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# Assessment of Research and Technology Transfer Needs for Wood-Frame Housing

Kevin L. Powell  
David C. Tilotta  
Karen L. Martinson



## Abstract

Improvements to housing will require both research and the transfer of that research to homebuilders, homebuyers, and others in need of technology. This report summarizes results of a national survey on research and technology transfer needs for housing and prioritizes those needs. Survey participants included academicians, builders, code officials, government officials, homeowners, manufacturers, and others. In addition to determining overall priorities, research and technology transfer needs are also categorized into important priority areas for housing: construction, design, disaster, durability, environmental factors, fasteners and adhesives, inspection, materials, operation, maintenance and rehabilitation, and other areas.

Analysis of the needs for housing research and technology demonstrates great interest in, and high priority for, moisture and mold issues, wood preservation and related fastening technology, and development of standardized inspection and installation procedures for materials and products. Priorities identified in this study will be used by the Forest Products Laboratory for developing a national program for housing research and development.

**Keywords:** Housing, research, wood, durability, disaster recovery, construction, design, wood fasteners, wood adhesives, and housing inspection, maintenance, rehabilitation, and priorities

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# Assessment of Research and Technology Transfer Needs for Wood-Frame Housing

**Kevin L. Powell**, Research Analyst  
NAHB Research Center, Inc., Upper Marlboro, Maryland

**David C. Tilotta**, Associate Professor and Extension Specialist  
North Carolina State University, Raleigh, North Carolina

**Karen L. Martinson**, Program Specialist  
Forest Products Laboratory, Madison, Wisconsin

## Introduction

The ideal house is comfortable, safe, affordable, durable, efficient, disaster resistant, and sustainable. Unfortunately, although great advances have been made in housing technology over the last few decades, the “perfect” house does not yet exist for the homeowner, and efforts to improve it must continue. Of course, advancements in housing require not only pursuit of basic and applied research to acquire knowledge, but also technology transfer to move that knowledge into practice.

Housing-oriented research and technology transfer are conducted and funded by several organizations. However, the wise use of resources mandates careful scrutiny of spending and development of priorities. Thus, by organizing and prioritizing national housing research and technology transfer needs, the Forest Products Laboratory has undertaken this comprehensive study. This report summarizes results of a national survey on housing research and technology transfer needs and then assigns priorities to those needs. The results presented here will form the basis for future plans.

## Objective and Scope

The objective of this study was to develop a comprehensive summary of research and technology transfer needs for housing and determine their relative priorities. The scope was wide in that all aspects of housing were considered, from material choice and design to finishing and rehabilitating.

## Methodology

### Overview

This survey was carried out in six steps:

1. Preparation of initial survey tool
2. Identification of survey participants
3. Completion of initial survey tool by participants

4. Refinement of initial survey results by surveyors
5. Prioritization of the refined survey results by the participants
6. Analysis of the data

### Step 1. Preparation of Initial Survey Tool

Targeted stakeholders were solicited for research ideas through a web-based survey tool (Appendix A). Information collected as part of the survey included stakeholder identity, geographic location of respondent, major research topic of interest, and description of the desired research activity.

### Step 2. Identification of Survey Participants

The National Association of Home Builders (NAHB) Research Center surveyed various stakeholders in the residential construction industry, including those from academia, government agencies, building code agencies, trade associations, consultants, builders, and remodelers. Participants were contacted through various distribution lists, personal contacts, and the NAHB Research Center’s ToolBase E-News.

### Step 3. Completion of Initial Survey Tool by Participants

An initial letter (Appendix B) was mailed to stakeholders to bring the survey to their attention. The letter summarized the purpose of the project and the information requested. Participants were asked to state research needs in the following nine categories:

- Materials
- Durability and preservation
- Engineering and design
- Construction
- Inspection
- Maintenance and rehabilitation
- Engineered systems

- Economics
- Other categories to be suggested by participants

**Step 4. Refinement of Initial Survey Tool by Surveyors**

Following the initial submission of perceived research topics, submissions were standardized to eliminate redundant themes and research topics that were considered out of the scope of housing. Thus, a total of 321 submissions were refined to 210.

**Step 5. Prioritization of the Refined Survey Results by the Participants**

The refined list from step 4 (above) was published on the NAHB Research Center website, and a new request was made to the same solicited participants to prioritize (rank) the list. A follow-up request letter (Appendix C ) was sent to all study participants, regardless of whether they had responded to the initial mailing or not. Again, groups and organizations were encouraged to solicit input from within their membership. Of the 328 letters sent in the second mailing, 182 responses were received by the NAHB Research Center. Participants were asked to rate each project as high, medium, or low priority on an electronic coding form (Appendix D).

**Step 6. Data Analysis**

Individual responses (perceived needs) from survey participants were first examined for duplication. Similar responses were combined and wording was edited as necessary. Following this step, priority rankings received for each of the needs (high, medium-high, medium, medium-low, and low) were then assigned a numerical value of 1 through 5, with 5 being the highest priority. The average numerical value for each need was then calculated, taking into account the number of responses received for each. Finally, research and technology transfer needs were then rank-ordered by importance using these average numerical scores.

**Results**

**Participants**

Participants in this study were from the following groups and organizations (followed by the number of postings they made): academician, 70; builder, 34; code official, 16; consultant, 59; contractor, 14; government official, 24; home owner or building manager, 4; manufacturer, 21; remodeler, 6; and trade association, 36.

