



Energy and Water Use in Tucson Nov. 2004-Oct. 2005

Civano Residences Compared to Tucson's Pre-1996 and 1998/99 Homes.

Prepared for the Pulte Corporation and the City of Tucson

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See ANE Inc. reports on Civano Energy and Water Audit 2001-2004 for wider analysis.

ANE, Inc. would like to thank Southwest Gas and Tucson Electric Power for providing data for Tucson, and participating residents of the City of Tucson and the Civano neighborhood for permission to use utility data in this study. ANE, Inc. thanks the City of Tucson Water Department, especially Tom Arnold, for providing water data, Christie Garrison for research assistance and editing and Cari Spring for writing and editing.



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I. Energy Use

1. Purpose of Study: Civano MOU, Tucson's Model Energy Code and the Sustainable Energy Standard

Per the Civano MOU 1998, Civano adopted the 1998 Sustainable Energy Standard (SES) for design and construction of all buildings in Civano. The 1998 SES identified beneficial use of solar energy and a maximum use for hot water, cooling, and heating energy as 50% of the local standard as paramount to attaining a sustainable level of energy use. Water use was also restricted to (see Part II: Water Use). Current revisions to the SES approved by mayor and council on October 1, 2005 identify beneficial use of solar energy as a minimum of 5% while keeping the 50% heating and cooling energy reduction standard.

1998 Sustainable Energy Standard

The 1998 Sustainable Energy Standard: The calculated target annual energy consumption of the building shell and mechanical system and domestic hot water heating shall be less than the energy required by the present Tucson/Pima County Model Energy Code by 50 percent. (Sustainable Energy Standard, Chapter 1, Section 101.4.)

The Model Energy Code (MEC) thereafter became the IECC when International Standards were adopted; in this report, the Model Energy Code is referred to as the IECC.¹

Cooling and heating energy use by homes built to the 1995 MEC was assumed to be approximately 36-54 kBtu/sq ft/year source energy. (Source energy is computed as the energy produced at the power utility to support the end-use; see the Appendix for conversions assumed.) The 1998 SES proposed that energy use for homes built to the SES be 50% of the MEC as specified in Table 1, and therefore between 18-27 kBtu/sf/yr depending on the square footage of the home. Evaluation of energy use was then to be evaluated yearly during the initial build out, as determined through energy audit of actual use.

small houses have more wall per sf than large houses

Building Sq. Ft. Range	kBtu/sq. ft./year/home as source consumption in kBtu		
	Heating	Cooling	Total
<1000	5	22	27
1000-1399	4	18	22
1400-1799	4	16	20
1800-2199	4	15	19
>2199	4	14	18

Table 1. 1998 Sustainable Energy Standard: Prescriptive Compliance Summary.

The 1998 SES also described a need for "beneficial use of solar energy" but provided no parameters. Solar hot water was most commonly provided by builders, but others relied on less rigorous criteria to meet this requirement which prompted the upgrading of the standard. The 2005 SES (October 1, 2005; Attachment B to Ordinance 10178) specifies the use of solar energy as 550 kBtu/yr/bedroom for residences and is prescriptively met using typical solar thermal hot water systems for up to four bedrooms. Other means include PV or other methods allowed by the standard. Commercial buildings are to demonstrate a 5% utilization of solar energy.

¹ ANE, Inc. reports on Civano Energy use for 2001-2002 and 2002-2003 provide a history of the development of the 1998 SES and its basis.

The 1998 SES limits hot water use to be 50% that of the 1995 Model Energy Code (1995 MEC), figures for expected use by houses built under the 1995 MEC are not estimated, nor is any criterion for evaluation of hot water energy given (extracting these data from the utility data is not possible under current reporting methods). The Arizona Solar Center calculates energy avoidance of the Progressive Tube Solar Hot Water Heater (used in some homes at Civano; model PT-40 CN with 40 gallons in collector storage) at 2,200 kWh/year. Converted to 7,512 kBtu/year, the savings from solar hot water use represents approximately 4.6 kBtu per square foot/year for Civano homes using solar hot water. Other collectors used include the Sun Earth collector, which is similar to the PT-40 and is expected to have similar performance.

