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

Builders Challenge Guide to 40% Whole-House Energy Savings in the Hot-Dry and Mixed-Dry Climates

Case Study:
John Wesley Miller Companies

ARMORY PARK DEL SOL | TUCSON, AZ

John Wesley Miller combined thick masonry walls with rigid foam sheathing insulation, R-38 attic insulation, high-performance windows, 14-SEER heat pumps, with solar photovoltaic and water heating systems for 50% energy savings over the Building America benchmark on all 97 standard units at Armory Park del Sol in Tucson.

A "Second-Generation" Net Zero-Energy Home

Solar home visionary John Wesley Miller has teamed with the U.S. Department of Energy to build two zero-energy homes at his award-winning 98-unit development in Tucson's historic Armory Park neighborhood.

Miller was one of four builders selected to work on DOE's Net Zero-Energy Homes program. Through the initiative, Miller worked with the National Association of Home Builders Research Center, the National Renewable Energy Laboratory, Devereaux and Associates Architects, and a team of suppliers and contractors to design one of the first true zero energy homes in the country in 2003. Four years later they improved on their design to build a second zero-energy home. Both homes are located in Miller's Armory Park del Sol community. Every home in the community already exceeds the 1993 Model Energy Code by 50% or more. The homes in Armory Park del Sol use about 7 kWh of electricity per square foot per year.

Two Net Zero-Energy Homes – Lessons Learned

Miller completed the first net zero-energy home at Armory Park in 2003. The 1,700-square-foot, two-story home uses 7,000 kWh of energy annually, compared with 18,000 kWh for a conventional home, and it produces nearly all the energy it uses on an annual basis. The home's solar hot water system provides almost all of the homeowner's hot water and home heating needs. Total energy costs in 2005 for the zero-energy home were about $15 per month—including all heating, cooling, lighting, and appliance use.

The second net zero-energy home was completed in 2007. This 2,168-square-foot home, which is 26% larger than the first home, is similar to the other 93 homes in the development in that it contains the same basic energy-efficiency features, such as photovoltaic panels for producing electricity, a solar thermal water heater, thermal mass masonry walls, exterior polyisocyanurate, and HVAC and ductwork located within the home's conditioned space. It also incorporates handicap accessibility and low-maintenance features to accommodate aging residents.

BUILDER PROFILE

Builder's Name:
Treasure Homes

Where:
Tucson, AZ

Development:
Armory Park del Sol

Size:
99 homes

Square Footage:
977 to 2,026 sq. ft.
(2-3 bedrooms and baths)

John Wesley Miller Companies

All homes come standard with a 1.5-kW photovoltaic system and solar hot water collector. *(left photo source: NAHBRC) (right photo source: JW Miller).*

KEY FEATURES OF STANDARD HOMES

- 1.5-kW PV system on standard homes, 4.2-kW on 1st generation ZEH, 5.7 kW on 2nd generation ZEH
- Copperheart solar hot water collector with 10-year guarantee
- Seisco tankless water heater
- R-38 ceiling insulation
- Milgard dual-pane, low-E2 windows with lifetime guarantee
- 14 SEER high-efficiency heat pump
- Masonry wall superstructure with exterior foam sheathing and 3-coat stucco finish
- Copper water lines
- Universal accessibility design with 3-foot-wide doors on single-level floor plans

Miller and his team also made several changes between the "first-generation" and "second-generation" zero-energy homes, based on NAHBRC's analysis of the energy usage data, interviews with the homeowners.

- **Changed plumbing from PEX to copper.**
  Although PEX piping had been used in the first-generation home, Miller prefers to use copper piping because of its perceived durability but recognized that the parallel piping design used in the first home would minimize resource-wasting wait times for hot water.

- **Changed space heating from solar hot water heat to air source heat pump and reduced solar hot water tank size foot print by two-thirds.**
  In the first home, the solar thermal system for heating domestic water was designed to handle 100% of the domestic water heating load as well as nearly 90% of the space heating load. However, this system required a large custom tank that needed post-installation modifications to work and took up too much space inside the home. In the second-generation home, the solar thermal system was downsized for less square footage of thermal collectors on the roof and a smaller storage tank designed to meet 90% of domestic hot water needs, with an electric on-demand water heater for back up. Space heating was provided by a SEER 17.6-rated high-efficiency air source heat pump for heating and cooling.

- **Increased PV size from 4.2 kW to 5.7 kW system.**
  The solar photovoltaic system is approximately 65% larger than the first zero-energy home's PV and provides nearly all of the energy annually to operate the home, including the increased electricity demand of the electric water heater and heat pump. Although a larger photovoltaic system is more expensive than a larger solar thermal system, in this case the builder felt that the benefits of increased installation simplicity, lower maintenance, and smaller sized water tank outweighed the higher cost.

- **Switched from recessed can lights to high-efficiency lighting without recessed fixtures.** The first-generation home contains recessed "can" lights located in the ceiling. These lights resulted in high lighting costs and in penetration of the ceiling thermal boundary. The second generation home contains high-efficiency lighting with predicted savings of 50% (2,548 kWh to 1,274 kWh).
- **Added 1.5 inches of rigid foam insulation above roof frames.** This rigid polyisocyanurate foam is wrapped in aluminum foil and laid above the roof frames with R-38 insulation below for an equivalent of R-55 roof insulation. By adding insulation above the roof rafters, Miller is able to increase R-value while avoiding the higher costs associated with increasing the depths of the rafter to accommodate increased insulation thickness.

Insulation from the Elements

Interior comfort can be difficult to maintain in the extreme outdoor conditions found in Arizona. However, John Wesley Miller incorporates several best practices that protect against the temperature swings found in desert climates.

