Building With New Technologies

Introduction

New housing technologies can improve the value of housing through incremental and radical changes in residential construction products or processes. These available technologies can improve the constructability and affordability of new homes as well as the long-term durability, strength, and value of the housing. While not intended to be a comprehensive listing of building technology innovations, this article provides a basic understanding of innovative construction technologies.

In this article, the term "technologies" refers to construction products or processes that can improve the home's affordability, durability, strength, or design flexibility. In many cases, affordability is directly related to the speed of construction. The use of products that reduce the construction period can shorten the length of the construction loan, thus lowering financing and other construction-related costs. Using innovative, more durable materials enables the builder to build homes with reduced maintenance costs (savings that accrue to the homeowner). Structurally stronger materials may enable designers to use fewer materials (and conserve resources) or provide space that better supports the homeowner's needs.

Awareness of innovative technologies can improve the understanding of how they contribute to the value of the home. As improved home values are reflected in appraisals and sales, manufacturers and builders will accelerate the acceptance and use of those technologies. The logical result of such acceleration is a greater demand and availability of technology innovations in housing, leading to stronger and more affordable, durable, and energy-efficient homes.

The Partnership for Advancing Technology in Housing (PATH) is a public-private partnership focused on increasing the rate of innovation and the acceptance of residential technologies. Administered by the Office of Policy Development and Research at the U.S. Department of Housing and Urban Development, PATH works with industry groups, manufacturers, builders, and others to speed the acceptance of innovations in housing.

Challenges

Builders seeking to use technologies in residential construction face many challenges. They may be unable to locate the products at their suppliers or may not fully understand how to use them. It may be impossible to locate subcontractors with skills to install the technologies, and builders may face building code officials unwilling to approve the use of new products. Builders also must address hesitant homebuyers who do not understand new products or materials.

Balancing these challenges, today's builders must find the technology acceptance "sweet spot," where benefits accrue to the builder and homeowner yet the home remains marketable to most buyers. If designs lag the capabilities of the technologies and customers' understanding, the homes will be less efficient and capable. If designs go beyond customers' acceptance, the builder will have to dedicate resources to raise buyer awareness, potentially slowing sales.

Recent experiences with builders successfully using innovative technologies suggest that most have identified the need to serve as an "educator," helping the homebuyer understand how the use of technologies adds value to the home. That these builders are as successful as their counterparts demonstrates that innovation adoption does not necessarily result in a marketing disadvantage.

Historical Perspective

Although the builders who first used light wood framing in the United States almost 200 years ago would recognize many construction techniques used today, they would also find many aspects of today's construction new.

For many of us, the home we live in is very similar to the home where we grew up. That means a light wood frame structure (typically using 2 by 4 studs) built from lumber transported to the jobsite. Last year, about 88 percent of new home starts were light-frame construction. Light-frame construction (often called "stick framing") has been traced to the Midwest where it was observed in the early 19th century. Since that time, available supplies and labor prompted changes in home design and construction. An early example of light-frame construction, known as balloon framing, used wall studs more than 20 feet long and attached (hung) the floors to a continuous wall. This technique gave way to today's platform framing, with studs only 8 to 10 feet long and the floor system sitting on top of the

wall. This change has been attributed to the fact that lumber is shipped great distances and is not locally harvested and milled. Handling shorter pieces of lumber, from shipping to installation, is much easier.

Changes to the selection and use of construction materials are influenced by cost, performance, and availability of materials. As some products increase in cost, builders will shift to others. For example, builders once built interior walls from wood studs with strips of wood (lath) covered with plaster. Over time, they began using cement backer board covered with plaster. Today, most builders use a single layer of gypsum board (drywall) for interior walls. Each change enabled the builder to increase the use of manufactured materials, reducing the need for labor in the field.

Similar changes have occurred with sheathing and siding material. With some products, the improved performance of the newer product facilitated the change. Lumber producers are marketing engineered wood studs for critical installations such as kitchen walls that must be flat to accept cabinets. Although the engineered product costs more than conventional studs, the new product's consistency and lack of warping benefit the builder in intangible ways, such as customer satisfaction.

Such innovation continues today. Manufacturers, builders, and designers continue to develop and integrate new technologies that add value to housing. The definition of value, however, may vary among the various parties in the homebuilding process (manufacturers, designers, builders, subcontractors, and homebuyers). If one party does not recognize the value, the product may not be accepted and used.

