Building America SM
U.S. Department of Energy
Research Toward Zero Energy Homes

High-Performance Home Technologies: Solar Thermal & Photovoltaic Systems

Case Study: Pulte Homes – Civano

Tucson, AZ

Pulte is building more than 1,400 energy-efficient homes in the Civano community of Tucson, Arizona.

Pulte Brings Building Science to Civano

Pulte Homes is putting building science to work in 1,500 energy-efficient homes at the Civano master planned community in Tucson, Arizona. Working with DOE's Building America Program, Pulte Tucson has put together a solar water heating and energy-efficiency package that is helping new Civano residents to cut their utility bills while the building company turns a profit.

Civano began as an idea proposed by local advocates and government officials in the 1970s called the "Solar Village." Construction started in the late 1990s and Fannie Mae took over as master developer in 2000. Civano's "New Urbanist" design scheme attracted attention and Civano's first phase of construction, Neighborhood 1, was voted the best new community in the Southwest by *Sunset Magazine* in January 2004. The New Urbanist design combines residential, commercial, community, and open spaces in a pedestrian-friendly layout punctuated by diverse southwest architectures and drought-tolerant landscaping.

Before Neighborhood 1 was built, planners of the Civano Community organized a committee of local engineers, code officials, and equipment providers to write a set of stringent requirements that builders must comply with when they build in the community. The requirements specify that energy consumption of the building shell, mechanical systems, and domestic water heating will be 50% less than the energy consumed by a house built to the Tucson/Pima County Energy Code. This equates to a 30% minimum reduction over the Building America benchmark. There is also a solar goal of meeting 5% or 550 kWh per bedroom of the household's energy needs with solar energy sources.

Other sustainability goals include a 60% reduction in potable water; xeriscaping with native plants, on-site recycling of construction debris, and reduced transportation by having at least one job at Civano for every two homes on site.

Builders were encouraged to experiment to meet the goals of the project and several approaches were tried by the eight different residential builders working in Neighborhood 1. These included passive solar design, advanced framing techniques, and construction with insulated concrete, straw bales, structural insulated panels (SIP), adobe, Integra block, and RASTRA (a lightweight product composed of 85% recycled polystyrene foam). Most builders in neighborhood 1 chose solar water heaters to meet Civano's solar energy requirement.

> "Pulte's involvement in Civano is the next step up from the exemplary level of efficiency and whole-building systems design already standard for the production builder."
>
> *Armin Rudd, Building Science Corporation*

BUILDER PROFILE

Builder's Name:
Pulte Homes, Inc., Neighborhoods 2 – 4. Mixed builders in neighborhood 1.

Where: Nationwide

Founded: 1950, Detroit, MI

Number of Staff: 13,400 nationwide

Development: Civano - Tuscon, AZ

Size: 1,517 to over 2,180 sq. ft. (Two to four bedrooms and two to three bathrooms)

Price Range:
$120,000 to $260,000+

KEY FEATURES

BUILDING ENVELOPE:

Ceiling R-22 cellulose

Unvented attic w/ tile roof

Walls 2x6 @ 24 o.c. R-19 w/ R-4 EPS or Walls 2x4 R-13 @ 16 o.c. w/ R-4 EPS

Foundation slab, uninsulated

Windows Low-e2 U=0.39, SHGC=0.33

Infiltration 2.5 sq in leakage area per 100 sf envelope

MECHANICAL SYSTEMS:

Heat 90% furnace in conditioned attic

Cooling 14 SEER

DHW 40 sf solar collector with solar tank

Natural gas backup

Ducts R-4, conditioned attic

Leakage; None (to outside) 5% of flow maximum

Totaline thermostat

Ventilation 45 cfm 10 min per hour

Pulte uses mechanical ventilation to bring fresh filtered air into the home and send humid air out for a healthy indoor living environment.

Pulte entered the picture in 2003 taking Fannie Mae's place as master developer for the second phase of construction at Civano, in Neighborhoods 2, 3, and 4. Pulte is also the primary builder of these neighborhoods, which it calls Sierra Morado, where Pulte intends to build 1,400 to 1,500 homes over the next five years, joining the nearly 500 homes already built in Neighborhood 1. Construction in these neighborhoods began in early 2005 and prices in 2006 ranged from $120,000 to the upper $200,000s. As with its other communities, Pulte brings to this project an understanding of building science and experience at managing the construction process.

