Tucson, Civano, and the Sustainable Energy Standard

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ABSTRACT

Civano was originally conceived as the "Tucson solar village," in Arizona as an outgrowth of builder and consumer interest in solar designs with a natural and appropriate extension of desert living. Led by the Metropolitan Energy Commission, a number of local builders and environmentalists obtained a commitment from the Arizona Energy Office to fund the planning and design of the prototype community. As research progressed, the planners soon began to contemplate comprehensive extensions of their original idea, including energy and water conservation, solid waste reduction, and lower air pollution. "Solar village" soon became a much larger concept, and the community of Civano began to take shape. It was to be sustainable, and it was to incorporate many of the compact, life-enhancing, and socially integrated aspects of America's small towns.

The goal of the Civano project is to demonstrate the marketability of sustainable community development on a large scale at affordable prices. This 820-acre traditional neighborhood development utilizes proven available technology to reduce natural resource usage substantially below current levels. The property is located on state trust land in the city of Tucson, southeast of Houghton and Irvington Roads; zoning in the area was modified to support the Civano project. At the time, Civano was the largest development experiment of its type, and perhaps still is.

Though only completed through the first phase of construction, the Civano experiment has already yielded very interesting results in all areas of development research from water and energy conservation to planning methodology and standards testing. The following report, fourth in a series, shows the early results of energy and water use in Civano as compared to the city of Tucson before and after the imple-

mentation of mandatory national energy codes adopted in Tucson in 1995. The results are a testament to the effectiveness of the Sustainable Energy Standard as applied in Civano. The Civano project went mainstream in 2001, when the state trust land was auctioned to private developers. If all stays on course, all four construction phases of Civano will be completed by 2014.

INTRODUCTION

Per the Civano Memorandum of Understanding 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 percent of the local standard as paramount to attaining a sustainable level of energy use. Water use was also restricted (see Part II: Water Use). Current revisions to the SES approved by the mayor and council on October 1, 2005, identify beneficial use of solar energy as a minimum of 5 percent while keeping the 50 percent 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.*

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 percent of the MEC as specified in Table 1, and therefore between

*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.

18-27 kBtu/sf/yr depending on the square footage of the home. Energy use was evaluated yearly during the initial build out, as determined through energy audit of actual use.

Table 1. 1998 Sustainable Energy Standard: Prescriptive Compliance Summary (small houses have more wall per square foot than large houses).

Building	*kBtu/sq. ft./year/home as source consumption in kBtu*		
Sq. Ft. Range	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

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 percent utilization of solar energy.

The 1998 SES limits hot water use to be 50 percent 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 ap-

proximately 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 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 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).

CHARACTERISTICS OF THE 2005 ENERGY USE STUDY

Data characterizing Civano homes were 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.

Evaluation of 2005 Energy Use

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

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

	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

Graphs 1 and 2 show total and heating and cooling energy (respectively) as average energy use in kBtu/square foot/month and show the two peaks of use arising from seasonal energy use for heating and cooling.

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.

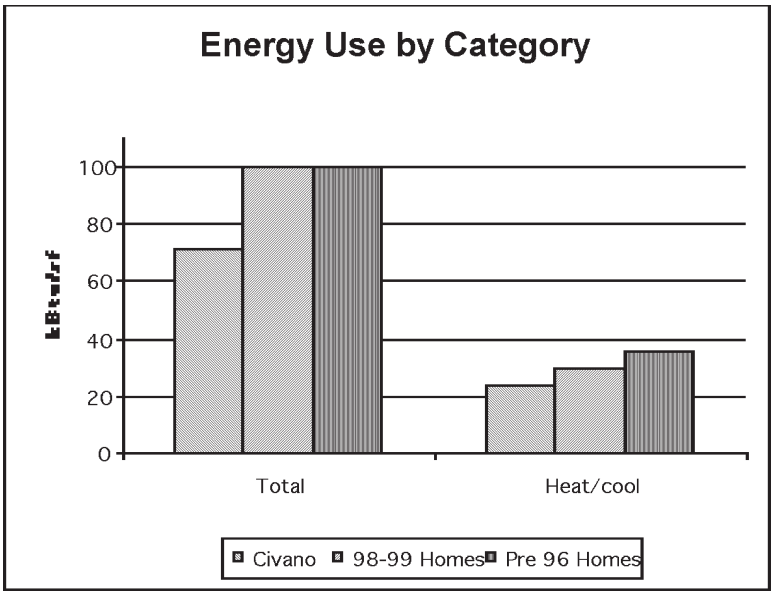
Cost and Energy Savings for the City and Civano

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.

