



REPORT ON CIVANO and TUCSON RESIDENTIAL ENERGY USE*

Prepared for the Community Civano LLC

by
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Table of Contents

1. Executive Summary
Terms and Definitions, Calculations, Conversions, Multipliers
2. Report on Energy Use in Residences at Civano and in Tucson

3. Analysis
 - 3.1 Introduction. Background: *Compliance with the Sustainable Energy Standard and the MEC*; Purpose of the Study: Evaluating Civano Solar Power & Energy Use; Methods
 - 3.2 Energy Use for Civano, Tucson, and 1998-99 Tucson homes
 - 3.2.1 Total energy use in single family residences
 - 3.2.2 Heating and cooling in single family residences
 - 3.2.3 Cost reductions in Civano homes
 - 3.2.4 Resource reductions: water, coal and CO2 emissions
 - 3.2.5 The Need for Additional Solar Technology

4. Appendices
 - A. *Civano IMPACT System Memorandum of Understanding on Implementation and Monitoring Process, June 26, 1998* (includes Sustainable Energy Standard as Exhibit 1).
 - B. Model Energy Code.
 - C. *Baseline Study for Residential Energy Use 1998/99.*
 - D. Normalization of Data in Tucson Baseline Study.
 - E. Solar Hot Water Savings-SRCC Certified Solar Water Heating Systems (Estimated Annual Performance).
 - F. Civano Certification for SES Compliance.
 - G. *Civano and Tucson Residential Water Use.* ANE, Inc., April 18, 2002.

1. Executive Summary

This report analyzes energy used by residences in the Civano Development built during 1998-99 under the Tucson Sustainable Energy Standard. It compares these data with energy use in two types of homes in greater Tucson. Comparison of Civano homes is first to energy use in Tucson homes “at-large”, i.e., built during any year, and second, to Tucson homes built between 1998-99 under the Model Energy Code. The latter are constructed during the same years as the Civano homes and exemplify building systems constrained by a less rigorous energy code than that constraining Civano homes. As such, these data provide a field by which to verify predicted energy savings due to explicitly different energy Codes. It also examines source and appliance energy use for gas and electric, and informs on-going evaluations of what constitutes “sustainable” energy use, and evaluation methods for sustainability compliance.

Table 1 summarizes source energy use as kilo-Btu per square foot per year for residence types identified above.

	Electric	Gas	TOTAL	Electric Base	Gas Base	TOTAL BASE	Cooling	Heating	
Civano AE	60	0	60	43	0		43	12	5
Civano DF	45	19	64	32	5		37	13	14
Civano Avg.	52.5	9.5	62	37	2.5		40	12.5	9.5
Tucson AL ¹	75	21	96	47	8		55	28	12
Tucson 98/9	67	24	91	43	7		50	24	17

Table 1. Annual energy use in source kBtu per square foot per year for Civano all-electric (AE), dual-fuel (DF), Average (Avg.) and Tucson at-large (AL) and Tucson homes built in 1998-99 (98/9) residences.

Table 2 shows the initial formulation of the Sustainable Energy Standard.

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 Sq. Ft. Range	kBtu/sq. ft./year/home (source consumption)		
	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

¹ The discrepancy between Tucson at-large numbers: 96 total kBtu per square foot per year, vs. the additive total of base loads at 55 and heating and cooling total of 40 (=90) is due to rounding to whole numbers.

Table 2. SES Summary for Compliance.

Conclusions

Heating and Cooling, and the Sustainable Energy Standard

- Energy used for cooling the average Civano home is 50% that of both types of Tucson home.
- Heating reductions at Civano—taken as an average across all-electric and dual-fuel homes—are 67% that of Tucson at-large and 1998/99 homes. This results from the high use of gas for heating in the Civano dual-fuel home. Finding the reason for high gas use at Civano is important and should be ascertained, with solutions resolved, as the second neighborhood is planned.
- In total, Civano homes use 56% of the heating and cooling energy of both Tucson at-large homes.
- Civano homes average 22 kBtu per square foot per year for heating and cooling: 9.5 kBtu per square foot per year for heating and 12.5 kBtu per square foot per year for cooling.
- While Civano improves on the SES specification by 2.5 kBtu, total use exceeds the SES by 2 kBtu. This is due to higher than expected energy use for heating, in particular, gas heating.
- Civano all-electric homes use 17 total kBtu per square foot for heating and cooling—12 for cooling and 5 for heating. Heating in the all-electric home falls within the specified allowances of the SES.

Overall Energy Use

- Overall, Civano total energy use is 67% of Tucson at-large homes, and 68% of Tucson 1998-99 homes. This is due to reductions, not just in heating and cooling, but also in reductions of base energy use at Civano to an average of 45 kBtu/sq. ft./year as compared to Tucson at-large base use of 55 kBtu/sq. ft./yr, and 50 kBtu/sq. ft./yr base use for Tucson 1998-99 homes. Base energy use at Civano is 90% that of Tucson 1998/99 homes and 81% that of Tucson at-large homes.
- Add to these findings the Civano reduction in every home (of this report) of 4.8 kBtu per square foot per year due to solar hot water heating, and it is likely that *the 50% reduction for heating, cooling and hot water heating* is being achieved at Civano.
- Given that the current formalization of the Tucson Sustainable Energy Standard misses the mark for gas heating (as it was based on experimental data only), and given the savings from hot water, the main issue which should be examined through redress of the Sustainable Energy Standard itself, is a need for use of exact and accurate parameters for (gas) heating specifications and methods for determining compliance of hot water, heating and cooling together.

Cost Savings

- As an average, Civano homes save \$624 annually (\$52 monthly) compared to Tucson 1998/99 homes (comparative cost data were not available for Tucson homes at-large).

Resource Savings

- Each year, the average Civano home uses 66% of the coal that the average Tucson at-large home uses, and 73% of the coal used by the average Tucson 1998-99 home. The

average Civano home uses 66% of the water pumped during the process of energy production from coal as compared to the average Tucson at-large home and 73% of that used by Tucson 1998/99 homes. (See Appendix G for additional water and energy savings reductions due to potable water reductions at Civano).

- Annually, the average Civano home avoids 36% of the CO₂ emissions from all energy sources as compared to Tucson at-large homes, and avoids 33% of the CO₂ emissions from all energy sources generated by the average Tucson 1998-99 home. The average Civano home avoids 57% of the CO₂ emissions from gas use compared to Tucson at-large homes, and avoids 64% of the CO₂ emissions from gas used by Tucson 1998-99 homes. Overall, the average Civano home avoids 34% CO₂ emissions from electricity as compared to Tucson at-large homes, and 27% of electricity CO₂ emissions as compared to Tucson 1998-99 homes.

The Impact of 150 Houses

- The findings of this report suggest that 150 average Civano homes will save 1,262,100 pounds of coal annually, relative to Tucson at-large homes and 930,000 pounds of coal annually, compared to Tucson 1998-99 homes.
- For electrical energy generation, which requires water for cooling of steam turbines, the energy savings of 150 average Civano homes will save 410,183 gallons of water annually from reduced electricity costs relative to Tucson at-large homes, and 302,250 gallons annually as compared to Tucson 1998-99 homes.
- Total reduced CO₂ emissions from reduced gas and electric use for 150 average Civano homes amounts to an avoided 1,763,265 pounds of CO₂ annually, relative to Tucson at-large homes, and 1,486,950 avoided pounds yearly, relative to Tucson 1998-99 homes.

The Need for Further Application and Measure of Solar

- Despite the savings shown above, 150 average Civano homes collectively use over 15 million kBtu of energy each year. Translated as coal, water and pounds of CO₂, this equals almost 2.5 million pounds of coal--which must be mined, transported and shipped to Tucson every year; approximately 800,000 gallons of water which must be pumped during the process of energy generation every year (this figure excludes water directly used for potable and gray water landscaping); and over 3 million pounds of CO₂ emissions from gas and electric combined--every year. A reliance on solar energy as the overarching design factor of the Civano vision was directed precisely at this problem.
- The energy reductions at Civano—in the form of solar hot water heating² and building systems efficiency—is a first step of many needed to decrease residential energy consumption. The Civano partners should act on the problem by integrating solar energy more uniformly and vigorously into the design of Civano. At present, there is no clear accountability for adequate use of solar. The SES should be reformulated to

² This report assessed data from homes built during 1998-99; as such it does not include data from the newest builder, Contravest, a builder which does not use solar hot water heating. Because the 4.8 kBtu per square foot/ year savings applied to Civano homes using solar hot water is what directly moves them into compliance with the SES, abandoning solar hot water heating as mandatory at Civano may be a problem.

reflect (gas) heating and cooling data and it should simultaneously set minimum criteria for use of solar through prescriptive accountability measures.

- A larger sample size from Civano residences should be the basis for future energy analysis. These data should come from all homes, not just volunteer homes.
- Further, the Certificate of Inspection required by the MOU needs to be provided at project completion.
- Finally, a Tucson Baseline that adequately evaluates individual residences for total energy consumed is necessary both to empirically substantiate the MEC and by which to adequately compare the results of building systems. This Baseline must use individual residences and screen them for non-residential energy consumption (section 3).