**Format of Presentation**

Responding stakeholders generated a list of 212 perceived research needs. However, it became clear upon examining the list that many of the “research” needs were, in fact, issues about technology transfer. Thus, the initial list of 212 total responses was divided into two lists of 133 research needs and 79 technology transfer responses. Further, within the “research” and “technology transfer” areas, needs were

refined by ranking them within each of 10 priority area categories:

<b>Priority areas</b>	<b>Example topics</b>
Construction	Methods and techniques, quality of construction, modular homes, site-built homes, manufactured housing, structural-insulated panels
Design	Affordability, code considerations and effects, universal designs, composite systems, structural loads, and resistance
Disaster	Fire, seismic, and wind considerations
Durability	Wood preservatives, air barriers, weather barriers, moisture management, biological attack
Environmental factors	Indoor environmental quality, forestry issues, recycling, life-cycle analysis, deconstruction
Fasteners and adhesives	Processes, materials, evaluation methods
Inspection	Construction, codes, methods, hardware
Materials	Wood, non-wood, sawn, engineered, products, adhesives, performance specifications, material interaction
Operation, maintenance, and rehabilitation	Remediation, historic structures, insects
Other	Stakeholder perceptions, novel approaches

Results of the priority rankings from all of these refined lists are presented in this report.

**Ranking of Overall Needs**

Overall research and technology transfer needs were ranked from highest to lowest:

- 1 Investigate simple, nondestructive tests to determine moisture levels within wall cavities.
- 2 Develop less corrosive chemical treatments for wood.
- 3 Investigate the building envelope for water-intrusion potential in relation to design, installation, and maintenance.

- 4 Investigate all potential areas of moisture accumulation in buildings and materials.
- 5 Investigate construction practices and associated moisture loading and mold potential.
- 6 Develop accelerated test protocols that more closely mimic in-use conditions for building materials.
- 7 Investigate processes of moisture accumulation in buildings, including moisture transport from the foundation into the living space.
- 8 Investigate moisture-control strategies to decrease mold.
- 9 Develop estimated lifespan and reliability of fasteners in natural and engineered wood products, especially those in contact with new preservatives. Evaluate the effect of different environmental conditions: coastal, high heat and humidity, etc. Also, investigate the effect of wood moisture content on fastener withdrawal, especially at corners on structural-insulated panels.
- 10 Investigate insulation systems that decrease mold and mildew growth.
- 11 Develop a new homeowner preventive maintenance program or checklist for homes.
- 12 Continue research on moisture and thermal movement in walls with subsequent model development and verification.
- 13 Gather empirical data describing performance of fasteners over time.
- 14 Generate or obtain better data on the parameters controlling initiation and rate of decay in wood-frame construction, particularly the effect of localized wetting and fluctuating moisture conditions on mold and decay fungi colonization.
- 15 Develop a flashing method that is more easily incorporated into the trade-contractor scheduling process to ensure that flashing will consistently be installed properly.
- 16 Develop guidelines for inspection criteria based upon case studies of natural disasters such as hurricanes, tornados, and seismic events.
- 17 Research the relationship of and differences from composite performance loss caused by initial moisture sorption and subsequent biological decay.
- 18 Develop clear information on requirements for fasteners and hangers to be used with copper-based treated wood.
- 19 Develop whole-house protection by design based on locale.
- 20 Determine the best solution for remediating a building that has been contaminated by mold growth or determine the best methods for cleaning and preventing re-growth of mold in buildings.
- 21 Investigate thermal and moisture performance of conventional exterior wall assemblies in different climate zones.
- 22 Develop a definition, specific testing standards, and criteria for air barriers and guidelines for their installation.
- 23 Develop design methods to increase housing energy efficiency, for both new and existing construction, with minimal cost.
- 24 Research effective ways to bond lumber laminations treated with alkaline copper quaternary (ACQ) or copper azole formulations.
- 25 Develop and test more sophisticated durability models for wall systems that take into account moisture transport, permeability, air leakage, exposure, and climate.
- 26 Develop nondestructive evaluation techniques for various members and systems.
- 27 Investigate how mechanical ventilation complements and augments natural air infiltration, exfiltration, and ventilation, and study specific performance characteristics (energy use, moisture removal, indoor air quality, fresh air distribution) of different ventilation designs.
- 28 Investigate effects that construction quality, structure design, and material choice have upon actual energy consumption during operation of a home.
- 29 Design ventilation standards for all climates, house designs, and conditioning systems.
- 30 Integrate inspection of building materials, assemblies, and entire homes.
- 31 Determine whether moisture-vapor permeable-insulative sheathing is needed or desired to manage wall-cavity moisture and enhance durability of wall enclosures.
- 32 Develop a standard for flashing doors and windows.
- 33 Develop technology that will nondestructively assess structural damage to framing and sheathing of stucco and exterior insulation finish systems- (EIFS-) clad buildings.
- 34 Develop installation guidelines for wood-based siding to facilitate enhanced durability.
- 35 Develop a database of code enforcement rather than construction activity and inspection rate for each state and local jurisdiction.
- 36 Investigate structural performance of engineered wood under seismic, high-wind, and fire conditions.
- 37 Develop an indoor humidity profile for different climates, seasons, and types of houses (age, style, foundation).
- 38 Develop economical ways to reduce common air contaminants in homes and educate people how to avoid contaminants.

