Concept Home Principles -

Alternative Basic Materials

Research Summary

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Background

Recent advances in science and manufacturing have resulted in a wider range of basic chemical, physical, and biological materials than at any other time in history. Given the wide array of products and systems that comprise modern housing, many of these emerging basic materials have the potential for application in the home building industry. This report explores a range of materials that enable other Concept Home principles.

Alternative basic materials are a key consideration because they have historically driven innovation in every industry, and could spur significant advances in today's housing. In order to gain acceptance, however, basic alternative materials must offer more benefits than the traditional material or system they replace. They must reduce costs, increase design flexibility, enhance sustainability, perform multiple functions, have superior performance characteristics, or meet a market niche. Another potential driver for adopting alternative basic materials is a shortage of existing natural materials or concerns about their long-term sustainability.

In recent years, shortages of core natural resources, including lumber, steel, and gypsum, have driven construction costs higher. This volatility of supply and price motivates the industry to look for more sustainable solutions. Sustainability and resource shortages, in fact, will help to drive innovations in the future. Growing support for the use of sustainable resources is evident when building certification programs, such as Leadership in Energy and Environmental Design (LEED), credit the use of resource-efficient materials in homes. Research programs within schools of architecture and engineering, such as the Massachusetts Institute of Technology (MIT), are focusing many of their efforts in this area, as well.

Metal house by Lustron Homes, circa 1940
Image Source: IQ Home, Consumer Reports, 1948

Historically, manufacturers—in coordination with architects and builders—have driven the use of alternative basic materials, as evidenced by a series of World's Fair Houses and other demonstration homes through the mid-1900s. For example, at the 1933 Chicago World's Fair "Homes of Tomorrow" exhibition, Good Housekeeping and the Stran Steel Corporation demonstrated a house built primarily from iron and steel. The house was largely prefabricated, fireproof, and affordable to average Americans ($7,500).

In the 1940s, Lustron built demonstration homes that were almost entirely constructed from steel. Today many remain in good condition with their original metal siding, roofs, and interior panels. The Lustron homes were prefabricated and designed to be efficiently delivered and erected on site. The homes also were marketed as an affordable housing option with price targets around $8,000.

Beyond metal materials, in 1957 Monsanto and MIT teamed to build the all-plastic Disneyland Monsanto House. The structure, interior walls, and even the furnishings and rugs were made of plastic. The designers envisioned it as the house of 1986, and boldly proclaimed that they "temporarily have gone ahead rather than merely kept the traditional two paces behind the housing needs and desires of Americans" (Wasserman, 2002). The materials for this home were estimated to cost between $7,500 and $15,000, and were promoted as rot-proof, durable, lightweight, and easy to disassemble and reconstruct elsewhere.

For all of the virtues of these efforts, only a few technologies were actually adopted by the home building industry and most never achieved high market penetration. While demonstrations and prototype homes have been received with fascination and interest, consumers generally have returned to more familiar choices when considering their own housing options. Builders, meanwhile, are averse to the liability risks associated with trying new materials and cite a lack of demand for their use. As a result, the industry continues to over-rely on traditional materials, despite supply issues and the limited prospects for innovation that they offer. Armed with lessons from the past, the PATH Concept Home is driven not by materials themselves, but by understanding how the materials can better meet consumer needs and desires.

While consumers typically do not directly demand basic, or *core*, materials, many currently available materials meet their desires for high quality, durability, comfort, sustainability, and ease of maintenance. For instance, some of the window coatings in this report have the potential to reduce glare and fading, while increasing comfort and enabling more efficient HVAC systems. Sustainable products made from recycled plastics and combined with sawdust, fly ash, and other waste products form composite materials that can be used for decking, trim, and other uses. Many of these products have progressed into the mainstream because they provide a more sustainable and lower maintenance option; Trex®, made from reclaimed hardwood sawdust and recycled polyethylene plastic, is one such material.