Terms and Definitions, Calculations, Conversions, Multipliers

Terms and Definitions

- *Dual fuel* homes use natural gas for heating, water heating, and cooking, and electric for other applications, including cooling.
- *All electric* homes use electricity for all applications, including heating and cooling.
- *Model Energy Code (MEC)*: Governs standard for energy use in Tucson for new construction homes. Energy used for heating and cooling is to be maximally, 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 maximizes heating and cooling energy at “half” that of homes built under the MEC. This quantity is no more than approximately 20 kBtu per square foot per year for homes of 1400 to 1799 square feet (heating and cooling energy ranges between 27 and 18 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 Webpage provides the following computation for energy savings due to solar hot-water heating: the Progressive Tube Solar Hot Water heater energy avoidance for model PT-40 CN (used at Civano) is 2,200 kWh per year. At a conversion (to kBtu) of 7,512 kBtu per year, the savings resulting from solar hot water use is approximately 4.6 kBtu per square foot per year per home for Civano homes using solar hot water. Data from all Civano homes in this report include use of solar hot water.

Calculations used in this report

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 2 pounds of coal are used per kWh of electricity;
- Approximately .65 gallons of water are pumped per kWh of electrical energy.

These calculations are applied to energy at point-of-use.

National Average:

- 11 pounds of CO₂ released per therm of natural gas.

Conversions used in this report

- Kilowatt-hour (kWh): 1,000 watt hours;
- KiloBtu (kBtu): 1,000 Btu;
- Therm: 100,000 Btu, 100 kBtu;
- 29.3 kWh per therm
- 3.41443 kBtu per kWh

67.39 pounds of CO₂ are released per therm of coal powered electrical energy, as compared with 11 pounds of CO₂ per therm of natural gas.

Multipliers

The *Sustainable Energy Standard* specifies compliance to be confirmed using source energy units rather than point-of-use energy use. *Point-of-use* refers to the place, where the energy is used; in this report, the home. *Source energy* is the total amount of energy, including point-of-use energy and energy used to deliver the power to the point-of-use. The SES specifies the multipliers to be used to assess source energy use: point-of-use electrical energy is to be multiplied by 3.1 for electrical energy to identify source energy, and point-of-use gas energy is to be multiplied by 1.11 to accurately assess total source energy.

2. Report on Energy Use in Residences at Civano and in Tucson

Background and Goals

This report analyzes energy used by residences in the Civano Development built during 1998-99 under the Tucson Sustainable Energy Standard. It compares these data with energy use in two types of homes in greater Tucson. Comparison of Civano homes is first to energy use in Tucson homes “at-large”, i.e., built during any year, and second, to Tucson homes built between 1998-99 under the Model Energy Code. The latter are constructed during the same years as the Civano homes and exemplify building systems constrained by a less rigorous energy code than that constraining Civano homes. As such, these data provide a field by which to verify predicted energy savings due to explicitly different energy Codes. It also examines source and appliance energy use for gas and electric, and informs on-going evaluations of what constitutes “sustainable” energy use, and evaluation methods for sustainability compliance.

With direct relevance to the Civano program of development, this report analyzes the degree to which Civano homes built in 1998-99 are in compliance with the Sustainable Energy Standard (SES). 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 (Appendices A, B). The larger findings of this report show that the comparative data lead to a need for re-examination of these assumptions.

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 (source consumption)			
	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. SES Summary for Compliance.

This report also examines *the demonstration of the use of solar energy as a guiding, organizing principle of community development*, as stipulated in the MOU (section 2). Based on the analysis, this report offers suggestions to ensure that Civano more closely meets its solar commitment as it begins design of the second neighborhood.

This report provides analysis of Civano energy (electric and natural gas) based on a small sample size (section 2). Future analyses of Civano utility data and compliance with the SES, as required by the MOU, should be based on a much larger sample size to corroborate findings presented here. And future reports should be based on Development-

wide residential utility data, rather than solely on volunteer data, to avoid artificial skewing. *This can best be ensured by obtaining permission to use utility data before owners move in to residences.*

Summary of findings—heating and cooling

Table 2 summarizes source energy use as kilo-Btu per square foot per year for Civano all-electric and dual fuel homes, for average Civano homes, for Tucson “at-large” homes (built any year), and for Tucson homes built under the model energy code during 1998/9—the same year as Civano homes evaluated here.

	Electric	Gas	TOTAL	Electric Base	Gas Base	TOTAL BASE	Cooling	Heating
Civano AE	60	0	60	43	0	43	12	5
Civano DF	45	19	64	32	5	37	13	14
Civano Avg.	52.5	9.5	62	37	2.5	40	12.5	9.5
Tucson AL ³	75	21	96	47	8	55	28	12
Tucson 98/9	67	24	91	43	7	50	24	17

Table 2. Annual energy use in source kBtu per square foot per year for Civano all-electric (AE), dual-fuel (DF), Average (Avg.) and Tucson at-large (AL) and Tucson homes built in 1998-99 (98/9) residences.

Civano homes average 22 kBtu per square foot per year for heating and cooling: 9.5 kBtu per square foot per year for heating and 12.5 kBtu per square foot per year for cooling. While Civano improves on the SES specification by 2.5 kBtu, total use exceeds the SES by 2 kBtu. This is due to higher than expected energy use for heating, in particular, gas heating. Note that Civano all-electric homes use 17 total kBtu per square foot for heating and cooling—12 for cooling and 5 for heating. Heating in the all-electric home falls within the specified allowances of the SES. Comparison of all-electric and dual-fuel homes at Civano show that the latter use approximately 4 kBtu per square foot per home *more* source energy than the former.

Energy used for cooling the average Civano home is 50% that of both types of Tucson home. Heating reductions at Civano—taken as an average across all-electric and dual-fuel homes—are 67% that of Tucson at-large and 1998/99 homes. This results from the high use of gas for heating in the Civano dual-fuel home. Finding the reason for high gas use at Civano is important and should be ascertained, with solutions resolved, as the second neighborhood is planned. It may be that source energy savings in gas are lost to

³ The discrepancy between Tucson at-large numbers: 96 total kBtu per square foot per year, vs. the additive total of base loads at 55 and heating and cooling total of 40 (=90) is due to rounding to whole numbers.

gas appliance inefficiency at point-of-use. Use of gas hot water for heating may be the problem. This question is important and requires attention.

In total, Civano homes use 56% of the heating and cooling energy of both Tucson at-large homes (*not* constrained by the Model Energy Code) and by 1998/99 homes (which *are* constrained by the Model Energy Code). While Civano all-electric homes comply with the heating specifications for the SES, Tucson homes (virtually all of which are dual fuel) use between 13-17 kBtu per square foot per home per year for heating, as compared with the Civano dual-fuel homes' use of 12 kBtu per square foot per year for heating. Tucson homes built under the Model Energy Code use *more gas* than Tucson homes at-large. The data and analysis in this report further suggest that the Model Energy Code is not accurately specified for quantity of energy use and it does not increase energy reductions over Tucson at-large homes.

Overall, Civano total energy use is 67% of Tucson at-large homes, and 68% of Tucson 1998-99 homes. This is due to reductions, not just in heating and cooling, but also in reductions of base energy use at Civano to an average of 45 kBtu/sq. ft./year as compared to Tucson at-large base use of 55 kBtu/sq. ft./yr, and 50 kBtu/sq. ft./yr base use for Tucson 1998-99 homes. Base energy use at Civano is 90% that of Tucson 1998/99 homes and 81% that of Tucson at-large homes. This may well tease apart the daunting question of whether energy reductions are due to buildings or behavior. Base reductions may well indicate behavioral components, while HVAC reductions may more accurately reflect reductions due to building systems.

Add to these findings the Civano reduction in every home (of this report) of 4.8 kBtu per square foot per year due to solar hot water heating, and it is likely that *the 50% reduction for heating, cooling and hot water heating* is being achieved at Civano. Note from that Civano's heating and cooling is 56 % of Tucson homes, but this figure does not tabulate savings—as a percent—due to solar hot water heating of 4.8 kBtu per square foot per year. The technology to ascertain exact percentile savings of all three together are not currently available. Given that the current formalization of the Tucson Sustainable Energy Standard misses the mark for gas heating (as it was based on experimental data only), and given the savings from hot water, the main issue which should be examined through redress of the Sustainable Energy Standard itself, is a need for use of exact and accurate parameters for (gas) heating specifications and methods for determining compliance of hot water, heating and cooling together.

Likewise, determination of the exact cause for the high use of gas relative to the initial specification of the SES would likely improve future building technology.

As an average, Civano homes save \$624 annually (\$52 monthly) compared to Tucson 1998/99 homes (comparative cost data were not available for Tucson homes at-large).

Each year, the average Civano home uses 66% of the coal that the average Tucson at-large home uses, and 73% of the coal used by the average Tucson 1998-99 home. The average Civano home uses 66% of the water pumped during the process of energy production from coal as compared to the average Tucson at-large home and 73% of that used by Tucson 1998/99 homes. (See Appendix G for additional water and energy savings reductions due to potable water reductions at Civano).