- 39 Research influence of flashing and impermeable membranes on siding durability.
- 40 Develop inspection guidelines for each stage of construction, illustrating compliant and non-compliant examples.
- 41 Develop better estimates of short-term, long-term, and life-cycle costs for renewable building materials compared with nonrenewable and slowly renewed products.
- 42 Estimate service life of wood–plastic composites and wood composites through lab testing and modeling.
- 43 Compare performance characteristics of various exterior cladding systems.
- 44 Define optimum permeability and hydrohead performance criteria for weather-resistive membranes and house wraps for different construction types (brick, stucco, vinyl, or wood siding) and different geographies or hygrothermal regions.
- 45 Develop and promote simplified field-tested framing details.
- 46 Develop educational materials aimed at consumers to guide material choice for improved durability.
- 47 Develop value-added products to sell from waste wood and plastic.
- 48 Perform value engineering for each stage of house construction and evaluate each stage for material savings, efficiency of construction, energy efficiency, and operational cost.
- 49 Compare various wall sections of differing drainage-plane locations and exterior cladding materials with varying distances between cladding and drainage planes.
- 50 Develop systems that more easily integrate connections between wood and non-wood elements such as concrete foundations to wood floor systems.
- 51 Research whether mold and other interior pollutants cause health problems, and if so, develop remediation strategies.
- 52 Compare thermal performance of design criteria of R-value compared with air infiltration.
- 53 Develop large-scale, accelerated testing protocols for large structures correlated to actual in-use conditions and performance.
- 54 Investigate the influence of wall panels on house performance for components susceptible to weather damage such as fenestrations, joints, and cladding transition.
- 55 Extend seismic performance data to include narrow shear walls and portals, and investigate methods for prediction of shear-wall performance based on simple properties such as lateral nail resistance or dowel-bearing strength.
- 56 Evaluate materials and prices to determine optimum material choices for structural performance, labor, and cost in multi-story construction.
- 57 Develop rehabilitation and maintenance guidelines for historic structures.
- 58 Develop a program to study and test performance of common nails in steel-to-wood connections. Develop pullout and shear values.
- 59 Simplify design procedures for lateral-load design in high-wind and seismic regions.
- 60 Study regional economics of wood recycling by the home-building industry.
- 61 Develop a priority list of problems contributing to inefficiencies in home construction.
- 62 Develop new technologies and methods for rehabilitating and maintaining historic buildings.
- 63 Research conditions necessitating sill pans for windows and installation techniques.
- 64 Develop recommendations for easily retrofitting existing buildings to enhance structural performance against seismic or high-wind events.
- 65 Investigate dynamic loading of timber structures.
- 66 Develop relational models and testing procedures to assess interactions between building products and systems to ensure that new products do not adversely affect overall building performance.
- 67 Develop tools to provide engineering analysis of lateral loads for establishing code compliance.
- 68 Develop a life-cycle analysis tool to contrast building materials by economics, carbon, and other greenhouse gas emissions and inputs of energy, capital, and labor.
- 69 Verify through testing the legitimacy of conventional construction provisions in the building code.
- 70 Investigate performance of I-beams under fire.
- 71 Develop guidance for designing structures with energy-efficient windows for a variety of architectural styles and climates.
- 72 Develop fastening requirements specific to power-drive fasteners.
- 73 Develop adhesive formulations and associated design parameters for connecting multiple members, shear walls, and other connections.
- 74 Develop educational materials designed to inform consumers that quality means more than countertop and cabinet upgrades.
- 75 Investigate alternatives for shear walls using staples and adhesives.
- 76 Investigate weathering characteristics of wood–plastic composites including fade, mold growth, and staining to improve performance of these materials.

- 77 Develop data on long-term degradation of ultraviolet light on unprotected and protected wood-plastic composites.
- 78 Develop a consistent approach to the utilization of perforated shear-wall designs.
- 79 Develop a process for getting variation in nail spacing recognized by code organizations.
- 80 Develop construction systems consistent with prevailing labor skills and quality construction.
- 81 Investigate reliability-based design of new composites, including structural capabilities, and marry technologies to produce new composites.
- 82 To establish benchmarks, determine construction workers' knowledge of and opinions related to construction and construction quality.
- 83 Research performance of perforated shear walls for factors such as wind-, seismic-, and snow-load.
- 84 Develop simplified and practical tools for analysis of load-transferring multiple vertical and lateral-load cases through a residential structure.
- 85 Develop nondestructive (ultrasonic) testing to evaluate building performance.
- 86 Develop new treatments and treatment technologies for wood and wood-based composites and investigate the effect of treatments on mechanical properties.
- 87 Develop a tested assembly approach to wall and floor systems to better identify composite action and develop a systems factor for generic assemblies that can be applied over a broad spectrum of dimension lumber sizes, grades, and species.
- 88 Determine a value for the increase in seismic or wind strength when a house is fully sheathed with plywood or oriented strandboard.
- 89 Research characteristics of wood fillers designed to replace decayed or damaged wood.
- 90 Investigate behavior and cold-climate moisture potential of open-celled, sprayed urethane-foam insulation applied directly to the underside of an unvented roof deck.
- 91 Design connections to transfer moment and beam splices and miscellaneous connections.
- 92 Rather than adapting current tests, work cooperatively with ASTM to develop and refine meaningful test standards that take into account the anisotropic nature of material.
- 93 Develop standards for wood-frame construction up to three stories.
- 94 Investigate insulation options in various housing assemblies to contrast installation ease, thermal efficiency, air sealing, and cost.
- 95 Research behavior of residential structural designs with taller stories (9 and 10 ft (2.7 and 3 m)) and open configuration (vaults, cathedral ceiling, two-story window walls) during seismic and high-wind loading.
- 96 Develop designs for homes to improve survivability in the wildland-urban interface.
- 97 Develop training materials about new construction products for designers and builders.
- 98 Develop exterior engineered wood products designed for structural and aesthetic purposes and robustness to exterior conditions.
- 99 Investigate attributes of wood compared with concrete in terms of lifespan, resistance to natural disaster, and environmental impact.
- 100 Investigate mold resistance of exterior wall-cavity designs by locating wall sheathing just behind drywall.
- 101 Quantify the cost of improperly installing materials.
- 102 Using structural composite lumber, test high-load diaphragms and quantify splitting limits with close nail spacing and lack of grain lines.
- 103 Investigate how adhesively bonding components (bond-line strength and stress transfer) can improve the integrity of housing.
- 104 Develop building materials that are durable and structurally sound but have environmentally friendly properties (such as being easily recycled or biodegradable) when discarded.
- 105 Provide information for consumers and builders about the renewability and other environmental effects of using structural wood products compared with other building materials in home construction.
- 106 Develop a system for code compliance analysis for all new building materials.
- 107 Develop foundation, wall, and roof-system alternatives that are energy- and resource-efficient, durable, cost-competitive, easily adopted, and code-recognized.
- 108 Develop methods to incorporate material installation instructions into the home inspection process.
- 109 Provide guidance on selection, characteristics, and use of available wood preservatives.
- 110 Develop integrated approaches to system design that decrease negative interactive effects of building materials and assemblies.
- 111 Investigate an advanced framing or optimum-value engineering approach to shear-wall construction that considers material size, number, and placement.
- 112 Develop remediation guidelines for damage caused by wood-boring insects.
- 113 Analyze market and economic factors that promote adoption of new materials and technologies and processes.

