Energy Use in Civano and Tucson Residences*

Prepared for the Community of Civano LLC

Al Nichols Engineering, Inc.

October 30, 2003

* ANE, Inc. would like to thank Tucson Electric Power for providing data for Civano energy use and averaged data for residences in Tucson, and participating residents of Civano for permission to use utility data in this study. We are grateful to Ms. Ardi Whalen for data compilation and Cari Spring, Ph.D., for research and analysis.

Energy Use in Civano and Tucson Residences

Contents

Terms, Conversions, Multipliers and Definitions

- *Model Energy Code (MEC):* Governs standard for energy use in Tucson for new construction homes. Energy used for heating and cooling is to be approximately 40 kBtu per square foot per year (range depends on square footage of home).
- *Sustainable Energy Standard (SES):* Civano was the model for the SES, which reduces heating and cooling energy by 50% of that of homes built under the 1995 MEC. This quantity is no more than approximately 20 kBtu per square foot source energy per year for homes of 1400 to 1799 square feet (heating and cooling energy ranges between 18 and 27 kBtu/sq. ft./year depending on total square footage of home).
- *Solar Hot Water* is provided by a water heating device that converts energy from the sun to heat water, which is then stored and used as the potable hot water in the home.

The Arizona Solar Center calculates energy avoidance of the Progressive Tube Solar Hot Water Heater (model PT-40 CN with 40 gallons in collector storage; used at Civano) at 2,200 kWh per year. At a conversion to 7,512 kBtu per year, the savings from solar hot water use represents approximately 4.6 kBtu per square foot per year for Civano homes using solar hot water. Other manufactured solar collectors used include the Sun Earth collector which is similar to the PT-40 and is expected to have similar performance.

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 1 pound of coal is used per kWh of electricity;
- Approximately 0.65 gallons of water are consumed per kWh of electrical energy.

National Average
- 11 pounds of CO_2 released per therm of natural gas.

Conversions
- kilowatt-hour (kWh): 1,000 watt hours;
- kilo British thermal units (kBtu): 1,000 Btu;
- Therm: 100,000 Btu, 100 kBtu;
- 29.3 kWh per therm
- 3.41 kBtu per kWh

67.39 pounds of CO_2 are released per therm of coal powered electrical energy, as compared with 11 pounds of CO_2 per therm of natural gas.

The *Sustainable Energy Standard* (SES) evaluates compliance using *source energy*, not *point-of-use* 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, including point-of-use energy together with energy used to deliver energy to point-of-use. The SES specifies the 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 fuel.

Section 1. Background: Civano and the Sustainable Energy Standard

The Community of Civano is a mixed-use 371 acre community (Phase I; the entire project totals 820 acres) incorporating traditional and new-urbanism neighborhoods with resource conservation in home design and construction. The Civano *IMPACT System Memorandum of Understanding on Implementation and Monitoring Process* (June 26, 1998) requires regular assessment of energy and water use at Civano to evaluate the results of Civano's resource use and reductions, and to assess compliance of homes with the Sustainable Energy Standard ("SES"; below).[1]

> 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, Sections 1-3).

The Civano MOU (Exhibit 2) requires inspection of plans with a certificate of compliance with the Sustainable Energy Standard upon successful plan inspection. These are kept on file at Civano. Additionally, Section 102.1.3 requires verification of proper installation of insulation (thermal barrier) before drywall installation, completion of the "Insulation Installation Warranty" and a signature by a representative of the developer and/or builder.

Before the inception of Civano, Dr. Nader Chalfoun and his students performed a limited evaluation of homes constructed in the 60's and suggested that those homes could have been 65% better in energy use with small changes in their construction.[2] The Civano IMPACT Statement and MOU cite this study; however, at the point of sale prior to Civano construction, the City required a method to objectively evaluate the building standards to assure that the energy component of the MOU could be evaluated after build out. The Metropolitan Energy Commission engaged a team to write the energy standards that would become the Sustainable Energy Standard adopted by Civano. At that time, the City had also adopted the national Model Energy Code which provided a base by which to compare energy savings as would accrue from the Sustainable Energy Standard. The team agreed that the new Model Energy Code had improved buildings by about 15% for heating and cooling energy. Thus, a standard achieving 50% more savings than a home built to the 1995 Model Energy Code would accomplish the original goal of 65%.