Annually, the average Civano home avoids 36% of the CO₂ emissions from all energy sources as compared to Tucson at-large homes, and avoids 33% of the CO₂ emissions from all energy sources generated by the average Tucson 1998-99 home. The average Civano home avoids 57% of the CO₂ emissions from gas use compared to Tucson at-large homes, and avoids 64% of the CO₂ emissions from gas used by Tucson

1998-99 homes. Overall, the average Civano home avoids 34% CO2 emissions from electricity as compared to Tucson at-large homes, and 27% of electricity CO2 emissions as compared to Tucson 1998-99 homes.

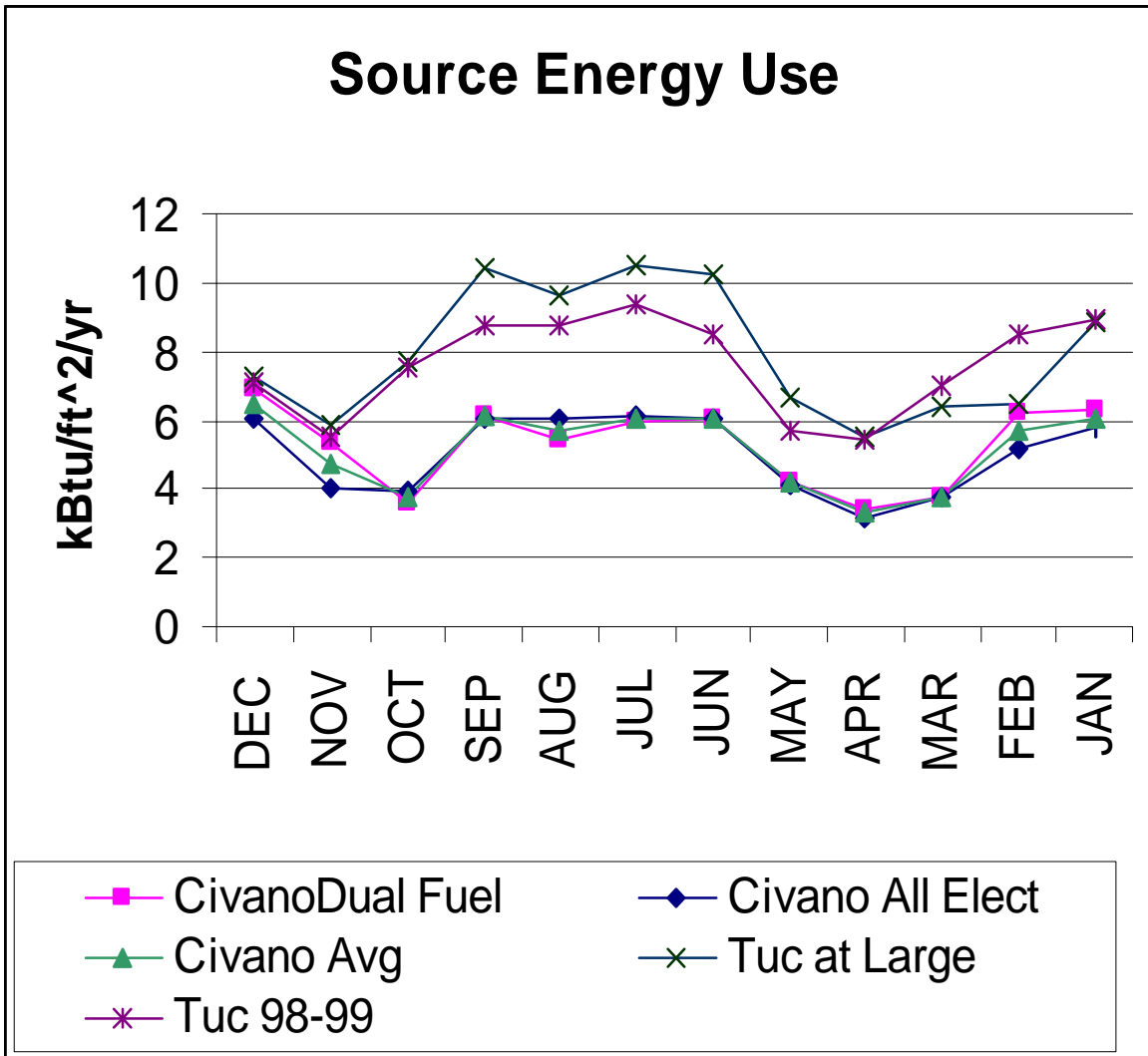
The Impact of 150 Houses

The predicted cumulative resource savings of Civano homes at the development-wide level can be demonstrated by comparing 150 average homes from Civano with 150 average homes from Tucson at-large and from the 1998-99 homes. The findings of this report suggest that 150 average Civano homes will save 1,262, 100 pounds of coal annually, relative to Tucson at-large homes and 930,000 pounds of coal annually, compared to Tucson 1998-99 homes. For electrical energy generation, which requires water for cooling of steam turbines, the energy savings of 150 average Civano homes will save 410,183 gallons of water annually from reduced electricity costs relative to Tucson at-large homes, and 302,250 gallons annually as compared to Tucson 1998-99 homes.

Total reduced CO2 emissions from reduced gas and electric use for 150 average Civano homes amounts to an avoided 1,763,265 pounds of CO2 annually, relative to Tucson at-large homes, and 1,486,950 avoided pounds yearly, relative to Tucson 1998-99 homes.

Despite the savings shown above, 150 average Civano homes collectively use over 15 million kBtu of energy each year. Translated as coal, water and pounds of CO2, this equals almost 2.5 million pounds of coal--which must be mined, transported and shipped to Tucson every year; approximately 800,000 gallons of water which must be pumped during the process of energy generation every year (this figure excludes water directly used for potable and gray water landscaping); and over 3 million pounds of CO2 emissions from gas and electric combined--every year.

	kBtu from electric	kBtu from gas	Total kBtu— all sources	Cooling kBtu	Heating kBtu
CIV AE	98,650	0	98,650	13,309	7,776
CIV DF	74,411	31,080	105,491	14,450	20,472
CIV AVG	86,530	15,540	102,070	13,879	14,124
TUCSON A-L	131,060	36,519	167,579	31,639	19,525
TUCSON 98-99	119,343	43,230	162,573	33,472	27,730



Graph 1. Total annual energy use in kBtu per home. Figures indicated are based on source energy. Note that because Tucson at-large and 98-99 homes are typically larger than Civano homes, as well as being less efficient, cumulative energy use in the former is higher—as is resource use.

A reliance on solar energy as the overarching design factor of the Civano vision was directed precisely at this problem.

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. Civano MOU, Appendix A).

The energy reductions at Civano—in the form of solar hot water heating⁴ and building systems efficiency—is a first step of many needed to decrease residential energy consumption. The Civano partners should act on the problem by integrating solar energy more uniformly and vigorously into the design of Civano. At present, there is no clear accountability for adequate use of solar. The SES should be reformulated to reflect (gas) heating and cooling data and it should simultaneously set minimum criteria for use of solar through prescriptive accountability measures.

Further, the Certificate of Inspection required by the MOU needs to be provided at project completion.

Finally, a Tucson Baseline that adequately evaluates individual residences for total energy consumed is necessary both to empirically substantiate the MEC and by which to adequately compare the results of building systems. This Baseline must use individual residences and screen them for non-residential energy consumption (section 3).

3. Analysis

3.1 Introduction. Background: *Compliance with the Sustainable Energy Standard and the MEC*; Purpose of the Study: *Evaluating Civano Solar Power & Energy Use*; Methods

Background: Compliance with the Sustainable Energy Standard and the Model Energy Code

At inception, Civano served as the model for Tucson's Sustainable Energy Standard (*SES*; Appendix A) and the SES was adopted by Civano as the standard for maximum energy consumption in buildings. This initial formulation of the SES was configured with the goal of reducing energy consumed for heating and cooling by 50% over homes built in conformance with the Tucson Model Energy Code (*MEC*; Appendix B). The SES savings of 50% over the MEC were assumed in the initial formulation of the SES to require maximum energy consumption shown in Table 1 below.

Sustainable Energy Standard, Chapter 1, Section 101.4:

⁴ This report assessed data from homes built during 1998-99; as such it does not include data from the newest builder, Contravest, a builder which does not use solar hot water heating. Because the 4.8 kBtu per square foot/ year savings applied to Civano homes using solar hot water is what directly moves them into compliance with the SES, abandoning solar hot water heating as mandatory at Civano may be a problem.

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 (source consumption)		
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. Reproduced from the Sustainable Energy Standard, Table 402.1 (see Appendix A). Figures indicate initial estimation of maximal energy to be used for heating and cooling for houses conforming to the SES.