The acceptance of new technologies is also affected by experience with or knowledge of past innovations in housing. Aware of past failures and perceiving a potential liability risk, builders may be reluctant to embrace a new technology. Their concern is reasonable as the past is marked with notable, unanticipated materials failures. For example, in the 1960s, builders used aluminum electrical wiring. The wiring was safe to use as designed, but when used incorrectly it suffered failures from corrosion and loose connections. In the 1970s, many builders sheathed townhome roofs with fire-retardant-treated plywood, a material that degraded when subjected to the heat of the attic. In the 1980s, polybutylene pipe was widely used, but it experienced leaks at the connections. In the 1990s, builders used a product new to residential construction called EIFS (exterior insulation and finish system), in which foam panels were installed on the outside of the home and covered with a stucco-like finish. Because some installation requirements were not followed, many leaks occurred that caused significant moisture damage to homes.

In each case, the use of a product in the home resulted in a failure with significant litigation and liability consequences, fueling builders' hesitation to embrace innovation. In some cases, the opinions of other parties to the homebuying process also may influence the decisions that builders and purchasers make. REALTORS®, inspectors, appraisers, friends, and neighbors all can influence those decisions.

Housing Innovations

To whet the appetite for a more thorough examination of housing innovations, this article now examines notable examples, from the ground up. This discussion is not intended to be comprehensive, nor does it suggest that each innovation might be incorporated into a single home.

Foundations

Traditionally, basement foundations have been constructed with concrete blocks or cast-in-place concrete. When these materials are installed in the field, the foundation walls are often inconsistently sized and must be corrected later during construction. A correctly sized and square foundation is critical if a builder is using components (such as modular or panelized construction) that do not lend themselves to field adjustments. Once the foundation walls are completed, later construction must address any foundation inadequacies. When using an innovation such as precast concrete basement wall panels, the builder excavates the basement, installs the underground utilities, and uses a crane to set the panels on a gravel bed. After aligning the walls (which are precast and cannot end up the wrong size), the builder connects them and places the concrete floor slab. While the cost of this method is comparable to other foundation methods, the speed of construction is faster. Because they are precast under factory conditions, the high-quality panels are strong and moisture resistant. After the excavation and site preparation (which take the same amount of time as with traditional methods), the builder can set the wall panels in less time than it takes to assemble forms for a conventional basement wall. A builder may be able to gain several days through this process.

Housing built on slab (without basements) is common across the country. In many areas foundations must extend below the frost line (the depth where the ground freezes), requiring builders to dig several feet down and then fill the trenches with concrete. Because excavation and concrete are expensive, innovators developed a construction technique called a frost-protected shallow foundation. The technique reduces footing depth by insulating the outer wall. This method allows the home to recapture heat lost through the floor slab and "raises" the frost line, allowing for shallower footings. The use of frost-protected shallow foundation technology enables builders to produce homes with a greater portion of the construction cost dedicated to living space. The ToolBase Web site (sponsored by PATH at www.toolbase.org) estimates that frost-protected shallow foundations can reduce the cost of foundations by 15 to 20 percent, with actual savings reported up to $4,750 over the cost of conventional foundations.

Walls and Floors

Historically, most homes have been built with masonry or light-frame wood. Other specialized systems—such as log, timber frame, straw bale, and adobe construction—have been used, but they have never received any degree of acceptance in the market.

The traditional method for constructing walls in a light-frame home involves assembling site-built wall panels on the just-built floor. After framing the wall panels and attaching sheathing to the exterior side, the builder tilts the panels and nails them in place. After constructing the next story and the roof and making the home weather tight, the builder installs wiring and insulation. During this process the interior of the home may be exposed to the weather, resulting in moisture infiltration and warped lumber and leading to problems such as mold.

Wall panels constructed off site can address many scheduling, speed, and moisture issues. With a number of approaches available, many builders have elected to replace on-site panel construction with a panel assembly method using structural insulated panels (SIPs) or wood-framed panels.

A SIP is a sandwich of insulating foam covered with oriented strand board sheathing. A SIP's insulating value (R value) can provide significantly more energy efficiency than a conventional wall can. SIPs typically are produced with foam cores ranging from 4 to 10 inches (R-20 to R-50). During production, door and window openings and utility chases are installed in the panels. On site, the builder need only connect the panels and install the utilities, drywall, and exterior siding.