The (Tucson) *Baseline Study for Residential Energy Use 1998/1999* performed for the City of Tucson Energy Office (released in 2002 by McKnight Consulting, LLC) confirmed for the year studied that cooling and heating in a sample of Tucson homes built to the 1995 MEC used approximately 40 kBtu per sq ft per home per year for heating and cooling for homes averaging 1780 sq ft. Current analysis of cooling and heating in Tucson homes for comparison to the Civano shows a lower use by City homes (below).

Energy evaluation of homes built in different years and per different energy standards potentially allows evaluation of the effects of codes and standards on real energy use. These results are important to stakeholders of Civano and of Tucson. Broadly, evaluation of the 1998 SES and its methods helps to evolve conceptions and methods in sustainability. It aids the evolution of adequate (complete and correct) evaluation methods. The latter goal is explicit in Civano's Memorandum of Understanding.

The goal of the Memorandum of Understanding is to confirm the strategies for sustainable development and to implement and monitor the Civano IMPACT System...**Subsequent monitoring of performance...will provide the basis for determining the success in meeting the IMPACT System Standards as well as the basis for improving future conservation and sustainability strategies and standards** (Civano IMPACT MOU 1998, Sections 1-3; bold added).

2. Characteristics of the 2005 Energy Use Study

Data characterizing Civano homes was collected from Tucson Electric Power and Southwest Gas based on voluntary participation in the study by Civano homeowners. Participation in Civano's energy audit is always on a voluntary basis as respondents reply to postings around Civano. 37 participants contributed to the current study; homes averaged 1,700 square feet. As neighborhoods expand, the sample size is expected to increase. One home in the Civano study uses photovoltaics and is a near net zero home (0.12 kBtu/sf total utility energy use/yr; \$171 per year).

Homes for the Tucson sample included those built before the first energy codes were enacted (pre-1996 City homes), and homes built immediately after the first energy codes were enacted (1998/99 City homes). Names and addresses were obtained from Pima County tax records. A program then was used to choose homes built during target years and release/information forms were mailed to 400 residents. A dismal response resulted in 37 relevant responses. Of these, energy data returned from Tucson Electric Power and Southwest Gas company provided samples for 36 homes with 12 months of data; 24 homes returning data were constructed prior to 1996 (no existing energy code) and 12 were constructed during 1998-99 under the Model Energy Code.

The Tucson Baseline study of 2002 reported average Tucson home square footage at 1,748-1,789 square feet, ranging between 1,111 and 3,552 square feet.

Energy bills were examined by month, and energy use evaluated and reported in source kBtu/sf/yr (see Appendix for conversions). The cooling/heating energy was determined by averaging the “base” (or “plug”) loads for each month. The calculated base load was then eliminated to reveal the heating or cooling energy for the month. Base loads are those devices that use energy throughout the year, not on a seasonal basis. The base load is expected to be consistent throughout the year and provides for the measured energy use during each and all months.

Base loads are calculated using Tucson Electric Power Company’s method for base calculation: the lowest monthly energy use found during March/April is averaged together with the lowest of the two months October/November. The resulting number is utilized as the base calculation for the sample.

In fact, base use is difficult to measure and the method followed here is a good approximation. This procedure will always produce at least one month with negative numbers. As an evaluation measure, this procedure assumes little or no heating and cooling for the selected base months of the year, March/April, October/November, whereas it might be that *both* heating and cooling take place. In the latter case, some of the energy attributed to base load would therefore actually be heating and/or cooling energy.