The Sustainable Energy was thereafter adopted to evaluate Civano homes; use of energy bills to calculate energy use is the method by which evaluation is performed (below).

At inception, Civano served as the model for Tucson's Sustainable Energy Standard. This initial formulation of the SES prescribed energy use reductions for heating and cooling by 50% over homes built in conformance with the Tucson Model Energy Code.

---

[1] See also ANE, Inc.'s *2002 Report on Civano and Tucson Residential Energy Use*, and 2002 and 2003 *Civano and Tucson Residential Water Use*.

[2] For details of the study, consult Dr. Nader V. Chalfoun of the University of Arizona CAPLA, School of Architecture 1040 North Olive Tucson, Arizona 85721 621-6751.

Sustainable Energy Standard, Chapter 1, Section 101.4: 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.

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

Table 1. Sustainable Energy Standard: Prescriptive Compliance Summary

Civano homes strive to satisfy the SES through use of the following features in home construction:

Superior wall and ceiling insulation;
Sealed and tested ductwork;
Blower door testing;
High-performance windows;
High-efficiency heating and cooling systems;
Solar technology.

Energy savings in the initial formulation of the Sustainable Energy Standard can be demonstrated through use of a *prescriptive* method or through use of *sample comparison to homes built to the 1995 Model Energy Code (MEC)*. The *prescriptive method* meets the SES through reductions stipulated in Table 1. In practice, verification of energy savings via sampling methods can be accomplished through analysis of energy bills. The latter strategy is used here to evaluate a sample of Civano homes' 2002-2003 residential energy use.

Additionally, the Civano MOU, Section 1 is committed to use of solar technology:

> The goal of the Civano project is to create a new mixed-use community that attains the highest feasible standards of sustainability, resource conservation and development of Arizona's most abundant energy resource—solar—so that it becomes an international model for sustainable growth. The State of Arizona through the Department of Commerce Energy Office has provided significant financial support for the planning and design of Civano. This funding was explicitly in support of the demonstration of the use of solar energy as a guiding, organizing principle of community development.

How, and to what extent the solar commitment is met, varies by builder. Four current builders offer homes at Civano: Solar Built, TJ Bednar, Doucette, and Pepper Viner. Original Contravest homes use solar daylighting (SolaTube technology) toward meeting the Civano solar commitment and a heat-pump hot water unit is a standard feature of Contravest homes. At this time, the new builders (including builders using the old Contravest models) have committed to

using solar hot water heaters on all models. Photovoltaic electrical energy is offered as an option by Civano builders.

Possible building upgrades (i.e., use of the component method) to satisfy the SES include improvements to the envelope (wall, roof) through increased insulation and superior installation techniques; window upgrades (increased R-value); use of high-efficiency appliances (e.g., high SEER or EER rating, and/or use of Energy Star appliances); and use of solar energy for heating and cooling (passive solar orientation, solar thermal and/or solar electric technologies).

Section 2. Evaluation of 2002-2003 Energy Use at Civano and in Tucson

This report analyzes energy use by Civano residences built during 1998-2002 under the Sustainable Energy Standard (SES) and compares these data with energy use in two categories of homes in greater Tucson: 1) Tucson homes "at-large", i.e., built during any year; and 2) Tucson homes built between 1998-99 under the Model Energy Code. Since the three types of homes are built per different codes, beyond monitoring Civano compliance with the SES, the data here provide a field by which to begin to verify energy savings due to different energy codes under which different homes are constructed.

Energy use for gas and electric is calculated in this report, and analysis is per the MOU requirement to assess compliance of Civano homes built in 1998-2002 with the SES. It is further to revisit sustainability standards in order to identify functional and nonfunctional results toward an evolution of specific sustainable technology and building practices. The initial formulation of the SES, based on experimental predictions, was intended to improve on energy savings for heating and cooling by 50% over the Tucson Model Energy Code and assumed that such entailed a maximal use of 20 kBtu/sq. ft./year by "mid-sized" homes in Tucson (as detailed in Table 1).