It is important to recognize is that a 50% energy reduction by the SES is assumed to correlate to about 20 kBtu/sq. ft./year for a mid-sized home; mid-sized homes conforming to the MEC are assumed to use about 40 kBtu per sq. ft. per home per year. In fact, the assumption that ~20kBtu = 50% was a somewhat arbitrary standard, and based on experimental conclusions. Throughout this report we will see that while cooling requirements are generally achieved via the initial formulation of the SES, dual fuel homes—in all categories—do not use as little energy for heating as prescribed in Table 1.

Energy savings in the initial formulation of the Sustainable Energy Standard can, in theory, be achieved through use of *prescriptive*, *component* or *systems methods*. The *prescriptive method* refers to meeting kBtu as given in Table 1; and *component* and *systems method* refer to use of components or systems, as specified throughout the SES. In practice, determination of actual energy used via component or systems methods is difficult to evaluate, whereas validation of the prescriptive method can be determined either by confirmation or from energy bills.

Total energy, in the SES, refers to the total *source energy* used, not to the energy consumed at the building itself (i.e., not at *point-of-use*). *Source energy use* is the total amount of energy used at the home together with the energy needed to supply electricity or gas to the home; source energy use is different (more) than the amount of energy used at the home. This influences the way that total energy use is calculated, and it influences the way that CO₂ and other emissions are calculated for gas and electrical use (section 3). Natural gas “costs” about 11% to deliver to the home. So if one therm is consumed at the residence, about 1.11 therms is used—1 therm at point of use and .11 therm for the delivery of the gas to the home. The multiplier adopted by the SES for determining total gas energy consumption is 1.11 (multiplied by point-of-use therms). For electricity, the cost to deliver (i.e., the energy use together with the cost to deliver power) is about three times energy consumption at point-of-use. The multiplier selected by the SES to calculate total electrical energy use is 3.10 (times point-of-use kWh). 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, adjusted by multipliers specified in the formulation of the SES.

Source energy use for buildings meeting the Sustainable Energy Standard is to be calculated based on square footage of the home as given in Table 1 above (SES, Chapter 4). All homes evaluated in this report fell into the mid-sized range, between 1400 -1799 square feet, for which 20 kBtu/sq. foot/year are allowed for heating and cooling by the SES: 4kBtu/sq. ft./year for heating, and 16 kBtu/sq. ft./year for cooling.

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).

Purpose of the Study: Evaluating Civano Solar Power & Energy Use

The Community of Civano is a 371 acre, mixed-use community incorporating traditional and new-urbanism neighborhood design with resource conservation in home design and construction. In addition to the SES commitment, *the Civano MOU was founded on a covenant to use solar design and energy as a cornerstone of energy use:*

Civano MOU, Section 1; Appendix A:

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* (emphasis added).

Civano homes strive to satisfy the target reductions of the SES by including the following energy features as standard on homes:

- Superior wall and ceiling insulation;
- Sealed ductwork inside the conditioned space;
- High-performance windows;
- High-efficiency heating and cooling systems;
- Solar technology.

Photovoltaic electrical energy is offered as an option by Civano builders. How, and to what extent, each of these is used to satisfy the SES and the solar commitment, varies by builder. Four current builders offer homes at Civano: Solar Built, TJ Bednar, Duccette, and Contravest. Until the latest builder, Contravest, joined the team of Civano home builders in 2000, solar hot water heating was a standard component of the energy savings suite. Contravest uses solar daylighting (SolaTube technology) toward meeting the Civano solar commitment. A heat-pump hot water unit is a standard feature of Contravest homes (solar water heating is not used to supply hot water).

The Arizona Solar Center (Appendix E) has estimated the savings of the Progressive Tube (model PT-40-CN) solar hot water heater (used at Civano) to be approximately 2,200 kWh per year per home in Tucson. Converted into kBtu per square foot, this savings is approximately 4.6 kBtu per square foot per home at Civano for homes (excepting Contravest homes⁵).

The remainder of this report analyzes data from homes built in 1998-99, and does not include analysis of Contravest homes.

The Civano *IMPACT System Memorandum of Understanding on Implementation and Monitoring Process* (June 26, 1998) requires regular assessment to evaluate the results of Civano's resource use and reductions, and compliance of homes with the SES.⁶

⁵ Because the SES reductions are specified to be from energy used for heating, cooling *and hot water*, the impacts of energy reduction through use of heat pump hot water heating as compared to solar hot water heating can only be evaluated once significant numbers of Contravest homes are constructed and a calendar year of residential energy use data are available.

⁶ See also *Civano and Tucson Residential Water Use*, ANE Inc., April 18, 2002, for assessment of water data.

The Civano MOU requires inspection of completed homes, with a certificate of compliance with the SES issued upon successful completion of inspection (Appendix F).

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)

With 135 homes built in 1998-99 in the first Civano neighborhood, and with a preliminary Tucson baseline complete (Appendix C), residential occupancy data across a calendar year exist by which to evaluate Civano residential gas and electric use. Civano energy use is then compared to energy use in Tucson homes-at-large (i.e., all homes, new and old), and then to energy use by similar new homes in Tucson. “Similar” Tucson homes are those built under the Model Energy Code in the greater Tucson area outside of Civano during 1998-99. This report evaluates energy use at Civano through examination of 12 months of utility data from a relatively small sample of homes.

Besides evaluating Civano’s implementation of the SES, this report analyzes *the demonstration of the use of solar energy as a guiding, organizing principle of community development*, as stipulated in the MOU (above). Based on the analysis, this report offers suggestions to strengthen Civano’s commitment to solar energy as it begins design of the second neighborhood. Civano provides a rare opportunity to evaluate alternative design and construction methods; in so doing, by characterizing lessons learned and improving on past methods, it is hoped that this report will help Civano become the international model for sustainable growth envisioned by the founding partners, as stipulated at the outset of the project.

Methods

The Tucson *Baseline* (Appendix C) reports on average energy (and water) use for Tucson homes built during 1998-99 under the Model Energy Code. The Baseline provides two data sets for comparison to Civano. First, a small *consent* sample was evaluated, in which features of each Tucson home were balanced against each Civano home and average energy data were collected by month. In the *consent* sample, access to utility data was by homeowner permission; the small sample size ranged from 2-31 homes per month and was based on matched features between Civano homes and Tucson counterparts (see Appendix C for details). 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, 641 homes 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, *TEP*, and Southwest Gas, *SWG*, as an average of overall use by month.

Tucson Baseline data reported here are slightly different than those reported in the original study; they are normalized per methods reported in Appendix D. Additionally, the usefulness of the Tucson Baseline is limited in that it presents data across electrical energy consumed by residences and gas energy consumed by residences, but does not evaluate homes for total energy use. The author reports (personal communication) that “99%” of

the homes evaluated were dual fuel homes”. However, a comprehensive and explicit baseline is necessary both to confirm that homes built under the Model Energy Code in fact consume no more than the maximum amount allowed by the MEC (approximately 40 kBtu/sq. ft./year for heating, cooling and hot water for mid-sized homes, as detailed above), and by which to accurately compare Civano residences. Pending such, this report estimates total energy use per residence, based on available data.

Data for the Tucson at-large sample are based on energy used by 465 homes as provided by TEP; these homes were unrestricted for year of construction and hence not prescriptively constrained by the energy requirements of the MEC.

Data from individual Civano residences were collected from homeowners’ bills on a volunteer basis, as supplied by Tucson Electric Power and, for dual fuel homes, from Southwest Gas. *All electric* houses 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. Significantly, because participating Civano homes contributed *all* utility data (electric, water, and natural gas where applicable), each residence is evaluated for total energy (and water) use. Due to a methodology which examines all utility data for individual residences, a criterion for analyzing residential energy use *as distinguished from energy used during the pre-use stages of construction* evolved and was used to normalize data. Essentially, the move-in date for residency was determined when utility bills for each of potable water and electric (and reclaimed water and gas, if applicable) began to accrue. See Appendix D for details.

Pending demographic data, the per capita average for Civano and Tucson residences was assumed to be 2.25. The average square footage of Civano homes was evaluated based on collected data as 1,637 for all electric homes, and 1,659 for dual fuel homes, with an overall square footage estimated at 1,648 for the Civano home (assuming equal occupancy of dual fuel and all electric homes at Civano). 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 evaluated to be 1748 square feet, based on data provided by TEP and SWG.

3.2 Energy use for Civano, Tucson at-large, and newer Tucson homes

3.2.1 Total energy use in single family residences

Table 2 shows energy use by dual fuel homes at Civano; sample size is given, as are average kilowatt-hours and therms at point-of-use.

MONTH	2001 SS	2000 SS	TOTAL SS	2001 kWh	2000 kWh	AVG. kWh	2001 therms	2000 therms	AVG. therms		
DEC	19	14	33	589	486	538	56	49	53		
NOV	19	12	31	476	467	472	26	43	35		
OCT	19	10	29	444	424	434	9	17	13		
SEP	19	9	28	942	823	883	6	9	8		
AUG	19	9	28	762	786	774	6	8	7		
JUL	19	9	28	824	889	857	6	8	7		
JUN	19	5	24	779	998	889	6	6	6		
MAY	19		19	567		567	9		9		
APR	18		18	385		385	15		15		
MAR	18		18	395		395	19		19		
FEB	17		17	432		432	52		52		
JAN	17		17	404		404	56		56		
					Total kWh/ year: 7,030	Avg. kWh/ mo: 586				Total therm s/year: 280	Avg. Therms /mo: 23

Table 2: Civano dual fuel homes; sample size (SS) and average energy use in kilowatt-hours (kWh) and therms at point-of-use.