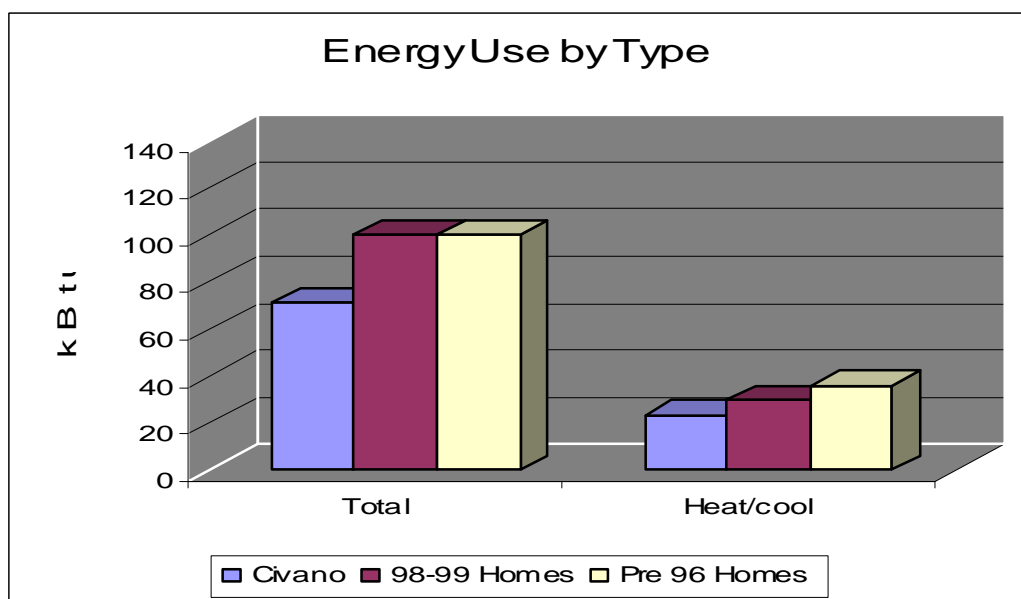
Average square footage for Civano Electric homes (20 samples) was 1,579 sf; for Civano dual fuel homes (use of gas and electric; 17 samples) was 1,847 sf; for City, pre-96 homes (24 samples) was 1,884 sf; and for City 98/99 homes (12 samples) was 1,747 sf.

B. Evaluation of 2005 Energy Use

Results for total energy use and cooling and heating energy for 2004-2005 are given in Table 2.

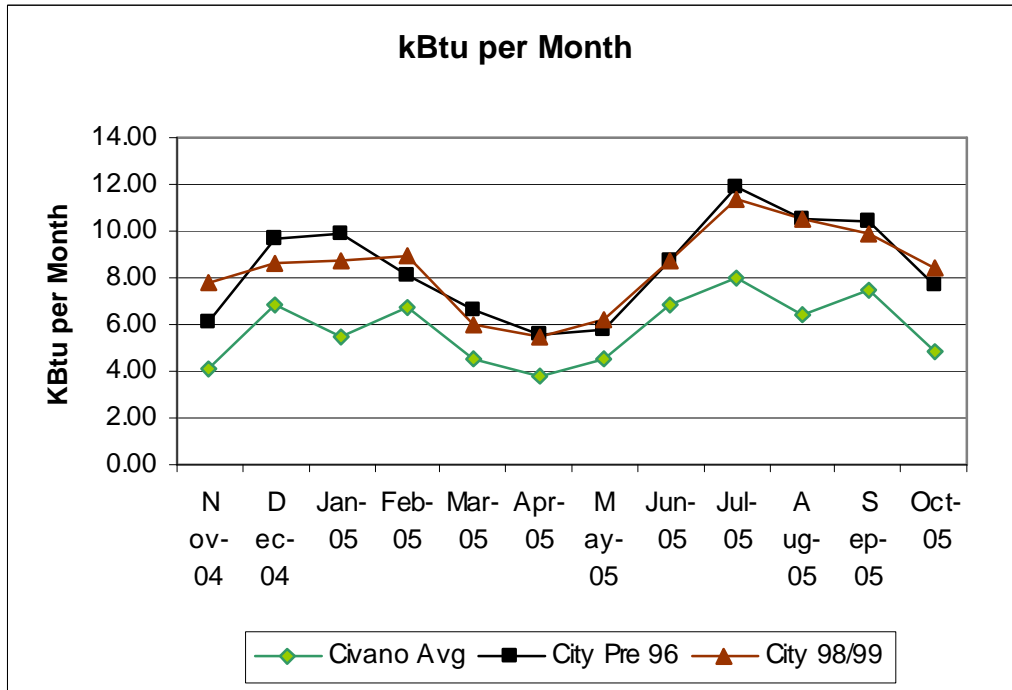
	Total use (in kBtu/sf/yr)	heating/cooling energy (in kBtu/sf/yr)
Civano	71	23
Tucson 98-99 Homes	100	30
Tucson Pre-1996 Homes	100	36