Methods

Energy Calculations

Total energy use calculated under the SES refers to the total *source energy* used, not to *point-of-use* energy. *Source energy* includes energy consumption at point-of-use, here, at the home, together with the energy needed to supply electricity or gas to the home. The latter amounts to more energy than that used at point-of-use; this difference influences the way that total energy use and CO_2 emissions are calculated for gas and electricity. Natural gas delivery requires about 11%: if one therm is consumed at the residence, about 0.11 therms is added to point of use energy to calculate total source energy cost. The cost to deliver electricity is approximately 3.1 times the energy (in kilowatt-hours) used at point-of-use. Compliance with the Sustainable Energy Standard is calculated in this report by analysis of the energy consumed per square foot of the building, based on energy consumption over a calendar year reported in energy bills, adjusted by multipliers specified in the formulation of the SES as given here.

Samples Used and Compared

The Civano sample includes 31 homes of which one home has a pool, two have spas, four have PV systems, all but four use solar hot water heaters. For the 17 solar hot water heaters, 10 use conventional gas back-up and seven use conventional electric hot water heating as back up. Six homes use tubular skylights.

Data from individual Civano residences were collected from homeowners' bills on a volunteer basis, and were supplied by Tucson Electric Power and, for dual fuel homes (i.e., those using gas and electric), from direct interpolation of homeowner's printed gas bill. Southwest Gas opted not to participate in this year's analysis.

All electric houses typically use electricity for all energy needs, including hot water, space heating, and cooking. *Dual fuel* homes use gas for space heating, water heating and cooking, and electricity for other applications. From the utility data (i.e., showing extremely low use in about half of the samples) it is clear that some home owners connect to the gas utility for cooking and gas fireplaces (with heat recovery) only. For this reason, an accurate analysis of the cost of gas verses electricity for heating purposes could not be determined and is hereafter not evaluated in this report.

The Tucson *Baseline* (not performed by ANE, Inc.; see ANE, Inc.'s report on energy use of 2002 for details regarding the Tucson Baseline) reports average energy (and water) use for Tucson homes. The first sample set examined therein comprises homes built during 1998-99 under the Model Energy Code. First, a small *consent* sample was evaluated, for which features of each Tucson home were balanced against features of each Civano home and average energy data were collected by month. In this *consent* sample, access to utility data was by homeowner permission; the small sample size ranged from 2-31 homes per month. To confirm the validity of the study, the Tucson Baseline then evaluated a second, larger, *criteria* sample of Tucson homes built in 1998-99. In the criteria sample, 641homes were evaluated for electricity and 916 for gas, but features of Tucson homes were unmatched to features of Civano homes. For the consent sample, utility data were provided by Tucson Electric Company and Southwest Gas as an average of overall use by month.

Tucson Baseline data reported here are slightly different than those reported in the original study, as normalized per methods reported in ANE, Inc.'s *2002 Report on Civano and Tucson Residential Energy Use*. Additionally, the usefulness of the Tucson Baseline is limited in the current report in that it presents data across electrical and gas energy consumed by residences individually, but does not evaluate homes for total energy use. The author reports (personal communication) that "99%" of the homes evaluated were dual fuel homes".

Clearly, an accurate, current and comprehensive baseline analysis of Tucson energy is critical to confirm that homes built under the Model Energy Code consume no more than the maximum amount specified by the MEC-- 40 kBtu source energy/sq. ft./year for heating, cooling and hot water for mid-sized homes. A current Tucson Baseline is in fact necessary to accurately compare energy use in Civano residences. Pending such, this report estimates and compares total energy use per residence, based on available data.

The second Tucson sample compared here to Civano energy consists of data for the Tucson at-large sample based on energy use by 465 homes "at-large". Data were provided by Tucson Electric Power and Southwest Gas. In this sample, homes were unrestricted for year of construction and hence not prescriptively constrained by any energy code.

Tucson Baseline data given in this report represent values from last year and are used here only for comparison. The City has yet to update the Baseline for this year and as such the comparison of Civano and the city cannot be considered as conclusive. This is because, in large part, weather fluctuations from year to year—which can be substantial—influence energy use for heating and cooling. A TEP recent internal company news article reported that cooling degrees for July-August 2003 were up 13% from normal weather data and up 20% from July 2002. Relative humidity and rainfall was also higher in 2003 than in the previous year; latent heat removal will also cause an increase in cooling. Clearly, these effects are not accounted for when

comparing Civano 2002-2003 energy use data to Tucson 2001-2002 energy use data; however, this is the only available alternative at the time of this report.