More visionary alternative materials that are still in the research phase include intelligent materials, fabric technology, and moisture-control materials (U.S. Department of Energy (DOE)). For instance, a promising material combining fabric technology and intelligent materials is MIT's Smart Fiber (web.mit.edu/bt/www/bt/bm_inc.html). Smart Fiber has optical glass fibers woven into architectural fabric. The material can monitor the health of a structure during construction and, over its lifetime, from a remote location.

The Importance of Technology Transfer

Applying innovative materials to home building requires an element of new material development, but technology transfer from other industries presents major opportunities for innovation.

"Tech transfer" for home building requires searching beyond the traditional confines of the industry and exploring what is possible using materials originally developed for automobile, aerospace, or military applications, for example. This model has brought materials such as plastics, Velcro, and titanium to the consumer marketplace.

Borrowing technologies from other industries, however, requires more than just combining new materials with traditional systems. For example, photovoltaic (PV) cells for on-site electric generation have been used in houses by simply applying them to existing, traditional materials. But when PV is actually integrated into a product to form a new type of material, it can result in a multi-functional building system with better overall performance and innovative new material properties.

Applications, or *composites*, of alternative materials such as structural insulated panels (SIPs) combine structure and insulation in one element, and enhance sustainability because they are formed from small diameter, fast growth lumber. They also provide reduced construction cycle time since large, prefabricated panels can be quickly craned into place on site. SIPs construction still represents a small share of the overall market, but is becoming more accepted by builders and consumers as they view it in demonstration homes such as Sarah Susanka's "Not So Big House" at the 2005 International Builders Show, and in prototype houses like the "Now House" by Clever Homes in San Francisco. In fact, *Better Homes & Gardens* is currently building a SIPS demonstration home, based in part on survey feedback it received from nearly 60,000 readers expressing what they want in a home.

The alternative materials, both *core* and *composite*, discussed in this report are market-ready or close to being market-ready. They provide flexible design solutions with superior performance and may combine multiple functions currently accomplished through several individual systems. This illustrates the enabling effect that alternative basic materials has on the other Concept Home principles, and underscores the importance of new materials as a pathway to innovation.

Performance Objectives

The objective of alternative basic materials is to develop new materials that spur innovation by serving multiple functions, increasing cost-effectiveness and efficiency, and using more sustainable materials. In many cases, these technologies form building systems that enable other Concept Home principles such as integrated functions, floor plan flexibility, and improved production processes. Alternative basic materials consists of core technologies that manufacturers can use to create products or systems and composite systems that builders can purchase and use to build homes.

Supporting Technologies

The range of alternative materials that can be considered for home building applications is enormous, given the quantity of products that make up modern houses. The cross-section of alternative materials highlighted in this report is not all-inclusive, and is intended to illustrate a variety of materials under development, along with potential applications. The materials discussed are at various stages of development, from basic "core" materials without defined applications to emerging "composite" materials formed into building products. And while specific applications for these materials may emerge as the material properties are refined and better understood, at this point they can be loosely categorized as Core Technologies and Composite Technologies.

Core Technologies

Alternative materials categorized as core technologies have the potential for application as films, coatings, or additives to other materials to create high-performance products or systems. By applying or adding the core material to another product, manufacturers can enhance the overall properties of a building system. In many cases, core technologies enable stronger, more durable, more sustainable, or more energy-efficient systems. The examples that follow highlight such technologies and their potential applications for building products and systems.

Heat-Reflecting Powders

Shepherd Color Company is the developer of the ARCTIC brand of infrared reflective pigments. The powdered pigments, which are designed to reduce temperatures on surfaces to which they are applied, can be added to paints, plastics, and other materials to give them a custom color. Unlike other products designed to reduce heat build-up, the color is not limited to white. According to the manufacturer, the ceramic pigments reflect infrared light and exhibit greater total solar reflectance than the same color made with conventional pigments. Thus, substances with the ceramic pigments are able to maintain lower temperatures than conventional surfaces.

Vats of Heat-Reflecting Powders
Image Source PATH (www.pathnet.org)

The manufacturer states that the benefits of a "cool" color roof include increased durability, significant energy savings, and reduced urban temperatures and air pollution. ARCTIC pigments are incorporated into roofing materials that qualify for an ENERGY STAR® label, a standard backed by the U.S. Environmental Protection Agency (EPA) that identifies superior energy performance. Some states and municipalities have recognized the advantages of cool roofs and now offer incentives or rebates for implementation, while others have written reflective roofs into their building codes.