Table 2. Civano and Tucson results in source kBtu per square foot

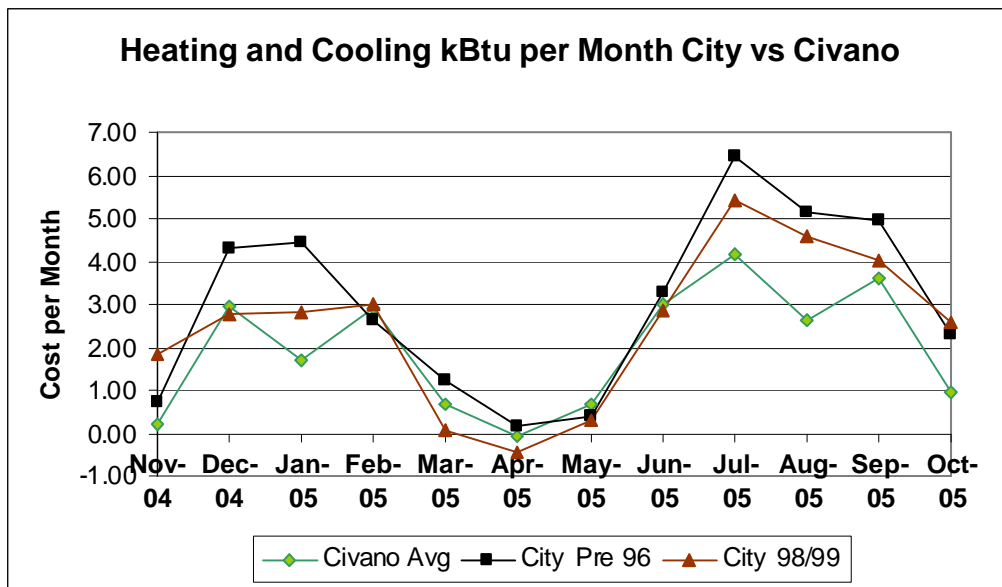


Graph 1. Total and heating and cooling energy for all homes.

Graphs 2 and 3 show total and heating and cooling energy (respectively) as average energy use in kBtu/square foot/month and shows the two peaks of use arising from seasonal energy use for heating and cooling.



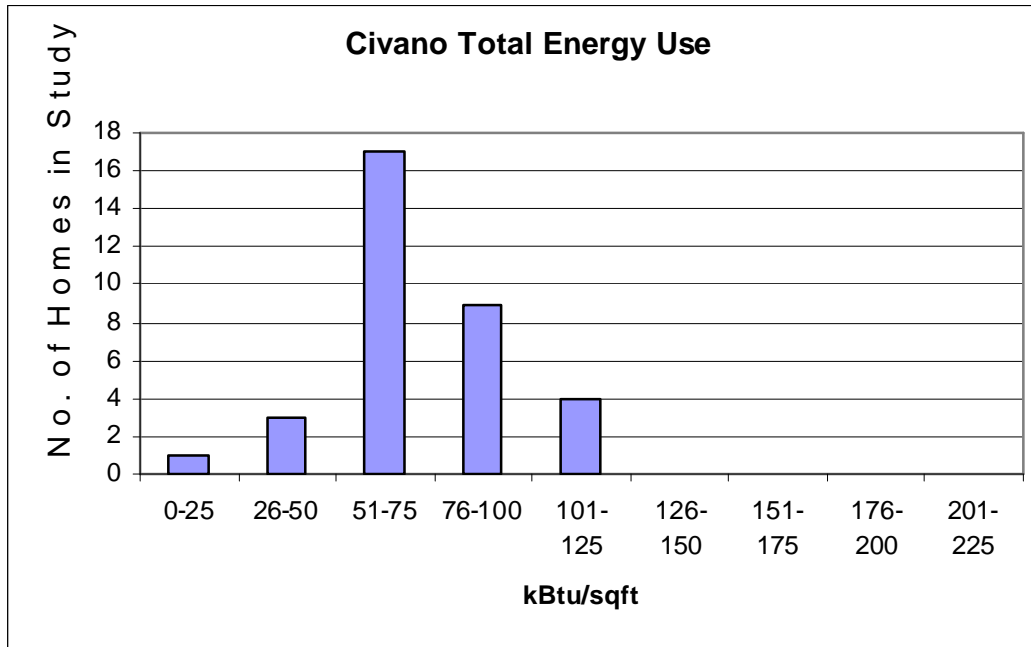
Graph 2. Comparison of total energy use for Civano and City.