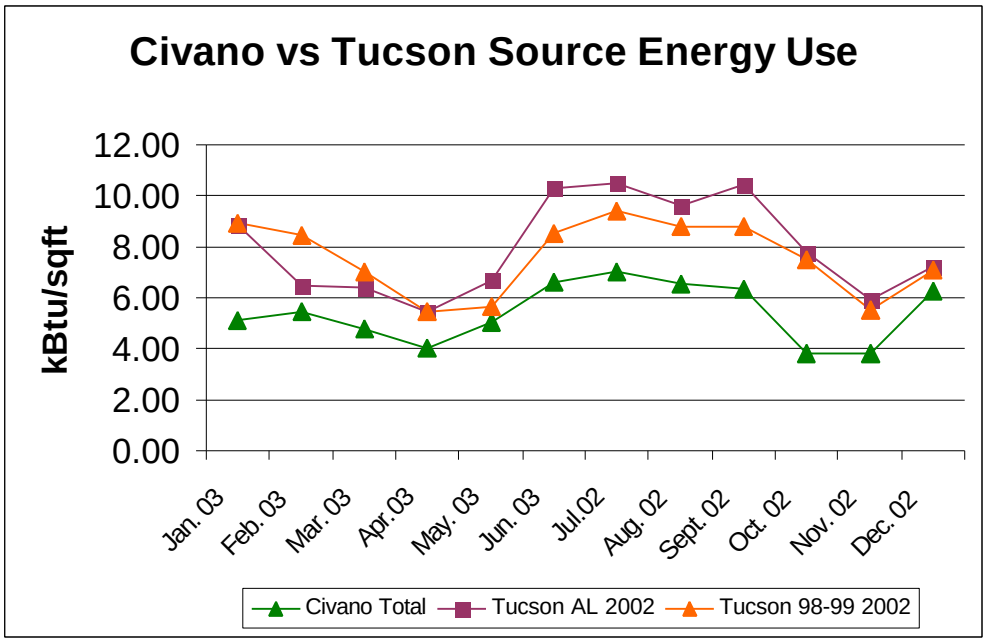
Per capita occupancy of residences was assumed to be 2.25. The average square footage of Civano homes was evaluated as 1,622 based on collected data for Civano homes, and range from 1,144 to 2,056. The Tucson Baseline study reported average Tucson home square footage at 1,789 square feet (ranging between 1,111 and 3,552 square feet) for homes in the consent sample; square footage data were not given for the criteria sample. Tucson at-large home average square footage was 1748 square feet based on data supplied.

Section 3. Findings—Heating, Cooling and Total Energy Use

Table 2 summarizes source energy use as kBtu per square foot per year for Civano homes, for Tucson "at-large" homes (built any year), and for Tucson homes built under the Model Energy Code during 1998/99. The results indicate that Civano homes are 50% better in heating and cooling (both home conditioning and water heating) than homes outside of Civano and have met the requirements of the MOU.

	Total/Year	Base Energy Use	Cooling	Heating	Total Heating and Cooling
Civano Avg.	64	4	13	7	20
Tucson AL	96	5	28	12	40
Tucson 98/99	91	4	24	17	41

Table 2. Annual energy use in source kBtu per square foot per year for Civano home energy use calculated for 2002-03 as compare to Tucson at-large (*AL*) and Tucson homes built in 1998/99 calculated for 2001-2002.
Base is lowest of Mar/April and Oct/ Nov averaged.
Cooling is the average of May to Oct less the base and times 6.
Heating is the average of Nov to April less the base and times 6.



Civano homes average approximately 20 kBtu source energy per square foot per year for heating and cooling: 7 kBtu per square foot per year for heating and 13 kBtu per square foot per year for cooling.

Energy used for cooling the average Civano home is approximately 46% that of Tucson homes at large, and 54% that of Tucson 1998/99 homes built under the Model Energy Code. (Again,

comparison here is to Tucson 2001-2002 energy use data—the best sample available—and does not accurately reflect energy use of Tucson AL or 98-99 homes in 2002-2003.)