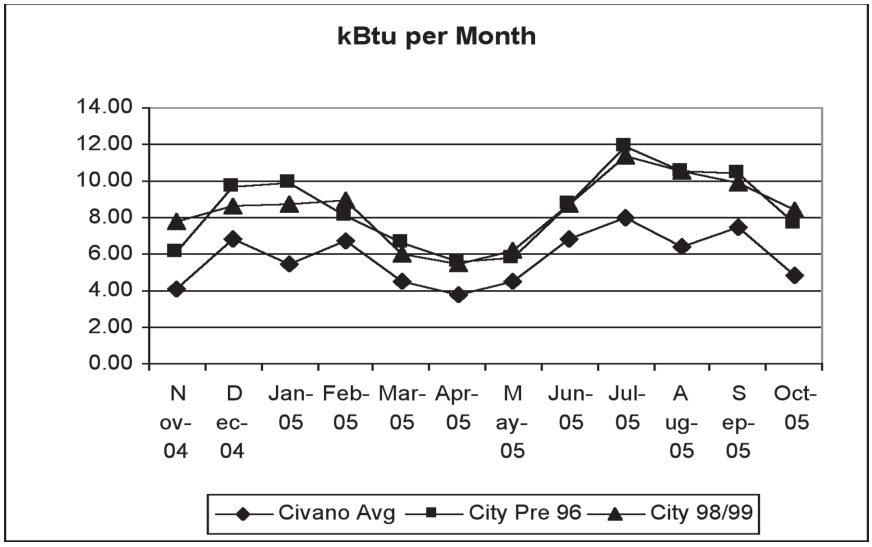
WATER USE

Civano and Sustainable Water Use Standards

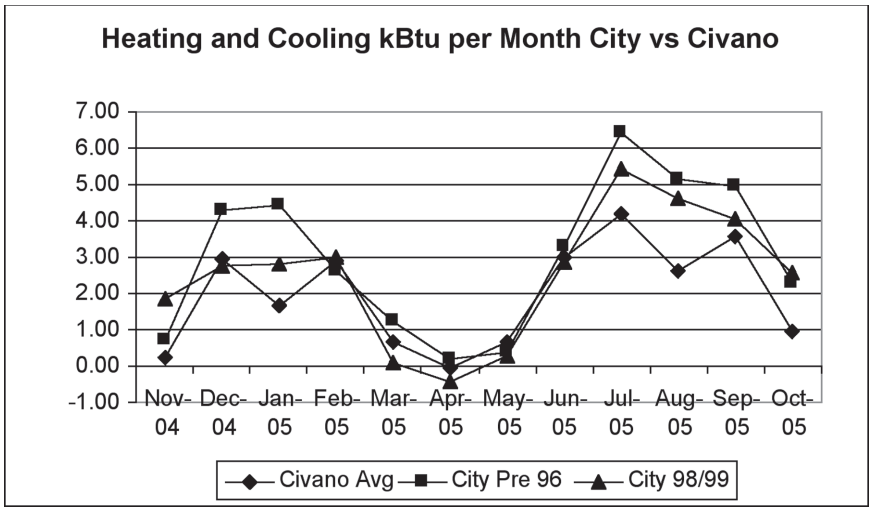
Civano (per MOU) adopted the 1998 Sustainable Energy Standard (SES) for energy and water use as 28 gallons per day per capita exterior and 53 gallons per day, per capita interior. For the 2005 water use



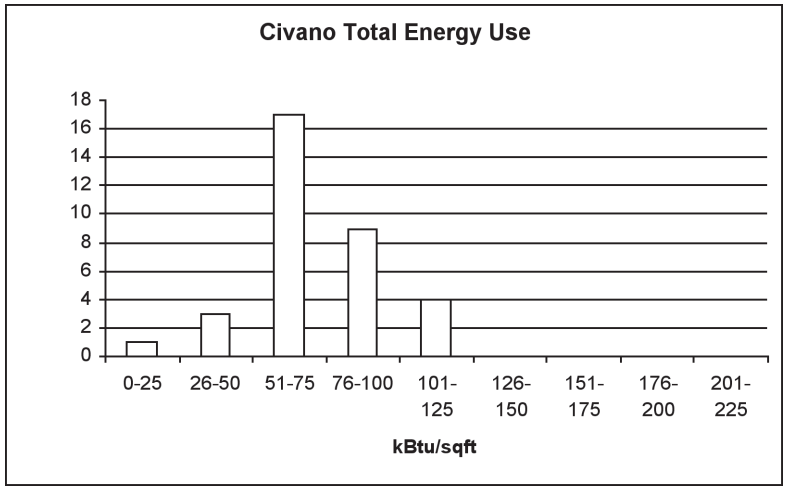
Graph 1. Total and heating and cooling energy for all homes.