- 114 Develop design criteria for installing HVAC systems that effectively condition an entire residential unit.
- 115 Compare conventional wood-frame construction to structural-insulated panel construction, insulated concrete form construction, timber frame, and log construction.
- 116 Develop standardized or universal wall-panel connections to incorporate plumbing, wiring, and versatility and also to connect energy-efficient wall panels together for a given climate zone.
- 117 Develop standards details and prescriptive provisions for attaching wood- and I-joists to the side or top of a steel beam.
- 118 Develop design guidelines and a suitable list of anchors and bolts for attaching decks to houses.
- 119 Investigate safety in truss design while considering installation errors and improper material handling and storage.
- 120 Investigate and compile engineering properties of wood-plastic composites including durability, fire performance, moisture characteristics, creep, and ultraviolet light resistance.
- 121 Investigate strength properties of field-applied corrections to framing and sheathing related to wood drying.
- 122 Develop a straightforward method of calculating strength of diaphragm elements (plywood sheathed floors, walls, roofs).
- 123 Investigate by regions panelized roof, wall, and floor systems including improvement opportunities, supply constraints, installation advantages, and interest by builders.
- 124 Investigate economies-of-scale improvements to more efficiently deliver residential structures that will be well received by the market.
- 125 Develop wood-based roofing products robust to hail and fire.
- 126 Develop data on long-term degradation of ultraviolet light on unprotected and protected wood.
- 127 Develop a “rule of thumb” guideline showing tolerance levels for fastener placement in shear-wall and diaphragm applications.
- 128 Develop a low-cost modular housing system for export to third world nations that would exhibit energy efficiency, seismic and wind load resistance, and would conform to local safety codes for regular or emergency/disaster housing needs.
- 129 To decrease damage done on construction sites, develop practical criteria for handling and storing trusses, engineered floor joists, and parallam beams.
- 130 Develop accurate design models that include the interaction of dissimilar materials, such as structural elements, with finish or aesthetic products. This design performance should include all aspects of function: energy, moisture, durability, and structure.
- 131 Investigate whether U.S. forests can sustainably supply existing demand for lumber, whether U.S. forest policy has resulted in economic loss in direct and indirect jobs and the cost of retraining, and whether other countries have had any positive results as they export their lumber to meet our internal demand.
- 132 Research effects that increased use of composite wood products have on sustainability of forests.
- 133 Develop workforce training on the importance and complexities of establishing an effective load path for transferring loads to the foundation of a structure.
- 134 Develop an understanding of fatigue mechanisms of mode-I fracture testing for bonded-wood systems.
- 135 Research the role of fasteners and resistance to seismic loads for plywood and oriented strandboard.
- 136 Investigate the need for two top plates for loads not in line.
- 137 Develop a strength-grading system and instrumentation with improved grading accuracy (as compared with traditional bending machines or Dynagrade).
- 138 Investigate the current minimum ratings for oriented strandboard including MOE, MOR, dimensional stability (linear expansion, thickness swelling, water absorption), and creep resistance for adequacy and compliance rate.
- 139 Investigate Formosan termite controls that are alternatives to bait stations and soil termiticides.
- 140 Develop recommendations for prevention of bat, powder post beetle, termite, fungus, and mold infestation.
- 141 Develop a user-friendly guideline for builders that shows where joist holes can be located.
- 142 Research long-term termite resistance to currently permitted pressure-treated wood, sill plate barriers, and untreated kiln-dried lumber adjacent to new-generation treated woods.
- 143 Develop specific guidelines on design and fastening of wood members.
- 144 Develop application guidelines that conform with, or are incorporated into, the International Residential Code to make post-frame homes a practical alternative to conventional framing.
- 145 Investigate the contribution of oriented strandboard to indoor air quality.
- 146 Research life cycles of various interior wood finishing products (wood flooring, wood mouldings, etc.) and develop life-cycle analyses for them.
- 147 Develop and compare energy sources such as solar, wind, and biomass-generating systems for homes and structures removed from utility grids.