Heating use at Civano is 58% that of Tucson at-large homes and 41% that of 1998/99 homes. (Again, comparison here is to Tucson 2001-2002 energy use data—the best sample available—and does not accurately reflect energy use of Tucson AL or 98-99homes in 2002-2003.)

In total, Civano homes use 50% of the heating and cooling energy of Tucson at-large homes (*not* constrained by the Model Energy Code) and 49% the energy use of 1998/99 homes (constrained by the Model Energy Code).

Overall, Civano total energy use is 64 kBtu/sf/year, while that of the Tucson AL and 98-99 home is 96 and 91 kBtu/sf/year. This represents a total energy use at Civano of 66% that of Tucson at-large homes, and 70% that of Tucson1998/99 homes.

An approximate 4.6 kBtu per square foot reduction (per year per home) at Civano results from the use of solar hot water heating.

Table 3 compares the results of last year's energy assessment with this year's results.

Year	Total kBtu/sf	Cooling kBtu/sf	Heating kBtu/sf
2002	62.00	12.50	9.50
2003	64.32	12.75	6.82

Table 3. Comparison of results for Civano home energy use in 2002 as compared to 2003 in source kBtu.

Section 4. Resource Use and CO_2 Production Associated with Energy Use at Civano and in Tucson

Civano homes use an average of 8,919 kWh/year and 207 therms/year (the latter averaged for dual fuel homes only; the significance is that half of the Civano homes in the sample use gas, while virtually all of the Tucson homes use gas. Hence, as a comparison across all houses, Civano homes would average 100 therms/year). Tucson 1998/99 homes average 11,275 kWh/year and 393 therms/year, while Tucson at large homes use 12,382 kWh/year and 329 therms/year (the latter data are taken from the Tucson Baseline reported in ANE, Inc. 2002). This averages as the following resource use and CO_2 emissions for Tucson homes as compared with Civano homes:

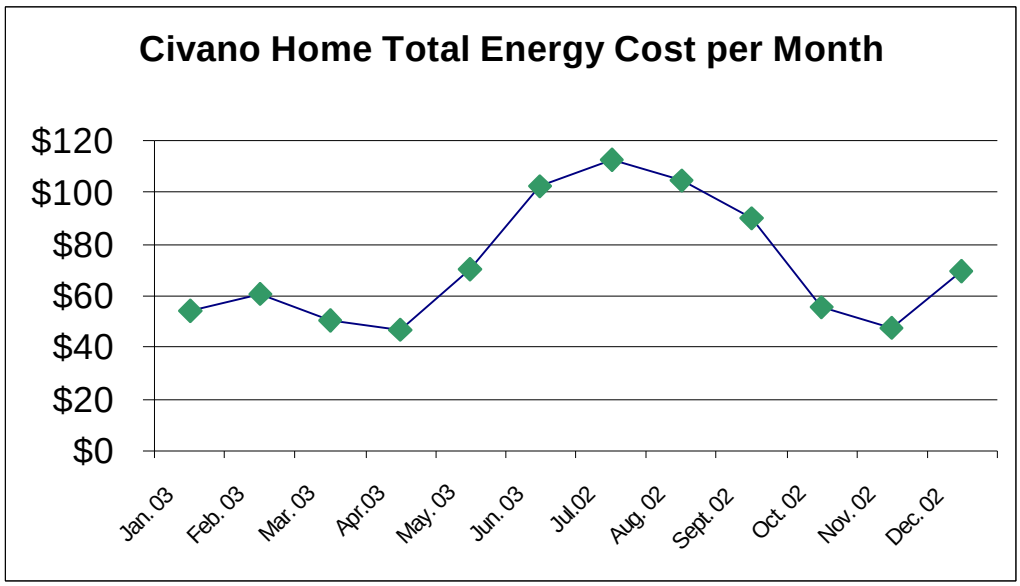
	Pounds CO_2 released per year	Gallons water used per year	Pounds coal used per year
Civano Avg. Home	21,614	5,797	8,919
Tucson at-large Home	32,098	8,048	12,382
Tucson 1998/99 Home	30,255	7,329	11,275

Table 3: Resource use and CO2 production associated with energy costs at Civano and in Tucson. (CO2 associated with natural gas is distributed across the entire Civano sample.)