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



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



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

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

Table 3. Utility costs for Civano and the city.

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

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.

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.

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

Table 4. Water use comparison.

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

water for Civano residences. Thus, total Civano potable water use is approximately 56.4 percent 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.

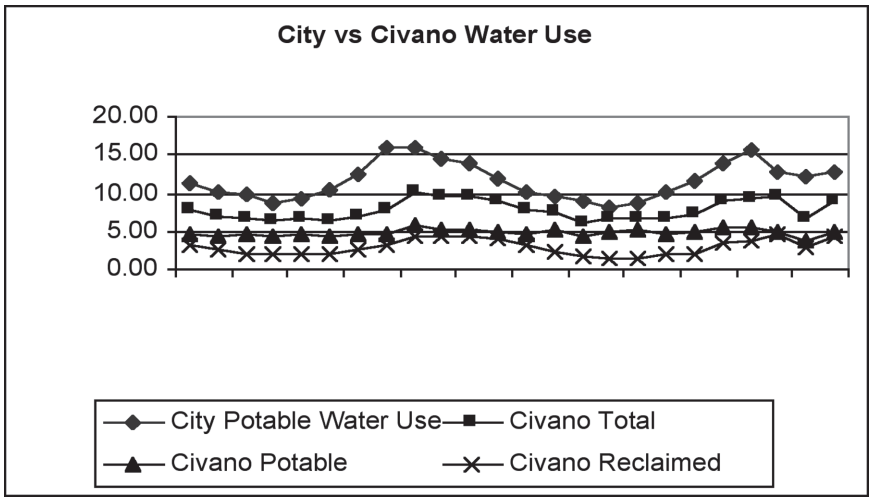
Graph 5 compares the city sample with Civano's for two years of energy data.

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

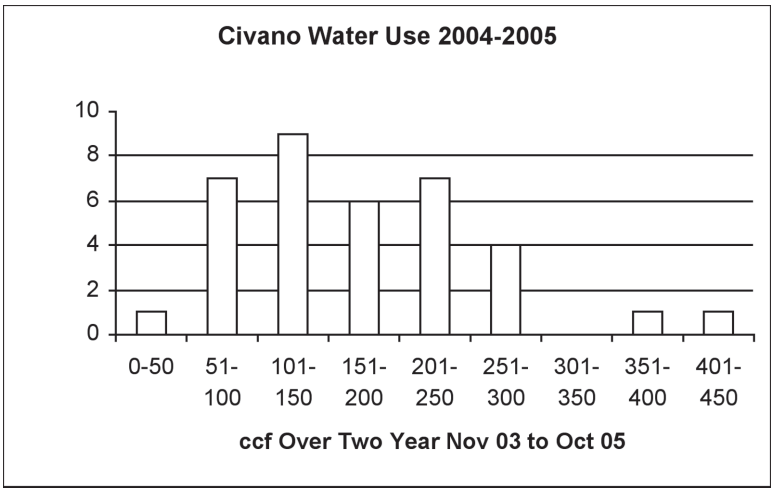
As can be seen from the spread in home water usage, great variation characterizes homeowner behavior. Previous reports have indicated a similar range in use patterns.