Table 3 shows sample size and electricity use for Civano all-electric homes.

MONTH	2001 SS	2000 SS	TOTAL SS	2001 kWh	2000 kWh	AVG. kWh
DEC	13	7	20	933	913	923
NOV	13	6	19	571	680	626
OCT	13	4	17	552	673	613
SEP	13	4	17	934	948	941
AUG	13	4	17	827	1053	940
JUL	11	2	13	950	945	948
JUN	10		10	928		928
MAY	10		10	640		640
APR	10		10	484		484
MAR	10		10	587		587
FEB	9		9	798		798
JAN	9		9	892		892
				AVG: 9,320 kWh/yr	AVG: 777 kWh/mo	

Table 3: Civano all electric homes; sample size (SS) and average energy use in kilowatt-hours (kWh) at point-of-use.

Table 4 converts therms and kilowatt-hours into kBtu's per square foot, for Civano dual fuel and electric homes. The average square footage of Civano homes was 1,637 for all electric homes, and 1,659 for dual fuel homes.

	DF- kWh		DF- Therms		DF- kBtu/sq. ft.	AE- kWh	
MONTH		Equiv. kBtu/sf		Equiv. kBtu/sf			Equiv. kBtu/sf
DEC	538	1.11	53	3.19	4.30	923	1.94
NOV	472	.97	35	2.11	3.08	626	1.31
OCT	434	.89	13	.78	1.67	613	1.28
SEP	883	1.82	8	.48	2.30	941	1.96
AUG	774	1.59	7	.42	2.01	940	1.96
JUL	857	1.76	7	.42	2.18	948	1.98
JUN	889	1.83	6	.36	2.19	928	1.94
MAY	567	1.17	9	.54	1.71	640	1.33
APR	385	.79	15	.90	1.69	484	1.01
MAR	395	.81	19	1.14	1.95	587	1.22
FEB	432	.89	52	3.13	4.02	798	1.66
JAN	404	.83	56	3.38	4.21	892	1.86
		14.46 kBtu/sf /yr electric		16.85 kBtu/sf /yr gas	31.31 kBtu/sf/ yr		19.45 Kbtu/sf /yr

Table 4. Civano all electric and dual fuel homes averaged in kBtu/sf at point-of-use. Energy equivalence is computed as 3.41443 kBtu/kWh, and 100 kBtu/therm.

Table 5 shows total source energy consumption, using the SES multiplier of 1.11 for gas and 3.10 for electricity, for Civano dual fuel and all electric homes. An average computation of Civano homes (assuming that occupied Civano homes are evenly distributed between dual fuel and all electric homes) is given as 61.83 kBtu per square foot per year.

	DF-kWh in kBtu/sf	Multiplier of 3.1	DF-therms in kBtu/sf	Multiplier of 1.11	Average DF source kBtu/sf	AE-kWh in kBtu/sf	Multiplier of 3.1
		Source kwh/sf		Source therms			Source kwh
DEC	1.11	3.44	3.19	3.51	6.95	1.94	6.01
NOV	.97	3.01	2.11	2.32	5.33	1.31	4.06
OCT	.89	2.76	.78	.86	3.62	1.28	3.97
SEP	1.82	5.64	.48	.53	6.17	1.96	6.08
AUG	1.59	4.93	.42	.46	5.39	1.96	6.08
JUL	1.76	5.46	.42	.46	5.92	1.98	6.14
JUN	1.83	5.67	.36	.40	6.07	1.94	6.01
MAY	1.17	3.63	.54	.59	4.22	1.33	4.12
APR	.79	2.45	.90	.99	3.44	1.01	3.13
MAR	.81	2.51	1.14	1.25	3.76	1.22	3.78
FEB	.89	2.76	3.13	3.44	6.20	1.66	5.15
JAN	.83	2.57	3.38	3.72	6.29	1.86	5.77
					63.36 kBtu/sf/ year		60.30 kBtu/sf/ year

Table 5: Source energy in kBtu per square foot per year for Civano residences; DF = dual fuel, AE = All Electric. Average kBtu/sf/year for Civano homes, assuming an equal occupancy of all electric and dual fuel homes rounds to 62 kBtu/sf/year.

Average annual energy use by Tucson single family residences for years 2000-2001 is shown in Table 6 (data were supplied by TEP for a sample size of 465 homes).

	AVG. kWh			Multiplier : 3.1	AVG. Therms		Multiplier: 1.11	Total source kBtu/sq. foot
MON	kWh	kWh/sq foot	kBtu/sq foot	Source kBtu	Therms	kBtu/sq foot	Source kBtu	
DEC	694	.40	1.35	4.19	49	2.79	3.07	7.26
NOV	785	.45	1.53	4.74	18	1.05	1.17	5.91
OCT	1,149	.66	2.24	6.94	13	.73	.81	7.75
SEP	1,613	.92	3.14	9.73	11	.65	.72	10.45
AUG	1,480	.85	2.88	8.93	11	.61	.68	9.61
JUL	1,616	.92	3.15	9.77	12	.67	.74	10.51
JUN	1,565	.89	3.05	9.46	13	.75	.83	10.29
MAY	928	.53	1.81	5.61	17	.96	1.07	6.68
APR	629	.36	1.23	3.81	26	1.50	1.67	5.48
MAR	592	.34	1.15	3.56	45	2.54	2.82	6.38
FEB	598	.34	1.17	3.63	44	2.54	2.82	6.45
JAN	733	.42	1.43	4.43	70	3.98	4.42	8.85
	Total kWh/ year: 12,382	Avg. kWh/mo: 1,032		75	Total therms/ year: 329	Avg. therms/m o: 27	21	96 kBtu/sf/ year

Table 6. Tucson homes at-large; sample size is 465 dual fuel homes. Energy data were given for August, 1999, through July, 2000. Avg. square footage was calculated to be approximately 1,748 square feet, based on kWh, therms and kBtu/square foot data provided by TEP (to hundredths).

Energy use in Tucson new homes built in 1998-99 was provided by *The Baseline Study for Residential Energy Use, 1998/1999* (for Tucson, AZ; Appendix C).⁷ The preliminary study reported on the results of a *criteria* study, in which a small sample of Tucson homes built between 1998-99 were evaluated for energy use. Sample size and energy use at point-of-use are shown in Tables 7 and 8 (see Appendix D for details of normalization applied to the Tucson Baseline data as reported here).

⁷ A *baseline* is an analysis of data used as the general case by which to compare different sectors or demographics; here, Civano energy use is the specific case being compared to the energy use in the more general local of Tucson residences outside of Civano.

MONTH	2001 SS	2000 SS	TOT SS	2001 kWh	2000 kWh	AVG. kWh
DEC		22	22		563	563
NOV		20	20		607	607
OCT		29	29		1150	1150
SEP		22	22		1328	1328
AUG	20	31	51	1416	1441	1428
JUL	26	21	47	1599	1366	1482
JUN	26	6	32	1327	1520	1423
MAY	26		26	822		822
APR	25		25	658		658
MAR	26		26	617		617
FEB	25		25	638		638
JAN	26		26	740		740

Table 7: Tucson Baseline: Consent sample(normalized; Appendix D) for electricity, with sample size (SS) and kilowatt-hours consumed at point-of-use.

MONTH	2001 SS	2000 SS	TOT SS	2001 therms	2000 therms	AVG. therms
DEC		2	2		50	50
NOV		2	2		36	36
OCT		3	3		11	11
SEP		2	2		10	10
AUG	1	3	4	8	9	9
JUL	2	2	4	13	9	11
JUN	2	2	4	14	10	12
MAY	2		2	17		17
APR	2		2	29		29
MAR	2		2	54		54
FEB	2		2	74		74
JAN	2		2	72		72

Table 8: Tucson Baseline: Consent sample (normalized; Appendix D) for gas, with sample size (SS) and therms consumed at point-of-use.

Because of concern over the small size of the consent sample, a second, larger *Criteria* study was performed on Tucson homes built between 1998-99; results are shown in Table 9.

MONTH	AVG. kWh	AVG. therms
DEC	651	61
NOV	743	13
OCT	1140	12
SEP	1424	10
AUG	1326	10
JUL	1465	11
JUN	1185	13
MAY	713	18
APR	554	30
MAR	574	58
FEB	603	80
JAN	712	77

Table 9: Tucson Baseline Criteria study (normalized) for electricity and gas. Sample size for electricity: 641 homes, for gas: 916 homes.

Energy use data for the Tucson Baseline Consent and Criteria samples are given in Table 10, as an average of the two.