- 148 Investigate biotechnology to produce new composites.
- 149 Investigate the durability of oriented strandboard in seaside applications.
- 150 Investigate the compatibility of wood-plastic composites with current wood preservatives.
- 151 Perform case studies to compare steel and wood (materials, labor, energy, environment ...).
- 152 Research the needs of aging and mobility-challenged populations concerning stair and handrail requirements, and develop building and rehabilitation guides to foster improved accessibility.
- 153 Explore methods to improve utilization of woody material from U.S. public lands.
- 154 Investigate whether small-diameter, eastern hardwood, hemlock, or low-grade eastern white pine fiber and material can cost-effectively provide material for engineered wood applications (either panel product, or structural element (I-joist)).
- 155 Design training programs to effectively relay the importance and techniques of temporary bracing.
- 156 Develop guidance for selection, installation, maintenance, and replacement of fiber cement siding.
- 157 Investigate the influence of species mix in oriented strandboard manufacture on structural performance and durability.
- 158 Develop natural finishes for longer-lasting decks.
- 159 Investigate narrow-faced studs and their effect on energy and sound transfer, raw material requirements, strength characteristics, and installation.
- 160 Develop methods of constructing tornado- or hurricane-safe rooms using all wood materials in modular and prefabricated homes.
- 161 Develop design information for stiffness and strength of steeply sloped roof diaphragms.
- 162 Develop fitch-plate design parameters for wood and steel, including engineered wood and fastening requirements for full-load transfer between materials.
- 163 Describe and quantify the number of defects or errors in prefabricated products delivered on site.
- 164 Develop design guidelines and information specific to modular housing including interaction between modules, connections at modules, shear transfer in floor and roof diaphragms, shear-wall requirements, and shear-wall anchorage requirements (especially at interior shear-wall locations).
- 165 Investigate bracing requirements (for example, cross bracing compared with diagonal bracing) for low-density fiberboard sheathing.
- 166 Explore comprehensive collaborative planning, from forest to customer, to optimize the supply chain of the manufactured house industry.
- 167 Assess whether structures or assemblies are over-designed as a result of poor installation practices.
- 168 Develop interior building materials to be more resistant to moisture exposure.
- 169 Investigate the material used for backfill and its correlation to moisture accumulation for a variety of construction materials.
- 170 Test and publish results for wholly unblocked diaphragms and for diaphragms that are blocked at the ends but not in the middle.
- 171 Investigate the fundamental nature of wood-plastic composites. Understand the effects of mix ratios, wood types and extractives, additive effects and interactions, and model mechanical performance and weatherability.
- 172 Determine the effect of certification standards on use of local wood from small landowners or the forest products industry.
- 173 Test the design of long-span structural-insulated panels.
- 174 Using finite element software, develop orthogonal constitutive properties for different composite materials so they can be used to analyze various new concepts and uses.
- 175 Develop finishing guidelines to prevent damage caused by wood-boring pests.
- 176 Investigate the influences of flange-web joints on performance of wood I-beams.
- 177 Develop randomly oriented strandboard for normalizing strength, improving dimensional stability, and reducing waste for structural-insulated panel manufacture.
- 178 Develop span tables for non-load bearing beams that support tray ceilings.
- 179 Investigate stakeholder perceptions, attitudes, and awareness of issues in housing research and technology transfer. (Please note that this need is identical to that listed in #185.)
- 180 Develop design values for shear walls using thicker materials than those used in current building codes.
- 181 Investigate T-ray technology for testing materials and structures.
- 182 Develop a prescriptive way of calculating lateral-load requirements that includes elements like drywall.
- 183 Develop guidelines, methods, materials, and training for temporary bracing of house assemblies during construction.
- 184 In cooperation with ASTM, develop a design regime for new applications similar to load and resistance factor design for wood-plastic composites.
- 185 Investigate stakeholder perceptions, attitudes, and awareness of issues in housing research and

- technology transfer. (Please note that this need is identical to that listed in #179.)
- 186 Investigate the influence that kiln-dried logs or lumber used for residential construction has on building quality compared with green logs or lumber. Quality measures include dimensional stability, durability, aesthetics, and insect resistance.
  - 187 Provide builders with alternative building techniques that use less wood per square foot of construction and still meet building code requirements.
  - 188 Develop a self-supporting laminated roof with insulation, wood skins of high-strength structural foam cores, and lightweight wood reinforcements.
  - 189 Compare fabrication and installation costs of panelized steel and wood homes.
  - 190 Develop updated and additional structural use information so that structural fiberboard finds broader code and builder acceptance.
  - 191 Develop guidelines for framing to accommodate potential accessibility modifications such as grab bars and railings.
  - 192 Develop evaluation methods based on ground-penetrating radar for properly fastening wood members after construction is completed..
  - 193 Develop tools to relate strength properties (MOE, MOR, density, latewood fraction of annual ring in gymnosperms, etc.) to forest-stand and tree predictors.
  - 194 Investigate structural-insulated panels for exterior corners.
  - 195 Develop tables and provisions for sheet steel and steel straps in wood shear walls.
  - 196 Develop methods to integrate oriented strandboard manufacturers' online quality assurance programs to the American Plywood Association's product standard PS2 compliance.
  - 197 Develop design provisions and prescriptive tables for combined wood plate and steel track acting as a load-distribution member.
  - 198 Research the effects on strength of transporting modular structures.
  - 199 Develop standardized profiles for framing to speed production and reduce errors.
  - 200 Compare current inspection tools for standing timber to evaluate each tool's ability to detect fungal decay, beetle attack, or termite destruction: Resistograph, IML-Resi, (IML, Inc., Kennesaw, GA); Sibert DDD (Sibert Technology Limited, Guildford, Surrey, England); and ThermiCam (FLIR Systems, Boston, MA).
  - 201 Create market assessments of sustainably produced forest products by region.
  - 202 Develop a structural wood–plastic composite.
  - 203 Develop spring-loaded wedges for a crack propagation study on wooden double-cantilever beams.
  - 204 Investigate home designs that facilitate easy finishing, remodeling, and wall relocation. These designs could potentially lead to more affordable finance programs that recognize the value of sweat equity.
  - 205 Investigate structural-insulated panels for dormer, outside corner, and gable ends as blow-out relief panels.
  - 206 Develop a building design methodology that begins with form and performance requirements and then specifies material properties.
  - 207 Investigate whether wood fiber from small-diameter trees can be utilized cost-effectively as insulation.
  - 208 Develop guidelines and road-mapping for implementation of lean manufacturing in the manufactured home industry.
  - 209 Identify and explore alternatives to dimension lumber as a structural material.
  - 210 Develop a prescriptive method for a hybrid wood and steel house.
  - 211 Develop design and construction methods to optimize home space using fewer materials while retaining marketability.
  - 212 Build a demonstration house that incorporates all the best-judged winners from each category of suggestions, such as a house that demonstrates the highest ranked needs in each of the priority areas.

### Ranking of Research Needs

Research needs were priority-ranked from highest to lowest:

- 1 Investigate simple, nondestructive tests to determine moisture levels within wall cavities.
- 2 Develop less corrosive chemical treatments for wood.
- 3 Investigate the building envelope for water-intrusion potential in relation to design, installation, and maintenance.
- 4 Investigate construction practices and associated moisture loading and mold potential.
- 5 Develop accelerated test protocols that more closely mimic in-use conditions for building materials.
- 6 Investigate processes of moisture accumulation in buildings, including moisture transport from the foundation into the living space.
- 7 Develop estimated lifespan and reliability of fasteners in natural and engineered wood products, especially those in contact with new preservatives. Evaluate the effect of different environmental conditions: coastal, high heat and humidity, etc.
- 8 Investigate insulation systems that decrease mold and mildew growth.