"Pulte is being successful at Civano. They are using Building America building science concepts and are scientifically doing a much better job, a more advanced job, to make their homes affordable and efficient," said Al Nichols, the professional engineer who evaluates builders' plans for Civano. "We will analyze the utility billing data in Spring 2007. I think Pulte will have greater performance than the Neighborhood 1 homes. But the goal of Civano is much bigger than this project alone. It's to show that you can have much greater performance anywhere without a lot of additional cost, and you can make money at it. The only way to survive in a depressed market is to build better homes."

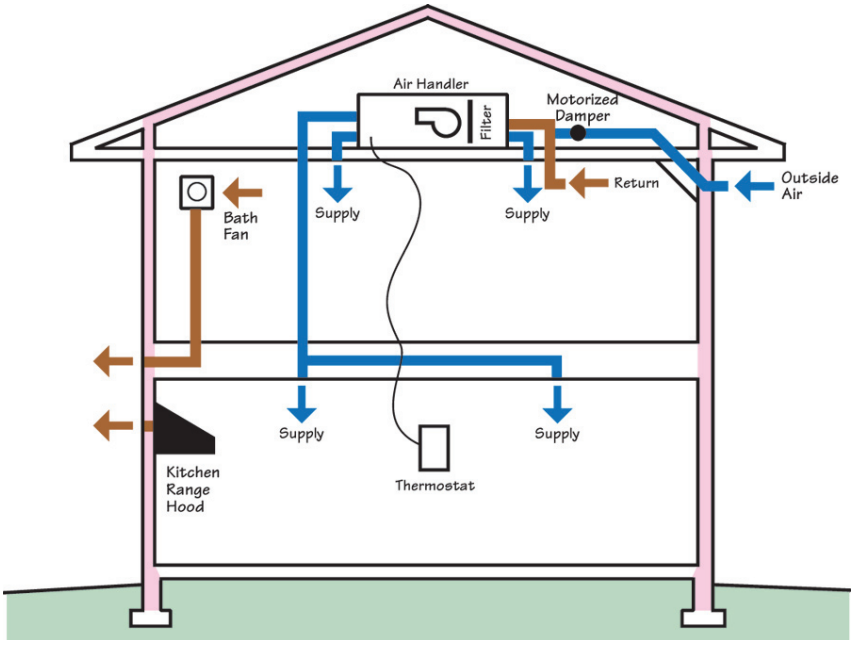
"Building America was very helpful in making decisions at the start of the project. We consulted with them on what kind of water heaters to install and what mechanical systems configuration would best meet the requirements," said Rich Michal, the Civano project manager for Pulte Tucson.

Solar Systems

Building America research partners studied the water heating systems used in Neighborhood 1 (see sidebar). Pulte Tucson used this research to select a system for its Neighborhood 2-4 homes.

Pulte is installing a SunEarth Empire EP40 system with a 40-sq.ft. flat plate solar collector mounted on the roof that heats a glycol fluid in a closed-loop, active system. Active systems use an electric pump to push the solar fluid through the collector and down to a heat exchanger that transfers the heat to potable water in an 80-gallon Rheem Solaraide HE hot water tank. The system also has a natural gas backup heater. The tank is installed in the garage. Pulte engineers the roof trusses for adequate structural strength to enable home owners to add future photovoltaic panels if they choose.

Michal noted that Pulte had been concerned about home orientation on the lots for solar gain but Building America research eased those worries. Building America partner Building Science Consortium did a study of placement of the solar panels to see if they met the Civano requirement. Building



Solar Thermal Water Systems: Passive or Active, Direct or Indirect?