MONTH	1 CON- kWh	2 CRI-kWh	AVG. kWh	1 CON- Therms	2 CRI- Therms	AVG. Therms
DEC	563	651	607	50	61	56
NOV	607	743	675	36	13	25
OCT	1150	1140	1145	11	12	12
SEP	1328	1424	1376	10	10	10
AUG	1428	1326	1377	9	10	10
JUL	1482	1465	1474	11	11	11
JUN	1423	1185	1304	12	13	13
MAY	822	713	768	17	18	18
APR	658	554	606	29	30	30
MAR	617	574	596	54	58	56
FEB	638	603	621	74	80	77
JAN	740	712	726	72	77	75
	11,456	11,090	AVG: 11,275 kWh/yr	385	393	AVG: 389 therms/year

Table 10: Average energy use by 98-99 Tucson homes based on two studies in the Tucson Baseline (1 = Consent study, 2= Criteria study). Personal communication by the author reports that these homes are “99%” dual fuel homes.

Table 11 shows averaged source energy as kBtu per square foot per year (square footage of the Consent sample was given as 1,789 while that for the Criteria sample was not given; 1,789 was assumed as the square footage of all homes).

MONTH	AVG. kWh	kWh as kBtu/sf	Multiplier: 3.1 Source kWh as kBtu/sf	AVG. Therms	Therms as kBtu/sf	Multiplier: 1.11 Source therms as kBtu/sf	TOTAL SOURCE ENERGY
DEC	607	1.16	3.60	56	3.13	3.47	7.07
NOV	675	1.29	4.00	25	1.40	1.55	5.55
OCT	1145	2.19	6.79	12	.67	.74	7.53
SEP	1376	2.63	8.15	10	.56	.62	8.77
AUG	1377	2.63	8.15	10	.56	.62	8.77
JUL	1474	2.81	8.71	11	.61	.68	9.39
JUN	1304	2.49	7.72	13	.73	.81	8.53
MAY	768	1.47	4.56	18	1.01	1.12	5.68
APR	606	1.16	3.60	30	1.68	1.86	5.46
MAR	596	1.14	3.53	56	3.13	3.47	7.00
FEB	621	1.19	3.69	77	4.30	4.77	8.46
JAN	726	1.39	4.30	75	4.19	4.65	8.95
	AVG: 11,275 kWh/yr		67 kBtu/sf/yr	AVG: 393 Therms/ year		24 kBtu/sf/yr	91

Table 11: Average energy use by 1998-99 Tucson homes as kBtu per square foot per year, and as source energy. This analysis is based on an assumed 1,789 square feet/home in the Tucson Baseline.

Table 12 compares *electricity use* and gas use as kBtu per square foot per year of Civano dual-fuel and all-electric homes, Tucson at-large (dual-fuel) homes, and Tucson 98-99 homes (averaged as dual-fuel homes). *Total energy consumption* of Civano homes, Tucson at-large and 98-99 homes is shown in the bottom row.

	Civ AE kWh as kBtu/sf	Civ DF kWh as kBtu/sf	Civ Avg	Tucson AL kWh as kBtu/sf	98/99-kWh kBtu/sf		Civ DF therms as kBtu/sf	Tucson AL therms as kBtu/sf	98/99-therms as kBtu/sf
DEC	6.01	3.44		4.19	3.60		3.51	3.07	3.47
NOV	4.06	3.01		4.74	4.00		2.32	1.17	1.55
OCT	3.97	2.76		6.94	6.79		.86	.81	.74
SEP	6.08	5.64		9.73	8.15		.53	.72	.62
AUG	6.08	4.93		8.93	8.15		.46	.68	.62
JUL	6.14	5.46		9.77	8.71		.46	.74	.68
JUN	6.01	5.67		9.46	7.72		.40	.83	.81
MAY	4.12	3.63		5.61	4.56		.59	1.07	1.12
APR	3.13	2.45		3.81	3.60		.99	1.67	1.86
MAR	3.78	2.51		3.56	3.53		1.25	2.82	3.47
FEB	5.15	2.76		3.63	3.69		3.44	2.82	4.77
JAN	5.77	2.57		4.43	4.30		3.72	4.42	4.65
	60	45	53	75	67		19	21	24

Table 12: Annual source energy consumption for four residential classes of house by square foot/year: Civano all-electric (AE), Civano dual-fuel (DF), Tucson at-large (dual fuel) home and Tucson 1998/99. Note that for the Civano all-electric home (only), this figure represents total energy use per square foot per year. Civano average energy use, assuming equal numbers of dual fuel and all electric homes, is also given (Civ Avg).

Table 13 shows average total kBtu/sq. ft./year of Civano homes and Tucson homes and Graph displays totals.

	CIV-DF	CIV-AE	CIV-AVG	Tucson A-L (DF) Home	98-99 Home
DEC	6.95	6.01	6.48	7.26	7.07
NOV	5.33	4.06	4.70	5.91	5.55
OCT	3.62	3.97	3.80	7.75	7.53
SEP	6.17	6.08	6.13	10.45	8.77
AUG	5.39	6.08	5.74	9.61	8.77
JUL	5.92	6.14	6.03	10.51	9.39
JUN	6.07	6.01	6.04	10.29	8.53
MAY	4.22	4.12	4.17	6.68	5.68
APR	3.44	3.13	3.29	5.48	5.46
MAR	3.76	3.78	3.77	6.38	7
FEB	6.2	5.15	5.68	6.45	8.46
JAN	6.29	5.77	6.03	8.85	8.95
Totals	64	60	62	96	91

Table 13: Average source kBtu/sf/year per home for Tucson A-L (= Tucson at-large) home; Civano all-electric (= CIV AE) home; Civano dual fuel (= CIV-DF) home; for average Civano (CIV-AVG) home; and for Tucson 1998-99 home.

Summary of findings:

Point-of-use energy

- Civano dual-fuel home uses 7,030 kWh/year, 589 kWh/mo., 280 therms/year, 23 therms/mo.
- Civano all-electric home: 9,320 kWh/year; 777 kWh/mo.
- Tucson at-large (built any year) dual fuel home: 12,382 kWh/year, 1,032 kWh/mo, average. 329 therms/year, 27 therms/mo.
- Tucson 1998-99 homes: 11,275 kWh/year, 940 kWh/mo electricity; 389 therms/year, 32 therms/mo gas.

Source energy

- Civano dual-fuel home: 64 kBtu/sf/yr. (45 kBtu/sf/yr for electric, 19 kBtu/sf/year for gas)
- Civano all-electric home: 60 kBtu/sf/yr
- Assuming that dual fuel and all electric homes are occupied evenly at Civano, the average Civano home uses 62 kBtu per square foot per year of source energy.
- Tucson at-large (built any year) dual fuel home: 96 kBtu/sf/year (75 kBtu/sf/yr for electricity and 21 kBtu/sf/yr for gas).
- Tucson 1998-99 homes: 91 kBtu/sf/yr (67 kBtu/ sf/yr electricity, 24 kBtu /sf/yr for gas).

3.2.2 Heating and Cooling in Single Family Residences

The electric utility (Tucson Electric Power)⁸ evaluates base energy use vs. that for heating and cooling by taking the lowest monthly use for each of spring and fall, and determining the average based on these two. This average is the monthly base (multiplied by 12 provides the yearly base; subtracted from total electrical use provides seasonal energy—heating and cooling). The results are shown in Table 14.

⁸This report was made the more accurate by the methodology provided from Linda Douglas, Tucson Electric Power Company, for the TEP Guarantee Program. It has been used to extrapolate base use for electricity this report. To determine the gas base, the average of the lowest two (summer) months was used. Linda Douglas points out that water inlet temperature fluctuates, hence influencing the actual gas base. For simplicity, this factor has been ignored for the purposes of this report.

	Civ AE: kWh as kBtu/sf	Civ DF: kWh as kBtu/sf	Tucson AL: kWh as Kbtu/sf	98/99: kWh as kBtu/sf	Civano therms as kBtu/sf	Tucson at-large therms as kBtu/sf	98/99- therms as kBtu/sf
DEC	6.01	3.44	4.19	3.60	3.51	3.07	3.47
NOV	4.06	3.01	4.74	4.00	2.32	1.17	1.55
OCT	3.97	2.76	6.94	6.79	.86	.81	.74
SEP	6.08	5.64	9.73	8.15	.53	.72	.62
AUG	6.08	4.93	8.93	8.15	.46	.68	.62
JUL	6.14	5.46	9.77	8.71	.46	.74	.68
JUN	6.01	5.67	9.46	7.72	.40	.83	.81
MAY	4.12	3.63	5.61	4.56	.59	1.07	1.12
APR	3.13	2.45	3.81	3.60	.99	1.67	1.86
MAR	3.78	2.51	3.56	3.53	1.25	2.82	3.47
FEB	5.15	2.76	3.63	3.69	3.44	2.82	4.77
JAN	5.77	2.57	4.43	4.30	3.72	4.42	4.65
Total	60	45	75	67	19	21	24
BASE	43	32	47	43	5	8	7
H/C	17 ⁹	13	28	24	14	13	17

Table 14: Base energy use of Civano and Tucson homes for electricity (left four columns) and for gas (right three columns). Yearly base is given in the second row from the bottom. Total energy use for each category is given in third row from bottom for comparison and heating and cooling totals are provided in bottom row (for Civano all-electric, this represents heating and cooling; for all others it represents heating or cooling, depending on whether electric (cooling) or gas (heating) is the column header.

