PNC SMARTHOME:
An Inspirational Exhibit of Extreme Energy Efficiency and Carbon Reduction

By David Beach

The term "natural history" often evokes a sense of the past, but increasingly, The Cleveland Museum of Natural History (CMNH) is showing the way to a more sustainable future. In 2012, CMNH developed an ambitious exhibit, the PNC SmartHome, to demonstrate the energy-efficient house of the future—a house designed to stay warm through a Cleveland winter without a conventional furnace.

Planning for the SmartHome began in late 2010, when CMNH staff members were making preparations for mounting a major travelling exhibit on the science of climate change. They wondered what else they could do to communicate the complex and challenging issue of climate change. Could they do something hopeful to demonstrate real solutions? Could they, for instance, build a house that would show how dramatic reductions in carbon emissions are really possible? Could they find a suitable vacant lot for a house, design it, get the plans through the city permitting process and raise funds to build it all in a couple of months? Could they find a construction team that could build a house in a matter of weeks—a home that was different from any house built in Northeast Ohio? And could the house be built next to the museum as an exhibit and then moved later to the vacant lot where it could be installed permanently and sold?

Notwithstanding a certain amount of drama (including the rainiest spring construction season in Cleveland history), the answers to these questions turned out to be yes. And the PNC SmartHome opened at the museum for guided tours on June 6, 2012.

The project had a number of goals that stretched the boundaries of a typical museum exhibit:

• Give thousands of people hands-on experience with attractive techniques of green building and energy conservation.
• Build local capacity for advanced green building and raise building design standards in Cleveland.
• Support efforts of neighborhood development organizations to help residents save energy and save money.
• Broaden awareness of the climate change impacts of the building sector.
• Build a practical house that would be an asset for a Cleveland neighborhood.

For the energy performance goal, the 2,800-square-foot, three-bedroom SmartHome was designed to achieve Passive House certification, the world's most rigorous building energy standard. According to the US Passive House Institute: "A Passive House is a very well-insulated, virtually air-tight building that is primarily heated by passive solar gain and by internal gains from people, electrical equipment, etc. Energy losses are minimized. Any remaining heat demand is provided by an extremely small source. Avoidance of heat gain through shading and window orientation also helps to limit any cooling load, which is similarly minimized. An energy recovery ventilator provides a constant, balanced fresh air supply. The result is an impressive system that not only..."
saves up to 90 percent of space heating costs, but also provides a uniquely terrific indoor air quality."

Because of their very low energy demands, most passive houses can achieve net-zero energy performance with the addition of a small amount of renewable energy generation. Thus, they are a major step toward building carbon-neutral communities. Buildings are responsible for nearly half of U.S. greenhouse gas emissions, so strategies to reduce these emissions from carbon-based fuels must focus a great deal on producing better buildings.

For CMNH, the SmartHome project was a natural extension of public education and climate change work already underway. It turned abstract policy discussions into a tangible exhibit that helped people see the opportunities inherent in transitioning to a low-carbon future. At a time when public opinion polls showed a declining understanding of climate science in the U.S., it was important to create educational experiences that helped mainstream audiences realize that dramatic reductions of carbon emissions were possible. While thousands of passive houses homes have been built in Europe, only a handful of them have been built in the U.S.—and none in Northeast Ohio. So the SmartHome—with its super-insulation, virtually airtight construction, high-performance windows, energy-recovery ventilation and orientation for passive solar heat gain—brought new design ideas to the region.

As an exhibit, the SmartHome was a hit. Nearly 10,000 museum visitors went on guided tours. Tens of thousands of additional people viewed the interpretive signage and ecological landscaping features (including displays of native plants and stormwater management techniques) surrounding the house. And the project attracted extensive media coverage locally and nationally.