- 9 Continue research on moisture and thermal movement in walls with subsequent model development and verification.
- 10 Gather empirical data describing performance of fasteners over time.
- 11 Generate or obtain better data on parameters controlling the initiation and rate of decay in wood-frame construction, particularly the effect of localized wetting and fluctuating moisture conditions on colonization by mold and decay fungi.
- 12 Develop a flashing method that is more easily incorporated into the trade-contractor scheduling process to ensure that flashing will consistently be installed properly.
- 13 Research the relationship of and differences from composite performance loss caused by initial moisture sorption and subsequent biological decay.
- 14 Develop clear information on requirements for fasteners and hangers to be used with copper-based treated wood.
- 15 Develop whole-house protection by design based on locale.
- 16 Determine the best solution for remediating a building that has been contaminated by mold growth or determine the best methods for cleaning and preventing re-growth of mold in buildings.
- 17 Investigate thermal and moisture performances of conventional exterior wall assemblies in different climate zones.
- 18 Develop a definition, specific testing standards, and criteria for air barriers and guidelines for their installation.
- 19 Develop design methods to increase housing energy efficiency, for both new and existing construction, with minimal cost.
- 20 Research effective ways to bond lumber laminations treated with ACQ or copper azole formulations.
- 21 Develop and test more sophisticated durability models for wall systems that take into account moisture transport, permeability, air leakage, exposure, and climate.
- 22 Develop nondestructive evaluation techniques for various members and systems.
- 23 Investigate how mechanical ventilation complements and augments natural air infiltration, exfiltration, and ventilation, and study specific performance characteristics (energy use, moisture removal, indoor air quality, fresh air distribution) of different ventilation designs.
- 24 Investigate effects that construction quality, structure design, and material choice have upon actual energy consumption during operation of a home.
- 25 Design ventilation standards for all climates, house designs, and conditioning systems.
- 26 Determine whether moisture-vapor permeable-insulative sheathing is needed or desired to manage wall cavity moisture and enhance durability of wall enclosures.
- 27 Develop technology that will nondestructively assess structural damage to framing and sheathing of stucco and exterior insulation finish systems- (EIFS-) clad buildings.
- 28 Develop an indoor humidity profile for different climates, seasons, and types of houses (age, style, foundation).
- 29 Research influence of flashing and impermeable membranes on siding durability.
- 30 Develop better estimates of short-term, long-term, and life-cycle costs for renewable building materials compared with non-renewable and slowly renewed products.
- 31 Estimate service life of wood-plastic composites and wood composites through lab testing and modeling.
- 32 Compare performance characteristics of various exterior cladding systems.
- 33 Define optimum permeability and hydrohead performance criteria for weather-resistive membranes and house wraps for different construction types (brick, stucco, vinyl, or wood siding) and different geographies or hygrothermal regions.
- 34 Develop and promote simplified field-tested framing details.
- 35 Develop value-added consumer products from waste wood and plastic.
- 36 Perform value engineering for each stage of house construction and evaluate each stage for material savings, efficiency of construction, energy efficiency, and operational cost.
- 37 Compare various wall sections of different drainage-plane locations and exterior cladding materials with varying distances between the cladding and drainage planes.
- 38 Compare thermal performance of design criteria of R-value compared with air infiltration.
- 39 Develop large-scale, accelerated testing protocols for large structures correlated to actual in-use conditions and performance.
- 40 Investigate the influence of wall panels on house performance for components susceptible to weather damage such as fenestrations, joints, and cladding transition.
- 41 Evaluate materials and prices to determine optimum material choices for structural performance, labor, and cost in multi-story construction.
- 42 Develop rehabilitation and maintenance guidelines for historic structures.

- 43 Study regional economics of wood recycling by the home-building industry.
- 44 Develop a priority list of problems contributing to inefficiencies in home construction.
- 45 Develop new technologies and methods for rehabilitating and maintaining historic buildings.
- 46 Research conditions necessitating sill pans for windows and installation techniques.
- 47 Develop recommendations for easily retrofitting existing buildings to enhance structural performance against seismic or high-wind events.
- 48 Investigate dynamic loading of timber structures.
- 49 Develop relational models and testing procedures to assess interactions between building products and systems to ensure that new products do not adversely affect overall building performance.
- 50 Develop a life-cycle analysis tool to contrast building materials by economics, carbon, and other greenhouse gas emissions and inputs of energy, capital, and labor.
- 51 Investigate performance of I-beams under fire.
- 52 Develop adhesive formulations and associated design parameters for connecting multiple members, shear walls, and other connections.
- 53 Investigate alternatives for shear walls using staples and adhesives.
- 54 Investigate weathering characteristics of wood–plastic composites including fade, mold growth, and staining to improve performance of these materials.
- 55 Develop data on long-term degradation of ultraviolet light on unprotected and protected wood–plastic composites.
- 56 Develop a process for getting variation in nail spacing recognized by code organizations.
- 57 Develop construction systems consistent with prevailing labor skills and quality construction.
- 58 Investigate reliability-based design of new composites, including structural capabilities, and marry technologies to produce new composites.
- 59 To establish benchmarks, determine construction workers’ knowledge of, and opinions related to, construction and construction quality.
- 60 Develop simplified and practical tools for analysis of load-transferring multiple vertical and lateral-load cases through a residential structure.
- 61 Develop nondestructive (ultrasonic) testing to evaluate building performance.
- 62 Develop new treatments and treatment technologies for wood and wood-based composites and investigate the effect of treatments on mechanical properties.
- 63 Research characteristics of wood fillers designed to replace decayed or damaged wood.
- 64 Investigate behavior and cold-climate moisture potential of open-celled, sprayed urethane-foam insulation applied directly to the underside of an unvented roof deck.
- 65 Rather than adapting current tests, work cooperatively with ASTM to develop and refine meaningful test standards that take into account the anisotropic nature of material.
- 66 Investigate insulation options in various housing assemblies to contrast installation ease, thermal efficiency, air sealing, and cost.
- 67 Research behavior of residential structural designs with taller stories (9 ft., 10 ft. (2.7 m, 3 m)) and open configuration (vaults, cathedral ceiling, two-story window walls) during seismic and high-wind loading.
- 68 Develop designs for homes to improve survivability in the wildland-urban interface.
- 69 Investigate attributes of wood compared with concrete in terms of lifespan, resistance to natural disaster, and environmental impact.
- 70 Investigate mold resistance of exterior wall-cavity designs by locating wall sheathing just behind drywall.
- 71 Quantify the cost of improperly installing materials.
- 72 Using structural composite lumber, test high-load diaphragms and quantify splitting limits with close nail spacing and lack of grain lines.
- 73 Investigate how adhesively bonding components (bond-line strength and stress transfer) can improve the integrity of housing.
- 74 Develop building materials that are durable and structurally sound but have environmentally friendly properties (such as being easily recycled or biodegradable) when discarded.
- 75 Develop foundation, wall, and roof-system alternatives that are energy- and resource-efficient, durable, cost-competitive, easily adopted, and code-recognized.
- 76 Develop integrated approaches to system design that decrease negative interactive effects of building materials and assemblies.
- 77 Investigate an advanced framing or optimum-value engineering approach to shear-wall construction that considers material size, number, and placement.
- 78 Develop remediation guidelines for damage caused by wood-boring insects.
- 79 Develop design criteria for installing HVAC systems that effectively condition an entire residential unit.
- 80 Compare conventional wood-frame construction to structural-insulated panel construction, insulated concrete-form construction, timber frame, and log construction.
- 81 Develop standardized or universal wall-panel connections to incorporate plumbing, wiring, and