Summary

Cooling—Electric use in dual fuel homes

- Civano dual fuel homes require 32 kBtu/sf/year for base electric and 13 kBtu/yr for cooling.
- Tucson at-large home requires 47 kBtu/sf/year for base electric and 28 kBtu/sf/year for cooling.
- Tucson 1998-99 homes use 43 kBtu/sq. ft./yr as base and 24 kBtu/sf/year for cooling.

⁹ For the Civano all-electric home, heating requires 5 kBtu/sq. ft./yr and for cooling is 12 kBtu/sq. ft./yr. See below.

Heating—Gas

- Civano dual-fuel homes use 5 kBtu/sf/yr as base and 14 kBtu/sf/yr for heating.
- Tucson at-large homes use 8 kBtu/sq. ft./yr as base and 13 kBtu/sf/year for heating.
- Tucson homes built in 1998-99 use 7 kBtu/sf/year as base and 17 kBtu/sf/year for heating.

Heating and Cooling in Civano AE house

For the Civano all-electric house, base use is 43 kBtu/sq. ft./yr, with 17 for heating and cooling. Based on seasonal patterns, where monthly energy use is above the base monthly use of 3.55 kBtu/sq. ft., cooling requires 12 kBtu and heating requires 5 kBtu per square foot per year.

Table 15 compares the average Civano home with Tucson at-large and 1998/99 homes.

	Civ Avg. kWh as kBtu	Tucson AL: kWh as kBtu/sf	98/99: kWh as kBtu/ sf		Civano Avg. Therms as kBtu/sf	Tucson AL therms as kBtu/sf	Tucson `98/99- therms as kBtu/sf
Total E-Avg.	40	75	67		19	21	24
H/C Avg.	13	28	24		10	13	17

Table 15. Comparison of Civano average home with Tucson homes for electricity (left three columns) and for gas (right three columns). Total energy (for electric and gas use) is given in the first row, and average kBtu/sq. ft./yr for heating or cooling in the second row.

Solar hot-water heating

The Arizona Solar Center (Appendix E) estimates the savings of the Progressive Tube (Model PT-40-CN) solar hot water heater used at Civano to be approximately 2,200 kWh per year per home in Tucson. Translated as kBtu per square foot, this savings is approximately 4.6 kBtu per square foot per home at Civano.

The SES stipulates 50% reductions for heating, cooling and water heating; however, current methods of metering and analysis disallow direct audit of energy costs, and hence energy comparisons, for water heating.

Summary of Civano Compliance with the Sustainable Energy Standard

Civano homes average 23 kBtu/sf/year for heating and cooling, 10 kBtu/sf/yr for heating and 13 kBtu/sf/yr for cooling. This figure exceeds the total maximum 20 kBtu/sf/year stipulated by the SES by 3 kBtu/sf/year. The 13 kBtu/sf/yr for Civano cooling exceeds the SES specification by 2 kBtu/yr, while heating exceeds the stipulated maximum of 5 kBtu/sf/yr by 5 kBtu/sq. ft./yr.

Interestingly, Civano all-electric homes comply with the heating specifications for the SES --because they use 5 kBtu/sf/yr for heating (actually, 4.75). Tucson homes use between 13-17 kBtu/sq. ft./yr per home for heating; *homes constrained by the Model Energy Code use more gas than Tucson homes at-large*. We speculate, therefore, that efficiency of gas appliances has not kept up with that of electrical appliances and that source energy savings in gas are being lost to appliance inefficiency or appliance use factors in the home. In a surprising result, comparison of all-electric and dual-fuel homes at Civano show that the latter use approximately 4 kBtu/sq. ft./home more source energy than the former. In total, Civano homes use 56% of the heating and cooling energy of both Tucson at-large homes (*not* constrained by the Model Energy Code) and by 1998/99 homes (which *are* constrained by the Model Energy Code). Two conclusions are relevant: 1) the Model Energy Code is not impacting energy reductions (compared to overall samples) to the extent that we would hope; and 2) while cooling reductions at Civano are 50% of Tucson homes, heating reductions are just 67%. It is the latter which causes Civano homes to overshoot the target heating reduction.

A second significant finding is that Civano overall energy use is just 67% of Tucson at-large homes, and 68% of Tucson homes built during 98-99 homes. This is due to reductions, not just in heating and cooling, but also in reductions in base energy use of Civano to an average of 45 kBtu/sf./year as compared to Tucson at-large base use of 55 kBtu/sq. ft./yr, and 50 kBtu/sq. ft./yr base load for Tucson 1998-99 homes.

Added to the reductions due to solar hot water heating, which is an avoided use of 4.8 kBtu/sf/yr for Civano homes (which in this study, all use solar hot water heating), and given energy reductions due to water savings (*see Civano and Tucson Residential Water Use*, Appendix G, it is likely that the 50% reduction for overall energy use, and heating, cooling and hot water heating is being achieved at Civano. The caveat remains that current auditing technology disallows absolute confirmation. And the current formulation of the Sustainable Energy Standard misses the mark for (gas) heating. The main issue, which should be examined through redress of the Sustainability Standard itself, is a need for use of exact and accurate parameters for heating specifications and methods for determining compliance. Simultaneously, examination of exact cause for the overuse of gas relative to the initial specification of the SES would likely improve sustainability success in the future.

3.2.3 Cost Savings

Table 16 shows comparative electricity costs for Civano all-electric and dual-fuel homes, and for Tucson 1998/99 homes (data are available for the criteria study only; utility data for Tucson at-large homes were not available).

	C-DF	C-AE	Tucson 98/99
DEC	\$48.09	\$61.19	\$63.60
NOV	\$43.22	\$42.96	\$76.30
OCT	\$45.77	\$47.79	\$113.90
SEP	\$88.76	\$75.41	\$138.90
AUG	\$82.73	\$94.72	\$130.30
JUL	\$90.67	\$96.18	\$142.30
JUN	\$94.23	\$94.61	\$117.60
MAY	\$59.74	\$53.40	\$71.10
APR	\$36.83	\$35.61	\$55.10
MAR	\$36.69	\$40.58	\$56.80
FEB	\$40.66	\$52.30	\$58.50
JAN	\$41.56	\$55.90	\$66.40
Annual	\$709	\$751	\$1,091

Table 16. Electricity costs for Civano dual-fuel, all-electric and 1998/99 homes.

Table 17 shows gas costs for Civano dual-fuel and Tucson 1998/99 homes (cost data for Tucson homes were available only from the Baseline Criteria sample)..

	CIV-DF	Tucson 1998/9
DEC	\$65.63	\$61.50
NOV	\$44.25	\$21.40
OCT	\$19.62	\$19.80
SEP	\$15.10	\$17.90
AUG	\$14.85	\$17.60
JUL	\$14.36	\$17.70
JUN	\$13.74	\$19.90
MAY	\$17.08	\$25.10
APR	\$22.45	\$35.10
MAR	\$25.92	\$60.20
FEB	\$56.93	\$79.80
JAN	\$66.93	\$76.30
Annual	\$377.00	\$452.00

Table 17. Gas utility costs for Civano dual-fuel and Tucson 1998/9 homes.

Table 18 shows annual total utility costs for Civano dual-fuel homes, Civano all-electric homes and for Tucson 1998-99 homes. The average Civano home (averaged from all-electric and dual-fuel homes) is also shown.

	Civ-AE	Civ-DF	Civ-Avg.	Tucson 98/99
electric	\$751.00	\$709.00	\$730.00	\$1,091.00
gas	0	\$377.00	\$189.00	\$452.00
total	\$751.00	\$1,086	\$919.00	\$1543.00

Table 18. Comparative utility costs for Civano and Tucson 1998/99 costs.

Summary of Comparative Utility Costs

Civano dual-fuel homes save \$457 annually (\$38.08 monthly) in energy costs over their dual-fuel buildings constructed in 1998/99. Civano all-electric homes, currently utilizing the TEP Guarantee for their all-electric homes, save \$792 annually (\$66 monthly). As an average, Civano homes save \$624 annually (\$52 monthly) compared to Tucson 1998/99 homes.

3.2.4 Resource reductions: water, coal and CO2 emissions

Resource impacts of Civano energy reductions are shown in Table 19, as based on total annual energy use per house, as calculated directly from energy bill data shown throughout this report and conversions stated at the outset. Resources are figured on point-of-use energy.

	kWh	COAL (x 2)	H2O (x .65)	CO2 (from electricity)	Therms	CO2 (from therms)	CO2— all energy
CIV AE	9,320	18,640	6,058	21,436	0	0	21,436
CIV DF	7,030	14,060	4,570	16,169	280	3,080	19,249
CIV AVG	8, 175	16,350	5,314	18,803	140	1,540	20,343
TUCS A-L	12,382	24,764	8,048	28,479	329	3,619	32,098
TUCS 98-99	11,275	22,550	7,329	25,933	393	4,323	30,256

Table 19: Resource use of average homes for Civano all-electric, Civano dual-fuel, Civano average homes, Tucson at-large homes and Tucson homes built in 1998-99; coal and CO2 are given in pounds, water is given in gallons. Note that the penalty of CO2 production for one therm equivalent of electrical energy is 67.69 pounds of CO2, whereas that for one therm equivalent of gas is 11 pounds.

