Balancing Energy and Water Consumption in an Urban Desert Environment: A Case Study on Phoenix, AZ

Omaya Ahmad and Darren Ruddell

Environmental Tradeoffs

Three foremost challenges facing the rapidly urbanizing and naturally hot Phoenix, AZ metropolitan area are the urban heat island effect, water scarcity, and energy consumption. The transformation of native landscapes into built environments and sources of anthropogenic heat have produced the heat island effect (higher nighttime temperatures in cities compared to nearby native areas). Recent research shows that local temperature variability within the urban environment is highly correlated with land use. Residential landscaping preferences, therefore, are strong drivers of local temperatures whereby the following tradeoffs exist:

1. Households with high vegetation mitigate high summer-time temperature exposure but use more water.
2. Households with drought-resistant landscaping have an increased exposure to heat stress but conserve landscaping water.
3. Households with drought-resistant landscaping have higher energy demands to provide cooling and energy generation requires a considerable about of water.

Analyses examine the complex relationship between the use of water to maintain lawns which provide cooler landscapes and the energy costs to cool homes.

Identifying Direct and Indirect Costs of Water and Energy Consumption

Study Area

Although studies have documented pronounced warming trends regarding the Phoenix urban heat island over the 20th century, recent research shows that temperatures vary significantly within the same urban area. To capture the variability of temperatures within the city of Phoenix, 16 diverse census blocks are examined.

Data

Three datasets are analyzed in the study:

1. The WRF climate model at a spatial resolution of 1-km for a 2005 summer heat wave to observe temperature variability
2. Water use data at the Census block group level for 2005
3. Energy consumption data from 2005 Census

Descriptive Statistics for Temperature (°C), Energy (MWhr), and Water (Hectare)

		Mean average temperature for 4-day heat wave	Total megawatt hours consumed for 2005	Annual Water Consumption for 2005
N	Valid	16	16	16
Mean		38.6	49762.9	143117.4
Std. Deviation		0.9	121612.1	151455.2
Range		3.6	496491.0	455442.0
Minimum		35.9	6577.0	4624.0
Maximum		39.5	503068.0	460066.0

Climate

Results

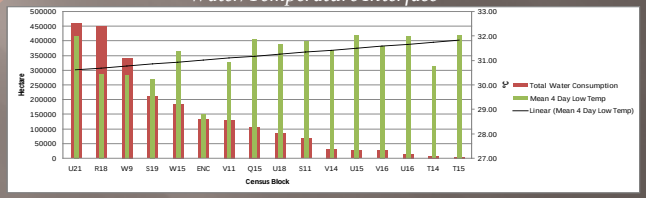
Nighttime Temperatures Affected by Water Consumption

- Annual water consumption is significantly correlated with temperature during the heat wave. Temperatures have an increasing linear relationship to water consumption as it decreases;
- On average, temperatures increase by 1ºC for every 100000 hectare decrease in water consumption;
- The census block T15 reported the highest temperature average and had the lowest annual water consumption.

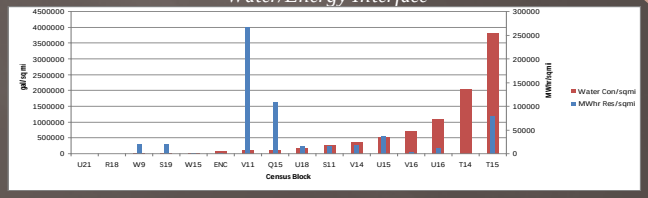
Trading off Water and Energy Use for Home Cooling

- Census blocks V11 and Q15 are most notable for their significant energy use and little annual water consumption;
- Although not consistent throughout, for the most part, higher water consumption is correlated with less energy usage;
- Census block T15, which had the lowest total water consumption, had the highest reported annual water consumption per square mile in conjunction with significantly lower energy consumption by comparison.

Water/Temperature Interface



Water/Energy Interface



Water

Energy

Conclusion

Research Observations

- There is a significant intra-urban variation of climate and water and energy usage, likely due to the varying use of land and population in each census block;
- More water or energy is used to cool and rarely are both methods used together in high amounts to cool;
- Results quantify the direct and indirect costs of water and energy consumption and offer recommendations on water and energy policy.

Future Research

- Examine vegetation fractions in census blocks using 2005 National Agriculture Imagery Project;
- Use PASS to examine social implications of tradeoffs between climate, water, and energy.

Acknowledgement

Authors recognize SRP / APS and the City of Phoenix for providing information for this study. Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of SRP / APS or the City of Phoenix.

Mesic Landscaping

Xeric Landscaping