The use of wood-framed panels is an approach that does not change the materials, labor, or tools normally used in wall installation. Wood-framed panels are conventionally framed wall panels with lumber and sheathing built at an off-site location. Following installation, the builder installs the utilities, insulation, drywall, and exterior siding.

As an alternative to framed or panelized walls, builders can build walls with insulating concrete forms (ICFs), a stay-in-place concrete insulating and form product. Most ICF forms have about 2 inches of foam on each side. The forms are stacked and filled with concrete. Builders save time using ICFs because the easily assembled concrete wall forms remain in place as the home's insulation. Homeowners value ICF homes because the technology provides disaster resistance (a solid concrete wall) and energy efficiency. Because the walls have a 4- to 6-inch concrete core, ICF walls are very quiet. Builders now use ICFs in about 5 percent of all exterior walls. Some communities building HUD-funded homes construct ICF homes as their normal homebuilding strategy.

A number of innovative technologies have improved walls and floors. Historically, structural materials for walls and floors have been dimensional, such as 2 by 4 (or larger) lumber. If spans for floor systems were too long to be supported with lumber, builders were forced to use steel beams or support columns. With interest in larger, more open spaces in homes, use of support posts or load-bearing walls is no longer an accepted alternative. Today, builders have a variety of alternatives to dimensional lumber such as open-web joists, engineered lumber I joists, light-gauge steel, and solid engineered lumber. Although it has taken more than 20 years for such engineered products to be widely accepted, engineered structural products are now well received. Builders benefit from using these products. The materials are significantly lighter than steel beams (eliminating the need for a crane), can be cut in the field, and often provide openings for installing utilities.

Plumbing

Innovation has provided alternatives to the conventional copper water supply and cast iron waste pipes used in homebuilding. In addition, new products have changed the design and construction of residential plumbing systems.

Water supply piping was once predominantly copper. Alternatives such as polyvinyl chloride (PVC) or cross-linked polyethylene (PEX) now are widely used. Both materials are more easily (and affordably) installed and, in the case of PEX, have the potential to reduce water waste and reduce the potential for leaks. Because PEX tubing is flexible and comes on long rolls, it requires fewer connections. These joints are accessible, making any potential repair easier. PEX is typically used in a "home-run" configuration with a single PEX tube delivering water to an individual water-using appliance. The PEX tubes start at a plumbing manifold with hot and cold valves for each tube. Because the tubes service only a single appliance, very little water pressure or flow variation occurs when multiple flows are started. Because most PEX tubing is smaller than copper piping (3/8 inch vs. 1/2 inch), homeowners spend 50 percent less time (and waste 50 percent less water) while waiting for hot water. This saves energy and conserves water.

The vent lines in a home's waste lines are designed to equalize pressures and prevent sewer gasses from entering the home. Vent lines are required by the building code. Residential waste lines connect to the sewer system; the vent lines penetrate the home's roof and exhaust into the atmosphere. For many homes, the air admittance valve (AAV) provides an attractive alternative for many direct vent requirements and roof penetrations. An AAV is a one-way valve, about the size of a soda can, that attaches to the waste lines under a sink or in another accessible space. As running water in the waste line creates suction, the AAV draws a small amount of air from the home into the waste pipe, equalizing the pressure and preventing the suction from drawing water out of the trap under the sink, which would allow sewer gasses to enter the home. Highly reliable, AAVs help builders save labor and materials by reducing the number of vent lines and making residential utility systems less complicated. AAVs also allow for plumbing fixtures on islands or other areas where vent installation would be difficult or costly. AAVs have been used for a number of years in the United States and are accepted by the building code.

Tankless water heaters provide significant benefits for all homes. These devices are high-capacity water heaters that save energy by heating water only as it is used. The amount of energy a conventional water heater uses in "standby" mode frequently is estimated at more than 30 percent of its total energy use. The size of a small roll-behind suitcase, a tankless water heater can be easily hung on a wall close to the point of use. This mounting saves energy and water; it reduces the length of hot water lines that must be flushed of cooled water.