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

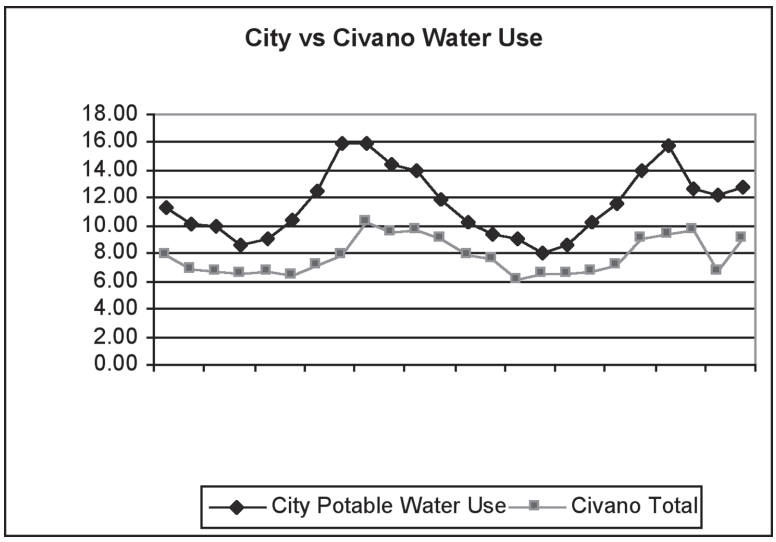
Although Civano potable water use is given the sample size and characteristics of this study, the increase may not be significant enough to require action at this time. However, methods to be applied in Civano Neighborhoods 2 and 3 require close study to assure compliance with the Civano water IMPACT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



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.



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



Graph 7. Tucson water use and Civano use over two years.

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 land-

scaping 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.

Conclusions for the 2005 Energy and Water Use Study

Though a small sample size 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.

As developers are obliged to achieve higher sustainability goals—both by the passage of laws and demands of the market—a higher standard of living will be attained. These benefits will be felt not only in our own homes and neighborhoods, but in environments around the world. Given that not all homes across the United States use either the same type of fuel for energy or have the same carbon footprint, it is difficult to make generalizations about energy savings across the nation for a particular action. Nevertheless, imagine this:

According to the National Association of Home Builders, the January, 2006, new home start rate was 2,265,000 new homes. If only those homes built in the United States in January were constructed to the SES standard and realized a similar savings as have thus far been attained in Civano, they would have consumed 65,685,000 fewer kBtus and 96,036,000 ccf of water every year! This can be achieved at an initial extra construction cost of only 0-5 percent.

In closing, we proudly report that in May, 2006, after seeing the results of logical standard development and enforcement, Tucson adopted a modified Sustainable Energy Standard that includes attainment of at least a Silver LEED certification in addition to the SES's 50 percent

energy savings and 5 percent solar utilization for all new city buildings and major renovations.

APPENDIX

Home Starts

Statistics are from the National Association of Home Builders website (www.HAHB.org).

Multipliers

- The Sustainable Energy Standard evaluates compliance with target energy goals using *source energy*.
- ***Source energy*** is the total amount of energy used to produce and transport energy to its point-of-use.
- ***Point-of-use*** energy refers to amount of energy used at a location, in this case, home energy use (indicated on a utility bill).
- 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 CO_2 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 one pound of coal and approximately 0.65 gallons of water are used per kWh of electricity.
- 67.39 pounds of CO_2 are released per therm of coal powered electrical energy.

National Average

11 pounds of CO_2 released per therm of natural gas.

References

The Memorandum of Understanding
http://www.civano1.com/pages/documents.html

The Sustainable Energy Standard
http://www.civano1.com/pages/documents.html
The Model Energy Code
http://www.tucsonaz.gov/dsd/Codes___Ordinances/Building_Codes/building_codes.html

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ABOUT THE AUTHOR

Al Nichols, P.E., C.E.M., G.B.E., L.E.E.D. A.P., has more than thirty years of professional experience in heating, air conditioning, energy systems, plumbing, and simulations. Project participation includes concept initiation, feasibility studies, cost analysis, energy analysis, modeling, grant applications, control sequences, design, and diagrams for new and renovation building projects. In addition, he spends much of his time serving the community by participating proactively in local government and as a speaker to help bring standards such as the Sustainable Energy Standard into use. Nichols was a commissioner for Tucson/Pima County Metropolitan Energy Commission (1993-2001), participated in early Civano inception for energy and solar standards, was commissioned to write Tucson's Sustainable Energy Standard with a broad spectrum from the energy community ("SES"; first tested at Civano) and later to review model, custom and commercial plans for compliance with SES. He was chair of the MEC during the inception of the MOU and the transition of the project to city control. ANE, Inc., also evaluates annual energy and water performance to comply with Civano SES and IMPACT Standards. If you would like to contact Mr. Nichols, please do so by sending an email to alnichols@aol.com.

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