Glass Coatings for Selective Infrared Reflection

A glass coating technology that can selectively "know" when to reflect infrared rays based on ambient temperature was recently highlighted in Discover Magazine (Webb, 2004). This smart-glass technology can be designed to deflect the sun's warming infrared rays at times when cooling is needed, and to allow them to pass at other times when they are beneficial.

The glass coating relies upon vanadium dioxide molecules doped with tungsten to form a layer that selectively reflects infrared rays. At low temperatures, vanadium dioxide is transparent to infrared. As the temperature rises, the bonding between the molecules changes and the material becomes reflective, like a metal. The amount of tungsten determines where this change occurs; a two-percent mix makes it happen roughly at a comfortable room temperature. Researchers hope to overcome the coating's yellow-brown tone, which is unappealing to builders. They estimate that intelligent-glass windows could be on the market within five years, costing about 20 percent more than the ordinary kind. Given the ability to reduce heat gain through glazing, this technology could offer significant energy savings through reduced air-conditioning costs.

Electro-Textiles

Electro-textiles are conductive materials that are woven or integrated into fabrics. These fabrics offer alternatives to the data and power transmission methods currently in use. Electro-textiles can be used to produce such diverse and imaginative applications as roll-up keyboards, jackets that interface with your mobile phone or PC, a television remote control sewn into the arm of a sofa, or light switches embedded in curtains and carpets. Electro-textile technology already exists to transmit data and small power requirements.


Electro-textile fabric with USB connectors
Image Source: PATH (www.pathnet.org)

In the context of housing, the possibility exists to develop electro-textiles to the point where systems that depend on wiring can be taken out of the wall cavity and integrated into the surface of finish materials. For retrofit applications, electro-textiles could offer an alternative approach to providing new electrical and communications wiring. For example, wiring for new lighting or audio systems could be surface applied with an electro-textile as opposed to fishing new wiring through a wall cavity. Likewise, with integration into carpets or other materials, creative and flexible designs could be created that allow for the movement of communications and other equipment without the need to install and rout separate wiring. These applications support the Concept Home ideas of flexibility and access to utilities.

Nano-Materials

Nano-materials contain thousands of atoms, rather than the millions or billions of atoms in particles of most conventional materials. They are materials with structural features, such as particle and grain sizes, in the range of 1-100 nanometers (nm) (1 nm is one millionth of a millimeter). For comparison purposes, the average width of a human hair is 100,000 nanometers, while a single particle of smoke is 1,000 nanometers. Nanostructures can be obtained in a variety of materials including metallic, ceramic, semi-conductor, and diamond. The examples below explain different types of nano-materials that could potentially be used to produce building products that are harder, stronger, and more durable.

Nano-coatings are produced by combining elements at the molecular level to form a denser product. One end result is a coating that can be applied to a material to make it stronger and more durable than in its original form. Reducing the molecular structure improves nearly all of the mechanical properties of the material, including yield strength, tensile strength, fatigue strength, and elongation. One downside is that nano-coatings can experience decreased ductility relative to the original coating material. However, current research is focusing on developing nano-coatings that have high strength and durability, while retaining their ductility.

Nano-coatings initially were designed to be applied to steel and other conductive surfaces using electro-plating processes. But further developments have provided a variety of uses and designs for nano technology. Some coatings are made of self-assembling monolayers (SAM), which are thin, one-molecule layers spontaneously formed by a substance. SAM coatings have many applications, from scratch-resistant coatings for glass to self-cleaning surfaces. Other coatings are applied as spray-on coatings or as powders that are added to composite materials to enhance the physical properties of the base material. Still other nano-coatings are used to increase the efficiency of solar panels by resisting composite and material build-up on the panel facing.