Masonry Construction

The Armory Park del Sol homes have a masonry wall superstructure consisting of conventional masonry concrete blocks. The concrete block is insulated on the exterior side with 1.5 inches of polyisocyanurate foam and covered with a 3-coat stucco finish. Interior framing consists of termite-proof steel framing. This masonry construction, notes Miller, provides a thermal mass wall to protect the indoor environment from outdoor conditions. The exterior walls cool at night; because they are so slow to transmit temperature, they emit a cool feeling to the home during the heat of the day and warmth at night. A side benefit for homebuyers is their sound-deadening properties. With the masonry walls and attention to air sealing at all envelope penetrations, Miller was able to achieve a very tight house (2.9 ACH50).

HVAC System

John Wesley Miller Companies works with a professional engineer to review house plans to assess the placement of ductwork and the proper sizing of HVAC equipment. At Armory Park del Sol, the ducts are sealed with mastic, tested for air leakage, and enclosed in soffits along the central core of the house within the conditioned enveloped of the home. Transfer grilles across doorways and a central return equalize air pressure throughout the house. This careful attention to the HVAC system and its placement further contribute to the home's energy efficiency.

Windows

Inferior windows can contribute to air leakage or heat transfer, which is why low-emissivity dual-pane windows were chosen for Armory Park del Sol homes. The spectrally selective coatings on these windows protect occupants from the heat and glare of the daytime sun, while the U-value of 0.31 indicates low heat loss during the night.

The first-generation zero-energy home contains an AC unit and an integrated solar water and space heating system. In the second-generation home, solar collectors provide water heating with backup water heating provided by a tankless gas water heater and space heat provided by an air source heat pump *(Photo source: by NAHBRC).*

Deep overhangs and porches help minimize heat gain to the interior of the home. Xeriscaping minimizes irrigation needs in the hot dry climate.

"John Wesley Miller Companies worked with the NAHB Research Center to analyze its first-generation net zero-energy home at Armory Park del Sol. Together they came up with a list of energy-, space- and cost-saving changes that simplify installation for the builder while still allowing the home to reach true net zero-energy use."

John Wesley Miller

The southwestern architecture of John Wesley Miller's Armory Park del Sol urban infill project cleverly hides the rooftop photovoltaic and solar water heating panels from passersby.

First-Generation Zero Energy

First Generation
R-38 blown attic insulation
1.5-inch rigid foam exterior wall insulation thickness
PEX parallel piping
Recessed can lights
4.2 kW PV
Solar hot water space heating
Custom-built, oversized solar hot water tank

VERSUS

Second-Generation Zero Energy

R-38 blown attic insulation plus 1-inch rigid polyisocyanurate foam sandwiched in aluminum foil for R-55 attic equivalent
2-inch rigid foam exterior wall insulation thickness
Copper modified parallel piping
High-efficiency lighting
5.7 kW PV
Air source heat pump
Standard solar hot water tank

Solar Energy Features

"In 1973, I became enthralled with solar energy" said Miller, whose solar energy credits include coming up with the concept for the original Solar Village, which evolved into the Civano planned solar community in Tucson. His passion has evolved into a homebuilding creed that puts solar energy first.

For example, each of the 99 lots within the Armory Park del Sol was carefully configured to take full advantage of the sun. The southwestern architecture—like flat roofs and parapet walls, are ideal for keeping PV and solar hot water panels hidden from view. All homes have wind-resistant, 1.0- to 1.6-kW (or better) PV systems with programmable thermostats, backed by a 25-year guarantee. The Homeowners Association (HOA) restricts the placement and maximum height of trees to avoid adverse shading conditions that could interfere with the efficiency of the PV modules.

In addition, each house was outfitted with a roof-mounted Copperheart solar hot water collector, which combines thermal collection (i.e., water heated by the sun) and storage in a single unit. It is backed up by a Seisco tankless water heater to ensure hot water on demand. Parallel piping was installed to improve hot water delivery time as well. This hot water distribution system features copper pipes that branch off of the main pipe to each hot water use point, speeding up delivery time and reducing energy losses.

Working Together

Miller has formed long-standing relationships with local subcontractors and holds frequent meetings with staff and trades to review building practices and discuss issues. This ensures that all parties are on the same page when working with new techniques or materials.

In addition to working with Building America, Miller is also involved with other national and local building organizations. The company has also formed a strong bond with Tucson Electric Power, the local utility. The utility aggressively promotes renewable energy power systems by offering rebates and other incentives. Miller is also participating in the utility's Guaranteed Home program. Tucson Electric Power offers every home in Amory Park del Sol guaranteed heating and cooling energy costs for five years. Tucson Electric Power inspects each home three times during construction to ensure that building science performance criteria are met. Miller is also involved in developing local county green building codes. Said Miller, "This is a volunteer program that gives builders incentives for doing good things instead of penalizing them. Too long we've been fighting each other. It's time to sit down at the table and work together to accomplish these common goals."

The Bottom Line

Miller believes that education is the key to helping buyers understand the long-term financial benefits of energy-efficient homes. "About 80% of our buyers looked us up on the web first. We probably have more Ph.D.s living in our little development than any other part of town. This doesn't mean you have to be a genius to appreciate the homes we build, but it shows that education and a willingness to learn about energy efficiency can drive sales," said Miller.

Local and federal incentives make high-efficiency features more palatable to price-conscious buyers. Tucson Electric Power agreed to a billing cap so heating and cooling bills are guaranteed not to exceed $1 per day for five years (depending on the size of the house). The utility also offered rebates for solar systems of $2.40 - $3.00 per installed watt, for a total rebate of $3,600 - $4,800 per house. This is in addition to federal and state tax rebates for solar and energy-efficient appliances and equipment.