Graph 3. Comparison of heating and cooling energy for City and Civano.

Graph 3 illustrates that the daily habits of Civano residents (relating to base loads) are very similar to those of the general population and indicates that the consistently lower use of kBtus is due to increased efficiency of the building envelope and the use of solar energy.

Graph 4 shows the histogram of energy use for Civano samples.



Graph 4. Histogram of energy use for all Civano homes in the study.

C. Cost and Energy Savings for City and Civano

Cost for utilities per year and cost for heating and cooling per year is averaged as seen in Table 3. Gas costs were collected from 21 samples and averaged across 38 homes in the sample.

	Annual Cost
Civano	\$1,028/yr
98-99 Homes	\$1,718/yr
Pre-96 Homes	\$1,886/yr

Table 3. Utility costs for Civano and the City.

3. Conclusions for the 2005 Energy Use Study

Due to a small sample size that limits the accuracy of this study, the results still show a significant improvement in energy conservation under the SES as applied in Civano homes compared to other homes of a similar nature. Furthermore, this study has shown that the requirements that achieve these savings are both financially and mechanically feasible for both the homeowners and the builders. Lastly, in future cycles of this study we will begin to see more accurate numbers as we grow our sample size, yielding clearer results. Most of the study participants have signed agreements giving us access to 10 years of utility information for their residences.

II. Water Use

A. Introduction: Civano and Sustainable Water Use Standards

1. Purpose of the Study

Civano (per MOU) adopted the 1998 Sustainable Energy Standard (SES) for energy and water use as 28 gallons per day per capita exterior and 53 gallons per day, per capita interior.

2. Characteristics of the 2005 Water Use Study

Potable and reclaimed water are metered individually for Civano residences. Data from potable water use by 44 individual Civano residences, and from reclaimed water use by 34 residences were supplied by Tucson Water Company. Of these samples, 37 provided a full year of utility data for potable water and 29 provided a full year of utility data for reclaimed water. (Of the 37 samples, eight do not use reclaimed water.) Three of these eight residences are on very small lots with very little landscaping, two have rain water cisterns and three stopped using reclaimed water over a year ago.

In the energy study performed by ANE, Inc. for Civano 2003-2004, 41 homeowners returned a survey questionnaire relating characteristics of Civano homes. Of those, 19 provided occupancy data. With a range between 1-5 occupants per home, these preliminary data indicated 2.17 occupants per residence at Civano. This compares with 2.25 occupants per residence assumed in previous reports. Since full and current demographics for the 37 homes in the sample are not available, we will use the 2.25 per residence assumed previously for the sake of consistency.

B. Evaluation of 2005 Water Use

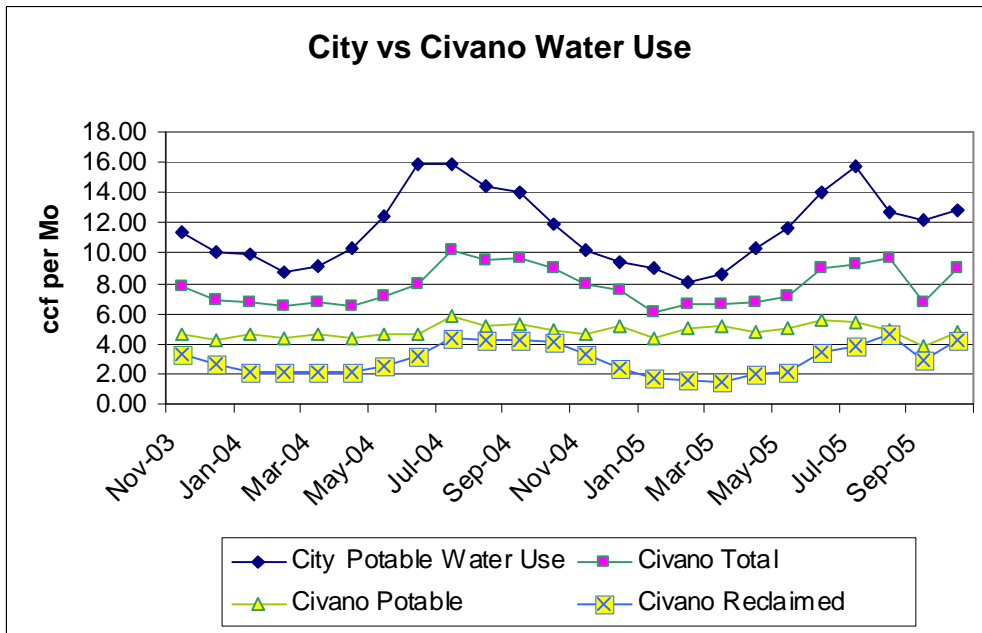
Two years of water data were reported by Tucson Water Company for the City vs. the Civano average. Samples returned indicate an overall average monthly potable water use as shown in table 4 below.