There are two ways of classifying the major differences among solar water systems—active versus passive and direct versus indirect. Active systems all have pumps that move fluid through the system. Passive systems have no pumps; they rely on gravity and the buoyancy of warm water to move fluid through the system. Indirect systems have two loops—one loop goes to the solar collector and contains a fluid (generally a water-antifreeze mix) that transfers heat well but has a very low freezing point. This fluid exchanges its heat content with potable water in a separate loop. Indirect systems are also called "closed-loop" systems. Direct systems have only one loop of potable water that passes through the collector and flows directly into the tank. Active, indirect systems with antifreeze, or controls that drain water from collectors, work best in climates with freezing conditions. Many passive and/or integral systems are only appropriate for areas with no or only occasional mild freeze conditions. Passive, direct systems are less complicated and sometimes less expensive. But direct systems are dependent on high-quality water for efficient operation and reasonable service life.

Science Consortium found only a 16% difference in performance between south, east, and west roof elevations. "We found that the active closed loop system works well even if it is 90 degrees off of due south. The panels can even be due east or due west and they will still operate at an 80% efficiency, i.e., they will still meet the 550 kW-per-bedroom requirement," said Michal.

Energy Efficiency

Builders in Neighborhood 1 tried several different construction techniques (including SIPS, insulated concrete, and even straw bale homes) to achieve the Civano energy efficiency goals.

Building America partners IBACOS, Sandia National Laboratories, and the National Renewable Energy Laboratory tested several of the Civano Neighborhood 1 homes and energy subsystems to document their performance. IBACOS did field monitoring of nine homes with a variety of construction types including 2x6 wood framing, SIPs, steel framing, and straw bale, and found that one-third did not meet the heating and cooling energy requirements. These research organizations provided analysis and lessons learned from Neighborhood 1.

"When Pulte agreed to come in as master builder of Neighborhoods 2-4, they said they would meet the Civano energy efficiency goals but they had their own way of doing it. They wanted to standardize production," said Rudd.

Pulte settled on one approach—the "platinum-level" home they had developed with Building America building science principles for use in other developments across the country (see sidebar on building science principles). Pulte Tucson had been working with Building America since the mid 1990s according to Rudd and had already used its platinum-level approach at several Tucson developments.

"Pulte has shown leadership in energy efficiency in Tucson. For a span of 10 years every house we built in Tucson was a platinum-level house," said Michal. "We have committed to platinum at Civano, even though our calculations show that the Pulte gold level would probably meet Civano's energy requirements."

"Pulte does their own blower door and duct blaster testing during construction to confirm that homes meet their platinum-level standard," said Rudd.

With help from Building America research, Pulte selected closed-loop, active solar water heating units.

Key Building America Building Science Principles

Pulte adheres to these principles in its Platinum Level houses for high-performance homes that deliver energy efficiency, safety, comfort, health, and durability:

Superior energy performance; HERS rating of 88 or better, which always includes high-performance windows with low U-value and low SHGC.

All ducts and air handling equipment must be located inside the conditioned space.

All combustion appliances in the conditioned space must be sealed-combustion (furnaces, boilers, and water heaters).

Mechanical ventilation per ASHRAE 62.2, including kitchen range hoods and bath fans that exhaust directly to outside.

Performance testing (per ENERGY STAR testing regime) with building air leakage of 0.25 cfm50/ft^2 surface area or less; duct leakage of 5% or less of the total air handling system rated air flow at high speed; and interzonal air pressure differences, when doors are closed, of 3 Pascals or less.

Adherence to water management details including drainage plane, capillary breaks and flashings, and attention to climatic wetting and drying potentials.

According to Michal, one of the biggest changes Pulte makes in construction techniques over standard practice is to place the mechanical equipment in conditioned space in the attic. "We use cathedralized insulation; in other words, we apply the insulation right up along the roof line instead of on top of the ceiling. We use a blown-in cellulose product. It is a mixture of recycled newspapers and a fire retardant. We staple a burlap type sheeting to the rafters, then blow in the insulation above the sheeting along the roof line to insulate the attic. We also apply it wet to the walls before sheetrocking; it sticks to the walls and dries in place," said Michal.

Pulte has also chosen high-efficiency HVAC equipment as a standard feature in each home, including a SEER 14 air conditioner and a 90% AFUE sealed combustion gas furnace, with all ducts located inside the conditioned attic. Controlled mechanical ventilation is provided by a central fan with fresh outside filtered air provided to the air handler through a motorized damper.

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Dollars and Sense

BSC evaluated 11 Pulte house plans against the Building America benchmark using the EnergyGauge USA software and found the Pulte homes will reduce total energy costs by approximately $500 to $850 annually.

