemma between constrained surface and groundwater sources and potential new water sources, Tampa Bay, FL (TB) and San Diego, CA (SD) were studied through 2030 accounting for changes in population, water demand, and electricity grid mix.

Study regions

With similar socioeconomic characteristics, water demands, and water scarcity profiles, TB and SD are vigorously developing alternative water supplies; however, these communities have significantly different water resources and regional energy grid mixes (Table 1).

Table 1: Baseline information for Tampa Bay Water Planning Region (TB) and San Diego County Water Authority (SD) related to population, area, economy, water demand, and the composition of the energy grid and freshwater supply.

Region	Pop. (million)	Area (km^2)	Regional GDP* ($ billion)	Water demand in 2010 (million m^3)	Projected demand increase by 2030	Grid mix	Water source
TB	2.7	5180	116	1.7	21%		
SD	3.1	3845	173	2.1	45%		

Water Management Scenarios

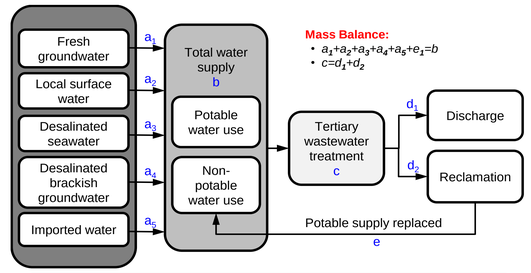


Figure 1: For TB and SD, the amounts of water supplied and treated by each type of water infrastructure in 2010 and project regional water demand in 2030 for three different water supply portfolio scenarios.

		a_1	a_2	a_3	a_4	a_5	b	c	d_1	d_2	e
TB	Current	848	541	42	19	0	1685	852	492	360	235
	S1	848	833	94	23	0	2033	973	613	360	235
	S2	848	723	227	0	0	2033	973	613	360	235
	S3	848	549	0	0	0	2033	973	0	973	636
SD	Current	0	208	0	61	1491	1843	1136	1052	83	83
	S1	0	208	568	106	1949	2990	1344	1185	159	159
	S2	0	208	1325	106	1192	2990	1344	1185	159	159
	S3	0	208	0	106	1332	2990	1344	0	1344	1344

Unit: thousand m^3/day

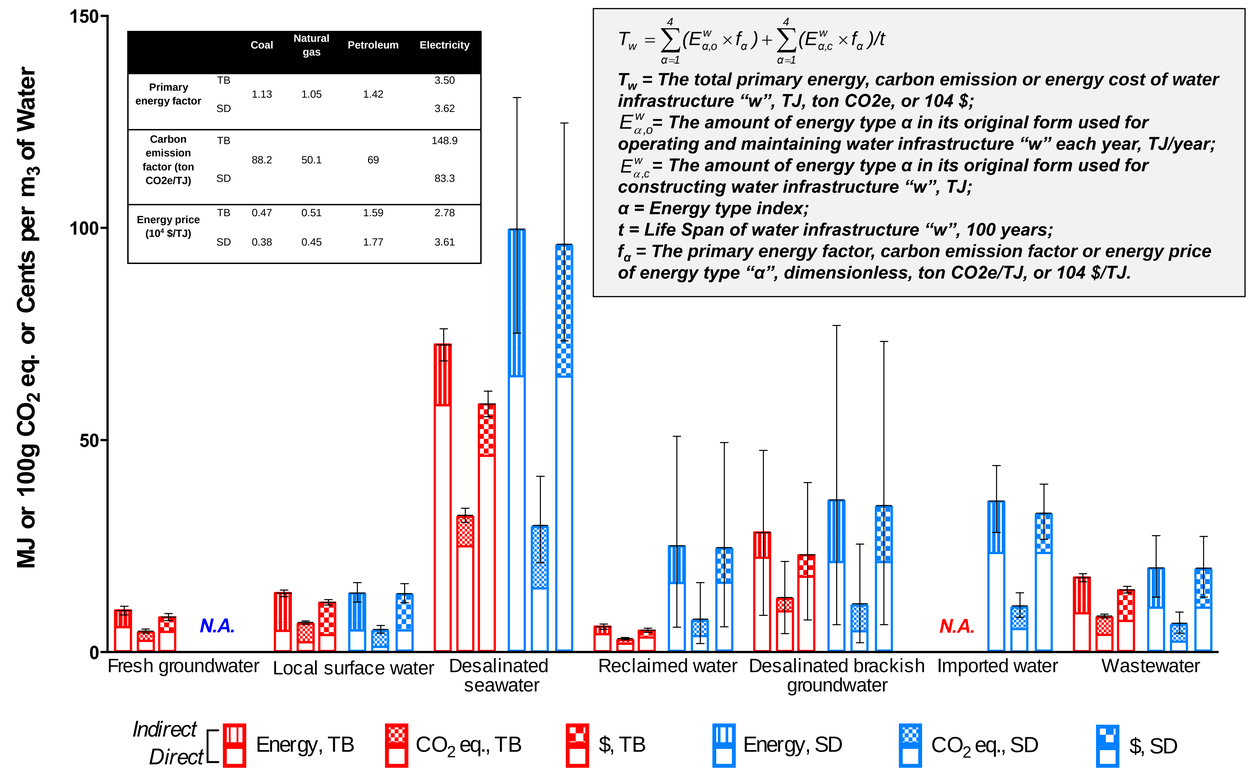
- Note: reclaimed water use efficiency (e/d_2) is 0.65 in the TB and 1 in the SD.