Inside the home, water saving technologies include low-flow fixtures and low-flush toilets. Although homeowners experienced problems with low flush-toilets when they were first introduced, newer low-flush toilets perform well. Outside the home, xeriscaping offers significant water savings. This landscaping technique emphasizes the use of irrigation-free plants and drip irrigation. Xeriscaping prevents waste by delivering water directly to the plants.

Heating, Ventilating, and Air Conditioning

Today, most new home heating, ventilating, and air conditioning (HVAC) systems include a furnace and air conditioner or a heat pump that provides heating and cooling. Older homes often have furnaces or boilers for heating and window units for air conditioning.

While central air conditioning systems have great capacity to dehumidify homes, selecting the correct size is critical, particularly in energy-efficient structures. Working collaboratively with the Portland Cement Association, PATH has developed a refined model for sizing air conditioners in concrete homes, which are particularly energy efficient.

Newly developed air conditioners can operate at multiple speeds, matching the unit's cooling output to demand. Heat pumps can now operate in a wider range of climate conditions. Because the devices typically use the outside air as a source of heat and cold, the extreme days of summer and winter can affect the performance. By using a heat source that remains at a stable temperature (the soil well below the surface), the heat pump works more efficiently. As a result, heat pumps can now be effectively used in both warmer and cooler climates.

Ventilation, which controls moisture in the home, is as important as temperature control. Homeowners want the option to ventilate their homes with fresh air, and modern, energy-efficient homes may require additional fresh air to maintain a healthy environment. Ventilation innovations include extremely quiet exhaust fans (either in the room or in-line fans at a remote location) and delay switches that cause the fans to run for predetermined periods. People are more likely to use a quiet fan. Delay switches allow the fans to run longer to exhaust moisture; the switches also ensure the fans are turned off after use.

Demand is increasing for radiant heating. This technology heats floors with warm water (or electricity,

in some cases) and the warmed surface subsequently heats the room. Recent investigations indicate that homeowners value radiant heat because of the even distribution of heat and the cleanliness of the system. Because air is not forced through ducts, dust is not distributed through the home, and room temperatures remain stable. Homes heated with radiant heat may still require duct systems for air conditioning. Recent evaluations indicate that radiant heat has about the same energy costs as conventional heat but is much better received by homeowners.

Roofing

Roofing has not undergone dramatic changes. Instead, incremental changes have improved existing roofing products. This evolution may be due to the highly visible nature of residential roofs; radical visual changes are unwelcome. Roofing innovations include more-durable materials that resemble traditional materials. For example, builders may use highly durable "artificial" slate made from recycled materials, architectural style asphalt shingles that offer longer service life and more wind resistance, and concrete roof tiles that substitute for clay tiles.

Some innovative roofing products are beginning to grow in market share. These products include steel shingles that look like wood shakes, roofing made with metal panels, and roofing with built-in photovoltaic energy cells.

The newer products provide greater durability and improved disaster resistance. In some cases, the products also decrease costs because the roof frame does not have to support as much weight.

Interior Treatments

New flooring material options include bamboo and cork. Both materials are sustainably harvested products and provide increased durability or comfort. Bamboo is strong and wears well, while cork provides cushioning under foot.

With increasing awareness concerning the need for clean air (both indoors and outside), volatile organic compounds (VOCs), associated with "fresh paint smell," have been identified as contributing to air quality issues. As a result, paint manufacturers now produce low-VOC paints and no-VOC paints.

Modular Construction

Modular construction is built to the same local construction standards (building codes) as conventional construction, but the individual elements are assembled in factory settings into large, nearly complete components frequently called "boxes." Modular construction is separate and distinct from manufactured (HUD Code) homes. The boxes are delivered with exteriors finished and all interior treatments (drywall, windows, doors, cabinets, carpet, and paint) installed. Homes often use four or more individual boxes. Because most of the construction process occurs before boxes are delivered to jobsites and homes are subsequently quickly assembled, modular construction presents tremendous opportunities for infill construction in urban areas. The home site progresses from a completed basement or foundation to a virtually completed home in just a few days. Because the home is not exposed to the elements during construction, the walls, floors, and lumber remain dry and are less likely to experience moisture problems. Advantages of the modular construction process include the factory setting for construction, the established quality systems, protection from the elements during construction, and the availability of lifting equipment to ease the physical labor of construction.