	Total		Reduction in Potable Water Use	
	Last 24 mo	Last 12 mo.	Total 24 mo	Last 12 mo
Civano Potable Water in ccf	116.2	58.8	58.3%	56.4%
Reclaimed Water in ccf	70.7	33.6		
Civano Total ccf per yr	186.9	92.4	Overall Reduction in Water Use 33.0%	31.4%
Average Usage City per mo All Residential Water Users	278.8	134.8		

Table 4 Water use comparison

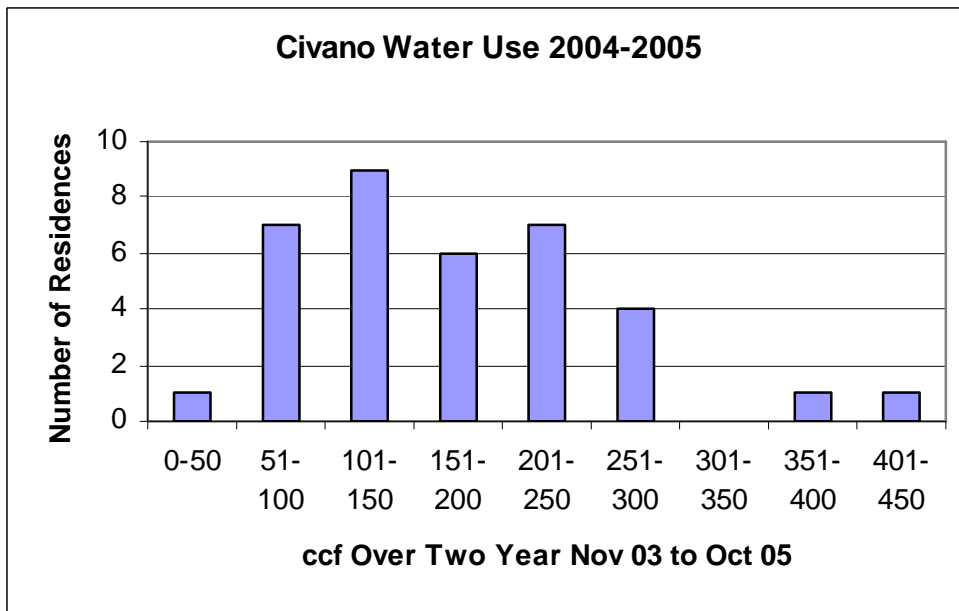
Tucson Water Company provided data from the total Tucson population of residential water users as 134.8 ccf per year compared to 92.4 ccf per year (total water) for Civano homes, and 58.8 ccf potable water for Civano residences. Thus, total Civano potable water use is approximately 56.4% lower than Tucson homes. Overall water savings is likely a result of strict landscape standards, small lot sizes, use of cisterns, reclaimed water and community awareness.

Graph 5 compares the City sample with Civano's for two years of energy data.



Graph 5. Comparison of City of Tucson (“City”) water use with Civano total water use; Civano potable and Civano reclaimed water use are shown for comparison.