With approximately 300 homes occupied at Civano, these resource savings across 300 average Civano homes compare to 300 average Tucson homes as follows: 300 average Civano homes avoid release of 2,592,300 pounds of CO_2 each year as compared to Tucson 98/99 homes built under the Model Energy Code, and avoid 3,145,200 pounds/year as compared with average Tucson at-large homes. 300 Civano homes avoid use of 459,600 gallons of water use/year associated with the production and transportation of energy as compared to Tucson 1998/99 homes built under the Model Energy Code, and avoid 675,300 gallons of water each year in association with energy production as compared to Tucson homes at-large. The coal use associated with electrical energy generation for 300 Civano homes accrues as a savings of 1,038,900 pounds per year of avoided coal relative to 300 Tucson at-large homes, and 706,800 pounds per year avoided coal as compared to Tucson 1998-99 homes. This is coal which therefore does not have to be mined and transported to Tucson from non-local origins at an additional energy/CO_2 and water cost (not calculated here).

Section 5. Energy Costs for Civano and Tucson

As an average, Civano homes save $677 annually ($56.38 monthly) on energy bills as compared to Tucson 98/99 homes (comparative cost data were not available for Tucson homes at-large).



5.3 Building Plan Requirements and Review

All plan submittals for building permits shall be determined in accordance with Section 7 to meet the following requirements in addition to all other applicable codes.

5.3.1 All building permit applications shall be certified in accordance with Section 7.0 as complying with the following:

5.3.1.1 Residential building plans shall provide a certification that the plans as submitted provide for a total energy use through the building shell, heating and cooling systems ("building energy use") of at least a 65% reduction for each dwelling from the 1990 Metropolitan Energy Commission annual energy use baseline commencing at the time of initial residential occupancy. The certification shall be in the form attached hereto as Exhibit 2.

5.3.1.2 Non-residential building permits shall provide a certification that the plans as submitted provide for a total energy use through the building shell, heating and cooling systems ("building energy use") of at least a 55% reduction for each structure from the annual energy use by a comparable non-residential structure in 1990 as established by the Metropolitan Energy Commission. The certification shall identify the 1990 level used, the method of determining that level and the source material documenting that level. The energy conservation shall commence at the time of initial occupancy. The certification shall be in the form attached hereto as Exhibit 2.

5.3.1.3 Building plans shall identify the manner in which the proposed structures will be designed to optimize solar orientation for passive heating and cooling purposes, consistent with Civano's goals.

5.3.1.4 Plans shall incorporate some beneficial use of solar energy to reduce the energy demands from heating, cooling and interior water heating. Solar devices such as currently found in A.R.S. § 44-1761 shall qualify as beneficial uses of solar energy will satisfy this requirement.

5.3.1.5 Landscape and hardscape coloration and/or vegetation shall be used to reduce the microclimate temperature adjacent to the structures. The average reflectivity of all major landscape and hardscape surfaces must be 0.5 or greater on the albedo scale or result in equivalent energy savings.

5.3.1.6 Plans shall identify procedures for preserving construction materials for recycling during construction and for the use of recycled construction materials in construction.

EXHIBIT 2

CERTIFICATION

The Community of Civano, LLC has reviewed the plan for _____(address), plan number _____to determine compliance of that plan with the conservation requirements for Civano as set forth herein.

The Community of Civano, LLC certifies it is familiar with and the plans meet the requirements of Memorandum of Understanding between the City of Tucson and the Community of Civano, LLC dated June 9, 1998 as indicated below:

_____ Sec 5.3.1.1 of the Memorandum of Understanding for Residential Buildings or the code requirements of the Sustainable Energy Standard attached to the Memorandum of Understanding.

_____ Sec 5.3.1.2 of the Memorandum of Understanding for Commercial Buildings or the code requirements of the Sustainable Energy Standard attached to the Memorandum of Understanding.

Compliance with section 5.3.1.1 or 5.3.1.2 has been determined by:

___ Prescriptive Method

___Component Method

___Systems Method;

____ Section 5.3.1.3;

____ Section 5.3.1.4;

____ Section 5.3.1.5;

____ Section 5.3.1.6.

Date:
Signature:
On behalf of the
Community of Civano, LLC