Scenario 1
Maximize current dominant supply

Scenario 2
Maximize seawater desalination

Scenario 3
Maximize water reclamation

Comparison of Different Types of Water Infrastructures in 2010 (Baseline)



		Coal	Natural gas	Petroleum	Electricity
Primary energy factor	TB	1.13	1.05	1.42	3.50
	SD				3.62
Carbon emission factor (ton CO2e/TJ)	TB	88.2	50.1	69	148.9
	SD				83.3
Energy price (10^4 $/TJ)	TB	0.47	0.51	1.59	2.78
	SD	0.38	0.45	1.77	3.61

$$T_w = \sum_{\alpha=1}^{4}(E^w_{\alpha,o} \times f_\alpha) + \sum_{\alpha=1}^{4}(E^w_{\alpha,c} \times f_\alpha)/t$$

T_w = The total primary energy, carbon emission or energy cost of water infrastructure "w", TJ, ton CO2e, or 104 $;
$E^w_{\alpha,o}$ = The amount of energy type α in its original form used for operating and maintaining water infrastructure "w" each year, TJ/year;
$E^w_{\alpha,c}$ = The amount of energy type α in its original form used for constructing water infrastructure "w", TJ;
α = Energy type index;
t = Life Span of water infrastructure "w", 100 years;
f_α = The primary energy factor, carbon emission factor or energy price of energy type "α", dimensionless, ton CO2e/TJ, or 104 $/TJ.

Figure 2: Embodied energy, GHG emissions and energy costs of water infrastructure systems in the regions of Tampa Bay, Florida and San Diego, California. (Note: Impacts of imported water were calculated as 15% from northern California and 85% from the Colorado River as reported by Cohen et al. (2004) as the proportional mix in 2010.)

Future Energy Grid Scenarios

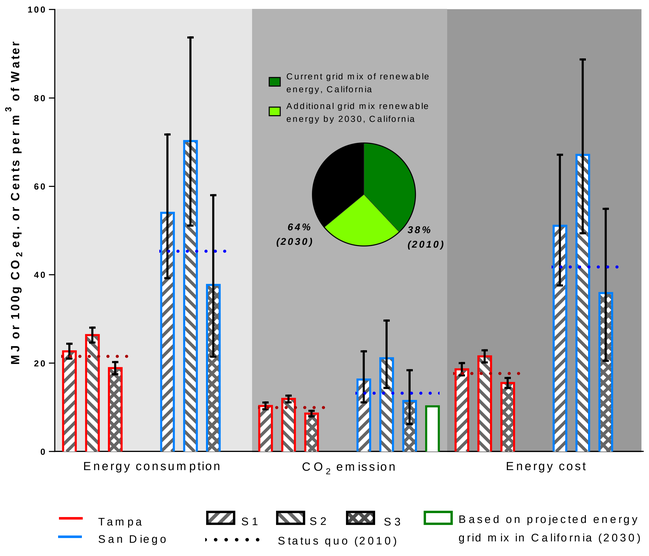


Figure 3: Embodied energy, GHG emissions and energy costs of the future water management scenarios in the regions of Tampa Bay, Florida and San Diego, California.

Acknowledgements

This material is based in part upon work supported by the National Science Foundation under Grant Numbers CBET 0725636. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Sensitivity Analysis

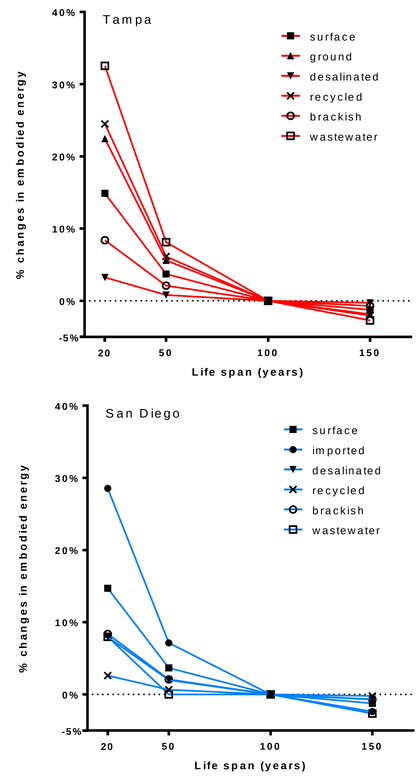


Figure 4: Percentage change in embodied energy when life span is 20 years, 50 years and 150 years respectively in Tampa Bay, Florida and San Diego, California.