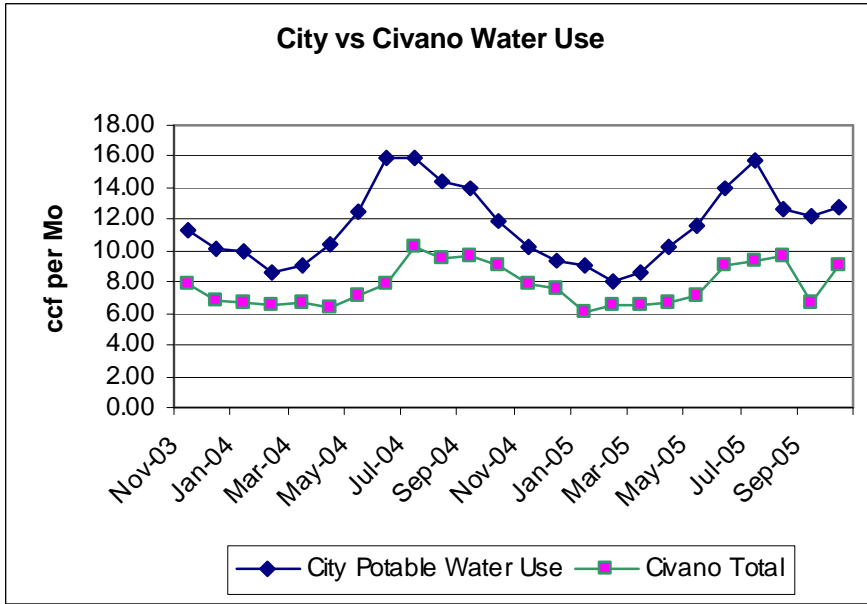
The range of water data gathered from the 37 homeowners at Civano appears as in Graph 6.



Graph 6. Histogram showing range of total water use per home as CCF over a two year period.

As can be seen from the spread in home water usage, great variation characterizes homeowner behavior. Previous reports have indicated a similar range in use patterns.

Graph 7 below compares city of Tucson water use with Civano use over two years. During this period, City water use dropped by 2.0%, while Civano total water use increased by 8.5%, and potable water use is up by 7.8%.



Graph 7 Tucson water use with Civano use over two years

Although Civano potable water use is given the sample size and characteristics of this study, the increase may not be significant enough to require action at this time. However, methods to be applied in Civano Neighborhoods 2 and 3 require close study to assure compliance with the Civano water IMPACT requirements.

3. Civano Water Use in Common Areas

Potable water is used in common areas only for the existing and new pools. Elsewhere, reclaimed water is used for common area landscaping needs. In addition to the individual residential total and potable water savings shown here, the common area landscaping uses xeriscape and reclaimed water, which further decreases potable water while successfully providing shade and grass spaces in the community. See the ANE, Inc. 2001- 2002 report for indications of the substantive contributions from use of reclaimed water for common areas (not computed this year as build out continues). A larger effort can be made to reduce water to replanted native trees that are now established and stable.

APPENDIX

Multipliers

The Sustainable Energy Standard evaluates compliance with target energy goals using *source energy*. *Point-of-use* energy refers to amount of energy used at a location, in this case, home energy use (indicated on a utility bill). *Source energy* is the total amount of energy used to produce and transport energy to its point-of-use. The SES specifies multipliers to assess source energy use: point-of-use *electrical* energy is multiplied by 3.1 to calculate source energy, and point-of-use *gas energy* is multiplied by 1.11 to assess source gas.

Correlations

In Tucson

- ? Approximately 2.3 pounds of CO₂ are released per kWh of electrical energy (charts appear in *Benchmarking Air Emissions of Electric Utility Generators in the United States*, National Resource Defense Council, 1996);
- ? Approximately 1 pound of coal and approximately 0.65 gallons of water are used per kWh of electricity.
- ? 67.39 pounds of CO₂ are released per therm of coal powered electrical energy.

National Average

11 pounds of CO₂ released per therm of natural gas.

Conversions

kilowatt-hour (kWh): 1,000 watt hours

kilo British thermal units (kBtu): 1,000 Btu; 3.41 kBtu per kWh

Therm: 100,000 Btu or 100 kBtu; 29.3 kWh per therm

~326,000 gallons/acre foot

748 gallons/CCF

~\$.17/ccf energy cost to deliver potable water

~5.21 lbs. CO₂/CCF emissions for potable water

-0.34 lbs. CO₂/CCF emissions for reclaimed water

See ANE Inc. reports on Civano Energy and Water Audits 2001-2004 for wider analysis.