Each year, the average Civano home uses 66% of the coal that the average Tucson at-large home uses, and 73% of the coal used by the average Tucson 1998-99 home.¹⁰ The average Civano home uses 66% of the water pumped during the process of energy production from coal as compared to the average Tucson at-large home. (See Appendix G for other water and energy savings reductions due to water reductions at Civano).

Annually, the average Civano home avoids 36% of the CO2 emissions from all energy sources as compared to Tucson at-large homes, and avoids 33% of the CO2 emissions from all energy sources generated by the average Tucson 1998-99 home. The average Civano home avoids 57% of the CO2 emissions from gas use compared to Tucson at-large homes, and avoids 64% of the CO2 emissions from gas used by Tucson 1998-99 homes. Overall, the average Civano home avoids 34% CO2 emissions from electricity as compared to Tucson at-large homes, and 27% of electricity CO2 emissions as compared to Tucson 1998-99 homes.

150 Houses

The predicted cumulative resource savings of Civano homes at the development-wide level can be demonstrated by comparing 150 average homes from Civano¹¹ with 150 average homes from Tucson at-large and from 1998-99 homes.

The findings of this report suggest that 150 average Civano homes will save 1,262, 100 pounds of coal annually, relative to Tucson at-large homes and 930,000 pounds of coal annually, compared to Tucson 1998-99 homes. For electrical energy generation, which requires water for cooling of steam turbines, the energy savings of 150 average Civano homes will save 410,183 gallons of water annually from reduced electricity costs

¹⁰ Overall, the Civano dual-fuel home uses 57% of the total coal used by the Tucson at-large home. Since both of these types of houses are dual-fuel, this number represents a more accurate perspective of coal savings than the average Civano home—which includes Civano all electric homes (which uses electricity for heating too). The Civano all-electric home uses 75% of the coal used by the Tucson at-large home. Note that for the Civano all-electric house, this total of 75% represents *all* energy in the house—including heating—while for the Tucson at large home, the energy excludes heating energy.

¹¹ As of this writing, approx. 135 Civano homes are in occupancy with over 200 sold. The comparison to 150 homes is a (round) figure, useful for comparing total impact scenarios only, and should not be taken as the exact number of homes currently effecting the utility data reported here.

relative to Tucson at-large homes, and 302,250 gallons annually, as compared to Tucson 1998-99 homes. Together with the direct water savings from potable water reductions at Civano (see by ANE, Inc., April, 2002, Appendix G), in which 150 Civano homes are predicted to save over 13 million gallons of potable water per year as compared to a comparable set of 150 Tucson homes, the energy savings shown here directly impacts additional water savings.

Total reduced CO2 emissions from reduced gas and electric use for 150 average Civano homes amounts to an avoided 1,763,265 pounds of CO2 annually, relative to Tucson at-large homes, and 1,486,950 avoided pounds yearly, relative to Tucson 1998-99 homes.

3.2.5 The Need for Additional Solar Technology

Despite savings due to more sustainable building practices and technologies, enormous amounts of energy are used annually in modern homes, even Civano homes. Table 20 demonstrates total annual energy use for all classes of homes reported here.

	kBtu from electric	kBtu from gas	Total kBtu— all sources	Cooling kBtu	Heating kBtu
CIV AE	98,650	0	98,650	13,309	7,776
CIV DF	74,411	31,080	105,491	14,450	20,472
CIV AVG	86,530	15,540	102,070	13,879	14,124
TUCSON A-L	131,060	36,519	167,579	31,639	19,525
TUCSON 98-99	119,343	43,230	162,573	33,472	27,730

Table 20. Total annual energy use in kBtu per home. Figures indicated are based on source energy. Note that because Tucson at-large and 98-99 homes are typically larger than Civano homes, as well as being less efficient, cumulative energy use in the former is higher—as is resource use.

Despite the savings shown above, 150 average Civano homes collectively use over 15 million kBtu of energy each year. Translated as coal, water and pounds of CO2, this equals almost 2.5 million pounds of coal--which must be mined, transported and shipped to Tucson every year; approximately 800,000 gallons of water which must be pumped during the process of energy generation every year (this figure excludes water directly used for potable and gray water landscaping); and over 3 million pounds of CO2 emissions from gas and electric combined--every year.

A reliance on solar energy, for which Civano gained funding from the State of Arizona Energy Office, as the common design factor of the initial Civano vision was directed precisely at this dilemma. The energy reductions at Civano--in the form of solar hot water heating and building systems efficiency—is a first step of many needed to decrease residential energy consumption. The Civano partners should be mindful of the enormous amounts of energy used by residential homes as the second Civano neighborhood is designed; the latter must integrate solar energy vigorously into the design fabric in order for Civano to comply with the foundations of solar upon which its commitments rest. Use of daylighting, photovoltaics, and passive solar for heating and cooling should be further elaborated in the design. Passive solar is not limited to orientation, but lies in appropriate use of thermal mass, shading and landscaping, and

architecture. All possible measures should be taken to move Civano toward better use of Arizona's most abundant resource—solar energy—which was the founding commitment of the Community of Civano. Heating and cooling, and use of lighting and other comfort technologies will be minimized by these actions.

Ses CHAPTER 1

ADMINISTRATION AND ENFORCEMENT

201.1 Application of Terms. *Beneficial Use of Solar Energy: The following devices/methods may be used to demonstrate compliance:*

- *Solar thermal or solar electric space heating systems.*
- *Trombe wall or clear view collectors for space heating.*
- *Solar Photovoltaic systems.*
- *Solar thermal/electric power generating systems, including stand-alone and grid connected parabolic trough and dish Stirling.*
- *Solar daylighting systems specifically designed to capture and redirect visible solar energy while controlling infrared energy (conventional skylights are specifically excluded) for at least one half of the non-bedroom space.*
- *Passive building heating for the winter through the use of optimum window shade structures and orientation.*
- *Solar water systems for domestic water heating or space heating.*
- *Solar pool or spa water heating.*
- *Solar oven that is built into the structure.*
- *Solar food dehydrator that is built into the structure.*
- *Solar water distiller attached to building.*

Source energy consumption shall be determined by multiplying the site energy usage in kBtuh per square foot by the following factors:

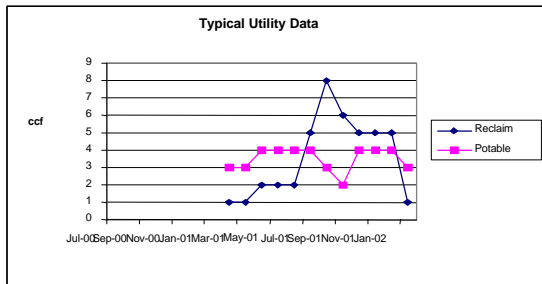
<i>Site Energy</i>	<i>Factor</i>
<i>Electric</i>	<i>3.10</i>
<i>Gas</i>	<i>1.11</i>
<i>Wood</i>	<i>1.00</i>
<i>Solar (amount of displaced electric or gas)</i>	<i>0.00</i>

APPENDIX D

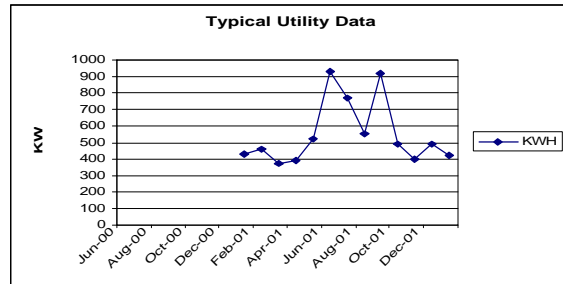
Two stages of energy use were reflected in the Civano data supplied to Civano: pre-use and use stages. *Lifecycle stages* of a house include a *use phase*—period that the house is in residential use—and a *pre-use phase*—the period that the house is under construction (pre-residential). The significance of the pre-use phase to the current report is that during this time, energy was used at the house site and therefore metered and reported. Inclusion of such data would not reflect true residential energy use. Significantly, in every case examined for this report, inclusion of pre-use data would artificially lower the reported average water use. Hence, they were eliminated from the Civano data. In a large enough sample, the numbers would eliminate the impact of this problem. To the best of our knowledge, neither the comparative Baseline, nor the Tucson at-large energy data use averages reflect this normalization. Figure 1 demonstrates the data normalization process assumed here.

Figure 1 data normalization. Since all three utilities are screened for the same residence, the probable move-in data aligns with the month at which all utilities were on—March, 2000. Note that while energy was used previous to these dates, the water was not on. The likely date for residential occupancy was assumed to be March, 2000.

WATER



ELECTRICITY



GAS