The SmartHome also created many partnership opportunities. The project involved more than 100 partners, including contractors, suppliers, neighborhood development organizations, the City of Cleveland and even local artists, who provided environmentally inspired artwork and furnishings for the exhibit. City residents from nearby neighborhoods were invited to free SmartHome tours and workshops on home energy savings. The SmartHome design-build team conducted technical workshops for local builders, architects, city officials, home inspectors and others in the home building industry. And CMNH staff worked with Enterprise Community Partners, a national funder of urban redevelopment and a supporter of the SmartHome, to organize a tour and roundtable discussion among development and neighborhood groups about energy efficiency and affordable housing.

Inspiried by the SmartHome, other building projects in Northeast Ohio are now incorporating passive design principles, including a new building for a community theater group. The project's design-build team is getting orders for more passive houses. The team is also exploring the feasibility of prefabricating insulated SmartHome wall systems for sale throughout the country. Thus, the project could have economic development spin-offs for Northeast Ohio.

According to the project architect, Chuck Miller of Doty & Miller Architects: "The PNC SmartHome has served as a catalyst that turns the wheels of curious minds and inspires entrepreneurs. The seeds of future opportunities are already starting to grow. We can see that future happening now with benefits to our economy, an improved quality of life and preservation of resources for future generations."

In October 2011, the SmartHome was moved to its permanent site a few blocks from CMNH. It will be sold and become the home of a Cleveland family. Thus, it will be a permanent investment in the revitalization of the city, as well as an enduring symbol of how a museum of natural history can be a center for innovative thinking about science and sustainability.
PRINCIPLES OF PASSIVE HOUSE DESIGN

The PNC SmartHome of The Cleveland Museum of Natural History is expected to consume 90 percent less heating and cooling energy than a conventional house (and about 70 percent less primary energy for all uses). It accomplishes this by following some basic principles:

- **Heat-retaining building shape:** The SmartHome has a simple, rectangular shape to minimize the ratio of surface area to volume.

- **Super insulation:** The walls are more than a foot thick and are packed with foam and cellulose to achieve an insulation value of about R-90, according to the rating system that measures insulation’s ability to resist heat flow. In comparison, Ohio’s building code requires a minimum side wall insulation level of just R-13.

- **High-performance windows:** The triple-pane windows achieve R-11 insulation value in the center of the glass, and they close like a bank vault to stop cold drafts.

- **Air-tight construction:** All the holes and seams in the building envelope (the outer perimeter of the living space) have been carefully sealed. As a result, it’s expected that the “draftiness” of the SmartHome will be less than 0.6 air changes per hour when measured by a pressurized blower door test. In comparison, a typical new house might have five air changes per hour, and a drafty old house might have rates as high as 10-15.

- **Thermal bridge-free construction:** It’s amazing how much heat can be conducted through a piece of wood, such as a 2x4 stud in a wall. The walls in the SmartHome are designed to eliminate such thermal bridging with the strategic placement of insulation.

- **Heat-recovery ventilation:** An airtight house can develop indoor air quality problems if adequate ventilation is not provided. But when you vent stale air from a house, you also lose heat. So the SmartHome’s ventilation system transfers the heat of the outgoing air to the incoming fresh air. The energy is transferred at 84 percent efficiency. As a result, the house has healthy fresh air with little energy penalty.

- **Efficient supplementary heating:** The SmartHome is designed to maintain temperature like a Thermos. The heating demand will be so low that the home needs no conventional furnace. Instead, the house can make it through the cold Cleveland winter with two small, ductless, air-source heat pumps, which require minimal energy. The heat pumps also provide supplementary cooling in the summer.

- **Optimal solar orientation and shading for passive solar gain:** The SmartHome was designed for a south-facing lot near Cleveland’s University Circle district. The large windows on the south side allow sunlight to enter and warm the house during the colder months of the year. The windows are shaded so that during the summer, when the sun is higher in the sky, sunlight is blocked.

- **Energy-efficient appliances and lighting:** It makes no sense to build an extremely energy-efficient house and then fill it with energy-hogging appliances and lighting. So the SmartHome features Energy Star appliances and extremely efficient LED lighting.

When you put all these design principles together, you get a house that is comfortable and quiet, has low energy costs and is simple to operate.