Energy Conservation

Innovations developed to conserve household energy include materials such as high-efficiency windows and insulation and products that use less energy. New energy-saving materials include spray-foam insulation, products made with recycled materials such as sprayed-in cellulose insulation, and windows with thermal coatings.

Building homes that include large ENERGY STAR® appliances such as furnaces, water heaters, and air conditioners (which consume about 65 percent of the energy a newer home uses) can provide real savings to the homeowner.

Barriers to Innovation

Well-documented barriers to innovation are often cited as reasons for the sluggish market penetration of most innovations among homebuilders.

Regulatory Barriers

Before a product is approved for use in construction, the manufacturer must demonstrate that it conforms to the appropriate building code. During construction, the local government performs reviews and inspections to ensure the products are being assembled correctly. These requirements help prevent materials or construction failure. As a result, they protect homeowners' safety and help maintain the quality of homes constructed with a given product.

Yet, failures in the approval process can create regulatory barriers. One widely reported barrier occurs when a local building code official denies a builder permission to use products that comply with the relevant building code. The code official may not be familiar with the products and requests additional information from the manufacturer, testing labs, or others. Instead of delaying the project, the builder may select a more "palatable" product. Or, the builder may retain an engineer or architect to review the product and certify its conformance with the building code. This substantial expense ultimately is passed on to the homebuyer.

Trade Contractor Availability

Many builders struggle to find contractors with the experience or desire to install a new product. The reasons for the scarcity of trade or specialty contractors include (1) requirements for the purchase of new equipment to install the new product, (2) training employees to install the new product, (3) perceived liability or performance issues, (4) increased product costs that may increase bids from the trade contractors, (5) lack of manufacturer support, (6) and more "hand holding" following installation. As a result, many trade contractors choose to wait until the technology is widely accepted before adding it to their offerings.

Builders' Willingness To Innovate

Builders retain significant liability when they complete a home. Because of their contractual role in the project and their visibility, builders are often identified if anything goes wrong in a home. For many small builders, the potential liability greatly exceeds the amount of their profit. As a result, risk aversion among builders may reduce the use of technologies in the home.

HUD Activities

The PATH program at HUD focuses on strategies to improve the penetration of innovation in housing. PATH approaches this challenge by sponsoring basic research, facilitating applied research, conducting field evaluations of available technologies, identifying strategies, and providing information to builders and product manufacturers. PATH's Technology Roadmaps describe research needs to advance the use of innovative technologies in housing. Technology Roadmaps have been developed for Energy Efficiency in Existing Homes, Whole-House and Building Process Redesign, Manufactured Housing, Information Technology, and Advanced Panelized Construction. These roadmaps help to describe a collaborative vision for research to advance technologies in the topic areas.

In many areas, innovative building products are difficult to find. To help builders and homeowners, PATH lists many innovative products in the PATH Technology Inventory. This information service is found on the ToolBase.org Web site (www.toolbase.org). It describes the technologies, discusses costs and benefits, and provides information to locate manufacturers.

PATH has conducted research to better understand how innovations are valued in the homebuilding process. The following two reports on that subject are available on the PATH Web site (www.pathnet.org):

Building Industry Roundtable—Housing Innovation and the Appraisal Process. http://www.pathnet.org/si.asp?id=554.

Measuring and Assessing the Consequences of Technology and Innovation for Affordability of Housing: Proceedings of the NIST-PATH Workshop, National Institute of Standards and Technology Report NISTIR 7064. http://www.pathnet.org/si.asp?id=957.

Realtors and Appraisers

REALTORS and appraisers rely on the recent activity of the residential real estate market. These professionals' home value assessments reflect what the market just did, not what it should (or could) do. As a result, innovative technologies may be perceived as worthless until the market values them. Faced with this chicken-egg conundrum, REALTORS and appraisers level with their clients and report that, for example, a highly durable roof provides virtually no additional value to the home.

Summary

Integrating innovative technologies into housing can be a daunting task. Because builders must keep projects moving, product acceptance difficulties or delays frequently force them to abandon efforts to use new technologies. These barriers can be overcome through training, information, and in many cases, time. Information is a key factor that can accelerate the integration of new technologies into residential housing. If homebuyers and others in the homebuying process desire (and require) homes with specific technologies, builders will find a way to incorporate those innovations into their products.