Nano-Ceramics are a type of nano-material with nanometer-sized particles embedded in a matrix that contains a large volume of material at the component interface due to the small particle size (some fibers developed are smaller than a DNA molecule). It is generally recognized that the smaller diameter fibers are more effective in strengthening ceramics, metals, or plastics. The University of Delaware has a U.S. Army-funded Center for Composite Materials. One of their objectives is to develop nano-ceramics for high-strain conditions.

Nano-Structure Metals and Metallic Glass. With this technology, the structure of metal or glass material is denser than traditional forms of the same material. Johns Hopkins University is working on high-strength nano-structure metals. The Defense Advanced Research Project Agency's (DARPA's) Structural Amorphous Metals program (see www.darpa.gov/dso/thrust/matdev/sam/index.html) and the NanoSteel Co. (see www.nanosteelco.com) have conducted extensive research regarding the production and use of bulk and sheet-steel materials.

A range of possible properties for nano-structured metals exists, including a steel material with the hardness of alumina ceramics and the strength of carbon-based fibers. Other potential attributes could include higher strength-to-weight ratios than titanium alloys, superior corrosion resistance over nickel-based alloys, and significantly increased weldability. One issue with nano-structure metals is that the higher strength and durability creates low ductility. Johns Hopkins University is working on lower strain-hardening technologies to help combat this characteristic.

Johns Hopkins University also is developing metallic glass composite materials for anti-armor applications. This would result in a material that is impact resistant and has extremely high strength. Possible applications include kitchen and bath fixtures, flooring, or advanced panel products.

Soy-Based Roof Coatings

The United Soybean Board recently funded a research project on soy-based roof coatings conducted by Niemann Laboratories of Chicago. The resulting product of this research came to be known as the Natural Bitumen Jacket (NBJ), a bright white product applied over bituminous substrates on flat-roofed buildings. More recently, the product was commercialized and promoted nationally by Green Products LLC (see www.greenproducts.net). The commercialized product is referred to as the Environmental Liquid Membrane System (ELMS), and is targeted for low-slope industrial/commercial roofs.

In terms of performance, ELMS significantly reduces the amount of energy absorbed from intense sunlight. Due to its ability to reduce the temperatures on the roof, the coating has gained an ENERGY STAR label.

Workers coating a roof with ELMS from Green Products LLC
Image Source: www.greenproducts.net

The resin system is formulated to provide significantly greater life and durability compared to elastomeric acrylic products. It can be applied by brush, roller, or spray applicator. The manufacturer makes the claim that it is 100 percent waterproof and, because of its excellent adhesion and flexibility, prevents UV-rays from drying and cracking underlying roofing material, which can add years to the life of a roof. The durability and energy-saving benefits of these roof coatings could lead to products that enhance the durability and energy performance of residential buildings.

Advanced Products Derived from Soybeans

The United Soybean Board publishes the *Soy Products Guide: A Listing of Soy Industrial Products,* and also compiles a searchable list of contacts for these products on their Web site (see www.unitedsoybean.org). This list contains several products that are under development for the building products arena, including:

- BioBase 1702 – A dense, closed-celled spray foam designed to insulate commercial and residential buildings (www.biobased.com)
- BioBase 501 – An ultra-low density, open-celled spray foam designed to insulate commercial and residential buildings (www.biobased.com)
- HealthySeal 500 – Spray-in-place foam insulation that is a two-part, open-cell product that is virtually nontoxic, with no harmful emissions, and complies with all building codes (www.unitedsoybean.org/what_nu_company.cfm?ID=28
- AgriStain for Fiber Cement – Can add the rustic look of wood to a home with fiber-cement siding and can be applied by painter's pad or by spraying and ragging (www.newcenturycoatings.com)