- versatility and also to connect energy-efficient wall panels together for a given climate zone.
- 82 Investigate and compile engineering properties of wood-plastic composites including durability, fire performance, moisture characteristics, creep, and ultraviolet light resistance.
  - 83 Investigate strength properties of field-applied corrections to framing and sheathing related to wood drying.
  - 84 Develop wood-based roofing products robust to hail and fire.
  - 85 Develop a low-cost modular housing system that could be exported to third world nations for regular or emergency/disaster housing needs. This system would exhibit energy efficiency, seismic and wind-load resistance, and would conform to local safety codes.
  - 86 Develop accurate design models that include the interaction of dissimilar materials, such as structural elements, with finish or aesthetic products. This design performance should include all aspects of function: energy, moisture, durability, and structure.
  - 87 Develop an understanding of fatigue mechanisms of mode-I fracture testing for bonded-wood systems.
  - 88 Investigate the need for two top plates for loads not in line.
  - 89 Develop a strength-grading system and instrumentation with improved grading accuracy (as compared with traditional bending machines or Dynagrade).
  - 90 Investigate Formosan termite controls that are alternatives to bait stations and soil termiticides.
  - 91 Research long-term termite resistance to currently permitted pressure-treated wood, sill plate barriers, and untreated kiln-dried lumber adjacent to new-generation treated woods.
  - 92 Develop application guidelines that conform with, or are incorporated into, the International Residential Code to make post-frame homes a practical alternative to conventional framing.
  - 93 Research life cycles of various interior wood finishing products (wood flooring, wood mouldings, etc.) and develop life-cycle analyses for them.
  - 94 Develop and compare energy sources such as solar, wind, and biomass-generating systems for homes and structures removed from utility grids.
  - 95 Investigate biotechnology to produce new composites.
  - 96 Investigate the durability of oriented strandboard in seaside applications.
  - 97 Investigate the compatibility of wood-plastic composites with current wood preservatives.
  - 98 Research the needs of aging and mobility-challenged populations concerning stair and handrail requirements and develop building and rehabilitation guides to foster improved accessibility.
  - 99 Explore methods to improve utilization of woody material from U.S. public lands.
  - 100 Investigate whether small-diameter, eastern hardwood, hemlock, or low-grade eastern white pine fiber and material can cost-effectively provide material for engineered wood applications (either panel product, or structural element (I-joist)).
  - 101 Develop natural finishes for longer-lasting decks.
  - 102 Investigate narrow-faced studs and their effect on energy and sound transfer, raw material requirements, strength characteristics, and installation.
  - 103 Develop methods of constructing tornado- or hurricane-safe rooms using all wood materials in modular and prefabricated homes.
  - 104 Describe and quantify the number of defects or errors in prefabricated products delivered on site.
  - 105 Develop design guidelines and information specific to modular housing, including interaction between modules, connections at modules, shear transfer in floor and roof diaphragms, shear-wall requirements, and shear-wall anchorage requirements (especially at interior shear-wall locations).
  - 106 Investigate bracing requirements (for example, cross bracing compared with diagonal bracing) for low-density fiberboard sheathing.
  - 107 Explore comprehensive collaborative planning, from forest to customer, to optimize the supply chain of the manufactured house industry.
  - 108 Develop interior building materials to be more resistant to moisture exposure.
  - 109 Test and publish results for wholly unblocked diaphragms and for diaphragms that are blocked at the ends but not in the middle.
  - 110 Investigate the fundamental nature of wood-plastic composites. Understand the effects of mix ratios, wood types and extractives, additive effects and interactions, and model mechanical performance and weatherability.
  - 111 Determine the effect of certification standards on use of local wood from small landowners or the forest products industry.
  - 112 Test the design of long-span structural-insulated panels.
  - 113 Using finite-element software, develop orthogonal constitutive properties for different composite materials so these concepts can be used to analyze new concepts and uses.
  - 114 Develop finishing guidelines to prevent damage caused by wood-boring pests.
  - 115 Develop randomly oriented strandboard for normalizing strength, improving dimensional stability, and reducing waste for structural-insulated panel manufacture.