According to Michal, the solar water heaters qualify homebuyers for pretty substantial federal and state tax credits and Pulte works with the installers to ensure that the homebuyer gets the documentation needed to qualify for their tax credits. The state of Arizona offers a solar tax credit for 25% of the cost of an approved solar device or system, up to $1,000. The homebuyer would also qualify for federal tax credits.

Those incentives could be enough to sway buyers in a competitive Tucson first-time home buyer market that was very hot in 2005 and early 2006 but has cooled considerably since.

The Bottom Line

"In a really high-growth area, there is a lot of competition and a push to just get homes up and fast. You could build a cardboard box and be successful in the first-time home market here when it was really hopping. We've had the leadership that was committed to building to a higher standard, going to the higher level. We are motivated to go for the return customer," said Michal. Michal, who lives at Civano, added his encouragement for builders contemplating solar. "I think it's the future. If we want to sustain the growth in this industry, we've

Solar Water Heating Lessons Learned at Civano Neighborhood 1

Many of the solar collectors and related copper pipes installed in Neighborhood 1 failed or experienced excessive pitting. The collectors were part of passive, direct systems that had city water flowing through them. Building America researchers found that the city water had CO_2 and potassium levels and a nitrate/nitrite ratio just high enough to be aggressive in terms of potentially corroding and pitting copper. The copper corrosion properties of the water were theorized to be enhanced by higher temperatures.

In Neighborhoods 2, 3, and 4, Pulte chose to use an active, indirect system where the fluid circulating through the solar collector is in a closed loop and is a combination of water and nontoxic antifreeze that does not have the city water's corrosive properties.

IBACOS, a Building America team leader, found other problems with the design of the original solar water heating systems. One problem was that pipe runs were as much as 120 feet from the collector to the tank in some homes. The Civano energy requirements have since been upgraded to require that rooftop collectors be installed within 20 feet of the storage tank.

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IBACOS also found that some houses equipped with the original solar water heaters were using more water heating energy than homes without solar systems. It turned out that these high-energy-consuming homes had hot water recirculation systems, a feature that provides instant hot water at faucets and showers. Some timer settings had the pumps running around the clock. The pumps pushed hot water from the tank into the solar collectors at night where the water was cooled. On its trip back around the system, the cooled water was reheated and then recirculated. Homes that used a button-activated recirculation pump, where the pump only ran for about 90 seconds, did not see this energy usage problem.

Solar Water Heating Lessons Learned

Problem	Solutions
Corrosion of copper pipes due to "aggressive" city water chemistry and high temperature	1. Add chemicals to soften water. 2. Choose a solar thermal collector with single glazed top rather than double glazed top for less heat buildup 3. Choose a closed loop system where glycol solution passes through copper collector pipes rather than chemically aggressive local water.
Long pipe runs reduce effectiveness of passive water transport mechanisms.	1. Locate solar collector less than 20 feet from tank. 2. Use an active solar collector system with a pump to move liquid through system.
Recirculation unit increases energy demand from hot water up to 550% over homes with standard water heating.	1. Don't use recirculation systems with single loop solar heaters. 2. Use recirculation system only with closed loop solar water heating systems.

"I'm aware of the problems previous builders had with the then-cheaper passive integrated solar water systems. One of the reasons we went with the product we did, and paid a premium for it, was because we didn't want to have the warrantee issues," said Michal. "When we were pricing systems in 2004, the passive integrated copper systems were less expensive. Now with the price of copper going through the roof, the passive systems are more expensive than the active systems we are using," said Michal.

Pulte purchases the solar systems through a local vendor and has the vendor do the installations. "We had never done solar water heating installations before," said Michal. "We pride ourselves on repeat business and good customer service. For us to do the installation with no experience would have been a warrantee and customer relations nightmare. We are construction managers, we subcontract out everything. We just make sure that our subcontractors do the job right. We have the quantity to get good pricing. I don't think we even considered doing it ourselves. Even in a market the size of Tucson I don't think you are going to find many plumbers and electricians who will have the expertise to do solar. The vendor has licensed plumbers and electricians specifically trained in solar installations. For us, this made the most sense."

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