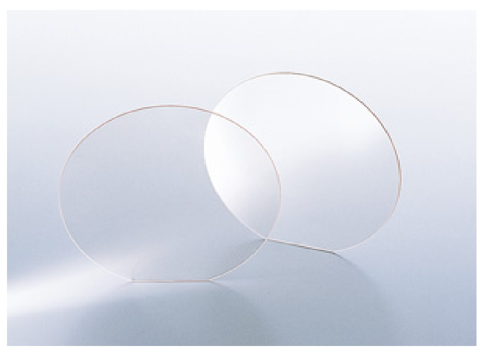
- Dow BIOBALANCE Polymers – Replaces a portion of the system required to make polyurethane carpet backing (cushioned and non-cushioned) (www.dow.com)
- EnduraTite – Open-cell spray-foam insulation, offered as a key component to a soy-based spray-in foam system (www.enduratite.com)
- Natural Environmental Barrier – A waterproof encasement coating for heavy metals and asbestos. NEB serves not only as an architectural coating for exterior building structures, but also as a tank and vessel coating and waterproofing agent for structural steel (www.greenproducts.net) (also see section on *Soy-based Roof Coatings* above)
- Soy Therm – Rigid-foam insulation for commercial and residential use, density of one-half pound per cubic foot. (www.soyoyl.com)
- SoySeal – Sealer for all wood, decks, and docks. Spreads water, emits no VOCs, nontoxic, nonflammable and biodegradable (www.soyclean.biz)

Transparent Ceramics

Transparent ceramics have gained attention over the past several years for their increased clarity and strength characteristics. One application under development by the Army Research Laboratory (ARL) is a transparent ceramic material for military armor applications. The materials exhibit enhanced thermal and mechanical properties while maintaining clear vision. The Army envisions a wide range of end use applications to include face shields, windshields, and windows. Beyond these applications, there also are numerous commercial applications for this technology, such as combined glazing and structural panels in the housing market.

Ceramics typically are opaque because their trapped pore structure scatters light. Transparent ceramics are manufactured with minimum porosity, resulting in the transmission of clear images. However, current materials of this type are prohibitively expensive, using today's production methods. ARL estimates more advanced single-crystal and polycrystalline materials will reduce the weight of transparent ceramic materials by 30 percent and thickness by 40 percent.

Murata Manufacturing has developed a transparent ceramic product called LUMICERA. Casio uses the LUMICERA as a lens for some of their digital cameras in an attempt to find better ways to create smaller and thinner cameras. The use of transparent ceramics allows for a significant reduction in the profile of zoom lenses. Not only is the refractive index of the LUMICERA much greater than that of optical glass, it also offers superior strength. Through recommendations by Casio, the ceramic material has been refined for use in digital camera optical lenses by endowing it with improved transmission of short wavelength light and eliminating pores (air bubbles) that reduce transparency.



Transparent Ceramic Lens
Image Source: Murata Inc. (www.murata.com)

Composite Technologies

Composite technologies combine one or more innovative core materials, and sometimes traditional materials, to create building components or entire systems. Depending on the particular system, various material properties are combined, such as thermal resistance, structural properties, or sound transmission, to form a single material that builders can use to accomplish multiple functions. The examples that follow highlight composite technologies that enhance building system performance.

SmartWrap™ Building Membrane

SmartWrap™ Building Membrane is a micro-thin composite that replaces the traditional components used in wall systems. SmartWrap™ integrates a collection of innovative technologies that provide multiple functions. Designed by the architecture firm of Kieran Timberlake Associates, SmartWrap™ is a composite material made of several layers, including a polyester film substrate, printed layers, and laminated layers, all of which are roll-coated into a single composite film. By incorporating several different technologies that are printed on or adhered to the substrate, this composite provides the functions of insulation, protection from wind and rain, lighting, power generation, and even information display.

Key technologies in SmartWrap™ include:

- A polyester film substrate, which provides the function of wind and rain protection.
- Micro-capsules of phase-change materials that are embedded into a polymer resin and then extruded into a film. This material provides temperature moderation by absorbing, storing, or releasing heat as it changes state.
- Organic Light Emitting Diode (OLED) technology, which emits light when an electric current is applied, provides lighting and information display.
- Thin film silicon solar cells to generate power, which can then be used to power the OLED technology.

SmartWrap™ Pavilion on display at Cooper-Hewitt National Design Museum
Image Source: Kieran Timberlake Associates LLP (www.kierantimberlake.com/SmartWrap/)

The multi-functional design of SmartWrap™ offers potential benefits to several of the Concept Home principles, notably Improved Production Methods and Integrated Functions.

Acrylic Pressure-Sensitive Adhesive Tapes for Structural Purposes

The Center for Adhesive and Sealant Science at Virginia Tech is testing and evaluating the use of pressure-sensitive tapes in residential structural systems. Thus far, research has modeled and tested the performance of tapes for the construction of wall panels, with future plans to expand the program to other applications.

Scientists are currently developing a methodology for tape applications on construction sites. The tapes are suitable for many substrates and can be hand applied without the use of special equipment. The thickness of the adhesive typically ranges from five to 55 millimeters and the tape widths can range from one-half inch to almost one foot. This provides enough coating area to establish secure bonds on uneven or irregular surfaces. Estimates of connection longevity are not readily available at this time. Pressure-sensitive tapes for structural applications offer potential production benefits by reducing the number of required metal connections (i.e., screws, nails, and ties) necessary to retain structural integrity.

Structural Acrylic Pressure-Sensitive Adhesive Taping
Image Source: MACtac (www.mactac.com)

Light Transmitting Concrete

The basic material of concrete has existed for centuries and is thought to be the world's most popular and widely used building product. It is a cost-effective, high-strength, and durable material that is relatively easy to work with. However, the interior of a concrete building tends to be rather dark and heavy in appearance. In an effort to transform this appearance, a Hungarian architect has combined conventional concrete with optical fiber to create a new type of concrete that transmits light.

A light-transmitting concrete product called LiTraCon™ is currently under development and should be available for sale in prefabricated blocks by the end of 2005 (Graydon, 2004). Parallel glass fibers are embedded into the concrete to form a matrix that can display a view through wall panels to the outdoors. As shadows,

Light Transmitting Concrete
Image Source: LiTraCon™ (www.litracon.hu)

Image Source: www.optics.org

and even color, are transmitted through it, the light-transmitting concrete can create a much different type of environment than traditional concrete walls. Further, beds of lighting can be incorporated with the material, allowing lighting to transmit through the concrete when desired (e.g., lighting an outdoor courtyard at night from below the LiTraCon™). LiTraCon™ is claimed to offer the same strength as traditional concrete and is likely to target the commercial and industrial markets once the concrete panel manufacturing process has been optimized.

Engineered Wood Products

While the main focus of this research summary is the development of alternative basic materials, a few examples of innovative applications of alternative materials are also included in the section below. These examples illustrate the eventual application of new materials to specific applications within the home building industry.

New developments in engineered wood products have led to materials that are more versatile, resource efficient, and capable of spanning longer dimensions. These engineered materials lack defects, inconsistencies, and other stresses commonly seen in solid sawn lumber.

Weyerhaeuser TrusJoist™ (www.trusjoist.com) has several engineered wood products currently available to the residential construction industry. Timberstrand Laminated Strand Lumber (LSL) is used for wall systems, beams, and headers. It has the appearance of oriented strand board (OSB) (although all the strands are typically positioned in the same direction, OSB strand orientation is mismatched for panel strength), but the LSL dimensions are the same as sawn studs and headers. LSL provides the ability to design and construct walls up to 30 feet in height without twisting and shrinking concerns.

Wood I-joist with LVL flanges and OSB web material
Image Source: MaineSci (www.umaine.edu)

As the text box on the following page discusses, the overall use of engineered wood products in the home building industry has increased rapidly in recent years. While part of this growth is due to product development and process improvements, the example of Laminated Veneer Lumber (LVL) highlights that the pathway from innovative materials to a market-accepted product can take many years and also is influenced by external factors such as the price of competing products and shifts in resource supplies.

Fabric Ceiling System

As consumer trends shift to open space floorplans and an increased use of hard materials such as hardwoods and tile, acoustical performance is declining in homes. Noise dampening a home can be costly, and accommodating the addition of sound attenuation material can significantly alter the design of the home (e.g., ceiling depth). A Fabric Ceiling System has been developed that is designed to improve acoustical performance in any size room, including large rooms with hardwood floors and cathedral ceilings, or in rooms with little headroom, such as basements – without significantly altering the appearance or dimensions of the room.

The Quietzone™ Solserene™ fabric ceiling material from Owens Corning is a complete stretch-fabric system designed for residential ceilings. It consists of: 1) a durable, dimensionally stable textile fabric; 2) an integrated high acoustical performance glass fiber blanket; and 3) a fabric-retaining track. The system can be installed directly onto the framing in a ceiling structure or over existing gypsum board. During installation, the Solserene fabric is cut to length and stretched over the one-inch thick white glass fiber blanket using a series of perimeter tensioning tracks. The fabric is available in widths up to 16' 4" and carries an NRC (Noise Reduction Coefficient) of between .85 and 1.00. More information on the fabric ceiling system is available from www.owenscorning.com.

Kevlar Storm Room

DuPont Kevlar® is a silky, soft manmade fiber that is five times stronger than steel on an equal weight basis. It combines great strength with great lightness. Kevlar® is best known for its application in the field of bullet-resistant personal body armor. DuPont has introduced a "StormRoom®" concept that could use these

Market Growth of an Innovative Material - Engineered Wood Products

Over the past decade, the use of engineered wood products in the U.S. has grown at a rapid pace of roughly 250 million board feet per year. Several factors have led to the increased market growth, including higher prices for sawn-lumber products and changes in resource characteristics. Engineered products were relatively expensive in the past, but the rise in sawn lumber costs, as well as the increase in competition within the engineered wood manufacturing sector, has helped to decrease the gap between lumber and wood product prices. Tree harvesting practices also have influenced the emergence of engineered wood products. Harvesting practices have moved toward shorter rotation and the use of faster-growing, lower-quality tree species. Engineered wood products offer the industry an opportunity to add value to smaller, lower structural quality logs.

One such engineered product, LVL, has been a popular choice in construction as an alternative to large solid-wood or steel beams, girders, headers, and I-joists. LVL is generally manufactured using a process comparable to that for plywood, except for differences in wood grain orientation and the roll press process. The parallel grain orientation used to manufacture LVL allows the product to carry large loads over increased spans.

LVL, which was first used for airplane propellers in World War II, was initially developed as a building material in the late 1960s. LVL began to make an impact on the wood products industry in the late 1980s and early 1990s, due mainly to a shift toward composite materials within the industry. This shift was due in part to the greater resource utilization possible with engineered wood products and their ability to use fast-growing, small diameter trees. As a result, the use of products such as LVL and wood I-joists increased significantly. According to the Engineered Wood Association (www.apawood.org), LVL production has increased 360 percent since 1980, to an output of 86.3 million cubic feet last year. It is one of the fastest growing non-panel engineered wood products available today.

reinforced fibers in the residential building industry. Application of the Kevlar® reinforcing system to a room will protect it from penetrations due to wind-borne debris from a major hurricane or tornado.

In impact tests, the StormRoom® withstood repeated hits by a 12-foot long., 15-lb. 2x4 fired at windborne speeds greater than those seen in Category 5 storms. And though the StormRoom® is heavily reinforced, it does not affect the performance of a cell phone signal, so a call for assistance can be made from inside the room.

StormRoom®
Image Source: DuPont (www.dupont.com)

Typical construction for a StormRoom® includes walls made of a foam core and an interior sheathing of Kevlar®, sandwiched between two layers of plywood or OSB. The interior walls can be finished to match the rest of the home, and electricity and plumbing can be easily added.

DuPont has developed several pre-built configurations to be incorporated into new or existing homes, and setup requires less than one day (cost ranges from $5,000 to $10,000 per room). The StormRoom® also can double as an extra closet or powder room. The Kevlar® StormRoom® was integrated into the NextGen home on display at the 2005 International Builder's Show in Orlando, FL. For more information on the StormRoom, visit www.dupont.com.

Electrochromic Windows

Electrochromic windows are windows that can be lightened or darkened electronically and can provide privacy, daylighting control, and heat-transmittal control. When a small voltage is applied to an electrochromic window, it causes the glass to darken, resulting in a window that may look anywhere from transparent to opaque or shaded in appearance. This allows the homeowner to control the amount of light that passes through their windows directly with the use of an electronic control, or indirectly through the use of an automatic switch that changes the window from light to dark based on the amount on sunlight it receives.

Electrochromic window in its lightened state
(Image Source: NREL)

Electrochromic window in its darkened state
(Image Source: NREL)

According to PATH's ToolBase Program (www.toolbase.org), there are currently a variety of electrochromic technologies under development. These systems generally change the light transmittance characteristics of a window in response to certain environmental factors, but rely upon different technologies to do so. Two examples include:

- *A technology that is comprised of transparent outside layers of electrically conductive film with inner layers that allow the exchange of ions.* As voltage is applied across the outer conductive layers, ions move from one inner layer to another, which causes a change in the tinting. When the applied voltage is reversed the tinting fades to clear. This tinting effect results in a variable light transmittance that can range from five to 80 percent. This technology, which is under development by DOE's Lawrence Berkeley National Laboratory (LBNL), does not require a constantly applied voltage once the tinting of the window has been altered.
- *Suspended particle display (SPD) technology involves molecular particles that are suspended in a solution between plates of glass.* In their natural state, these suspended particles tend to move randomly and collide, blocking the direct passage of light. However, when electricity is applied to the particle field through conductive coatings on the glass panes, the particles align rapidly and the glazing becomes transparent. This type of switchable glazing, sometimes referred to a "light valves," can block up to approximately 90 percent of light.

Electrochromic windows have the potential to reduce heat gain and increase privacy in home settings, and are being explored for applications to automobile sunroofs and ski goggles. One manufacturer of the SPD technology also has patented a process to retrofit switchable glazing technologies onto tradition windows in buildings. According to DOE's National Renewable Energy Laboratory (NREL), electrochromic windows could reduce annual U.S. energy consumption by several quadrillion (10^{15}) BTUs.

Conclusion

A survey of current material development efforts reveals many innovations that could eventually lead to housing technologies that support multi-function products, adaptable systems, and other themes of the Concept Home. New basic materials are an exciting development because the unique properties they offer can spur innovation and new ways of thinking about building systems and their functions. The materials reviewed in this report will be considered in terms of how they can support the Concept Home designs and their innovations.

Bibliography

Ahluwalia, Gopal. *Homes and Home Buyers of Tomorrow*. NAHB, January 2005.

Army Research Lab, Aberdeen, MD. www.arl.army.mil/wmrd

Dillard, David. Virginia Tech Center for Adhesive and Sealant Science, Blacksburg, VA. www.cass.vt.edu

Graydon, Oliver. *Concrete Casts New Light in Dull Rooms,* March 11, 2004, Optics.org http://optics.org/articles/news/10/3/10/1 (site last visited June 2005)

National Renewable Energy Laboratory. Electrochromic Windows Research. http://www.nrel.gov/buildings/windows/ (site last visited June 2005)

Scanlon, Jessie. "The Smart Home," *Popular Science*. 2004. http://www.popsci.com/popsci/whatsnew/article/0,20967,1063919-1,00.html (site last visited June 2005)

U.S. Department of Energy. *Building Envelope Technology Roadmap* http://www.eere.energy.gov/buildings/info/documents/pdfs/envelope_roadmap.pdf

U.S. Department of Housing and Urban Development/PATH. "Finding New Ideas for Housing." *Technology Scanning.* Issue 3 (May 2004).

Wasserman, Nina. "Plastic Didn't Feel Like Home." *Newsday.* July 2002. as viewed on http://www.mindfully.org/Plastic/Monsanto-Disneyland-HomeoftheFuture.htm (site last visited June 2005)

Webb, Sarah. "Glass That Keeps Its Cool," *Discover Magazine*. November 2004. http://www.discover.com/web-exclusives-archive/glass-keeps-its-cool1124/ (site last visited June 2005)

Web Sources:

- www.greenproducts.net
- www.darpa.gov
- www.nanosteelco.com
- www.trusjoist.com
- www.unitedsoybean.org
- www.shepherdcolor.com
- www.dupont.com
- www.kierantimberlake.com/SmartWrap/
- www.mactac.com
- www.owenscorning.com