- 116 Investigate stakeholder perceptions, attitudes, and awareness of issues in housing research and technology transfer. (Please note that this need is identical to that listed in #120.)
- 117 Develop design values for shear walls using thicker materials than those used in current building codes.
- 118 Investigate T-ray technology for testing materials and structures.
- 119 In cooperation with ASTM, develop a design regime for new applications similar to load and resistance factor design for wood–plastic composites.
- 120 Investigate stakeholder perceptions, attitudes, and awareness of issues in housing research and technology transfer. (Please note that this need is identical to that listed in #116.)
- 121 Investigate the influence that kiln-dried logs or lumber used for residential construction has on building quality compared with green logs or lumber. Quality measures include dimensional stability, durability, aesthetics, and insect resistance.
- 122 Compare fabrication and installation costs of panelized steel and wood homes.
- 123 Develop evaluation methods based on ground-penetrating radar for properly fastening wood members after construction is completed.
- 124 Develop tools to relate strength properties (MOE, MOR, density, latewood fraction of annual ring in gymnosperms, etc.) to forest-stand and tree predictors.
- 125 Develop design provisions and prescriptive tables for a combined wood plate and steel track for load-distribution member.
- 126 Research the effects on strength of transporting modular structures.
- 127 Compare current inspection tools—Resistograph, IML-Resi, (IML, Inc., Kennesaw, GA) Sibert DDD (Sibert Technology Limited, Guildford, Surrey, England), ThermiCam (FLIR Systems, Boston, MA)—for standing timber to evaluate each tool’s ability to detect fungal decay, beetle attack, or termite destruction.
- 128 Develop a structural wood–plastic composite.
- 129 Develop spring-loaded wedges for a crack propagation study on wooden double-cantilever beams.
- 130 Investigate home designs that facilitate easy finishing, remodeling, and wall relocation. These designs could potentially lead to more affordable finance programs that recognize the value of sweat equity.
- 131 Investigate structural-insulated panels for dormer, outside corner, and gable ends as blow-out relief panels.
- 132 Investigate whether wood fiber from small-diameter trees can be utilized cost-effectively as insulation.
- 133 Develop guidelines and roadmapping for implementation of lean manufacturing in the manufactured home industry.

### Ranking of Research Needs by Priority Area

In this section, research needs are ranked within their priority area.

#### *Construction*

- 1 Develop and promote field-tested, simplified framing details.
- 2 Perform value engineering for each stage of house construction and evaluate each stage for material savings, efficiency of construction, energy efficiency, and operational cost.
- 3 Develop a priority list of problems contributing to inefficiencies in home construction.
- 4 Develop construction systems consistent with prevailing labor skills and quality construction.
- 5 To establish benchmarks, determine construction workers’ knowledge of, and opinions related to, construction and construction quality.
- 6 Quantify the cost of improperly installing materials.
- 7 Develop standardized or universal wall-panel connections to incorporate plumbing, wiring, and versatility and also to connect energy-efficient wall panels together for a given climate zone.
- 8 Develop a low-cost modular housing system that could be exported to third world nations for regular or emergency/disaster housing needs. This system would exhibit energy efficiency, seismic and wind-load resistance, and would conform to local safety codes.
- 9 Describe and quantify the number of defects or errors in prefabricated products delivered on site.
- 10 Develop design guidelines and information specific to modular housing including interaction between modules, connections at modules, shear transfer in floor and roof diaphragms, shear-wall requirements, shear-wall anchorage requirements (especially at interior shear-wall locations).
- 11 Explore comprehensive collaborative planning, from forest to customer, to optimize the supply chain of the manufactured house industry.
- 12 Test and publish results for wholly unblocked diaphragms and for diaphragms that are blocked at the ends but not in the middle.
- 13 Test the design of long-span structural-insulated panels.
- 14 Compare fabrication and installation costs of panelized steel and wood homes.
- 15 Research the effects on strength of transporting modular structures.
- 16 Investigate structural-insulated panels for dormer, outside corner, and gable ends as blow-out relief panels.

- 17 Develop guidelines and roadmapping for implementation of lean manufacturing in the manufactured home industry.

### **Design**

- 1 Evaluate materials and prices to determine optimum material choices for structural performance, labor, and cost in multi-story construction.
- 2 Investigate dynamic loading of timber structures.
- 3 Develop simplified or practical tools for the analysis of load transferring multiple vertical and lateral-load cases through a residential structure.
- 4 Research behavior of residential structural designs with taller stories (9 ft., 10 ft. (2.7 m, 3 m)) and open configuration (vaults, cathedral ceiling, two-story window walls) during seismic and high-wind loading.
- 5 Using structural composite lumber, test high-load diaphragms and quantify splitting limits with close nail spacing and lack of grain lines.
- 6 Develop foundation, wall, and roof-system alternatives that are energy- and resource-efficient, durable, cost-competitive, easily adopted, and code-recognized.
- 7 Develop integrated approaches to system design that decrease negative interactive effects of building materials and assemblies.
- 8 Investigate an advanced framing or optimum-value engineering approach to shear-wall construction that considers material size, number, and placement.
- 9 Investigate strength properties of field-applied corrections to framing and sheathing related to wood drying.
- 10 Investigate the need for two top plates for loads not in line.
- 11 Develop application guidelines that conform with, or are incorporated into, the International Residential Code to make post-frame homes a practical alternative to conventional framing.
- 12 Research the needs of aging and mobility-challenged populations concerning stair and handrail requirements and develop building and rehabilitation guides to foster improved accessibility.
- 13 Investigate bracing requirements (for example, cross bracing compared with diagonal bracing) for low-density fiberboard sheathing.
- 14 Develop design values for shear walls using thicker materials than those used in current building codes.
- 15 Develop design provisions and prescriptive tables for a combined wood plate and steel track acting as a load-distribution member.

### **Disaster**

- 1 Develop recommendations for easily retrofitting existing buildings to enhance structural performance against seismic or high-wind events.

- 2 Investigate performance of I-beams under fire.
- 3 Develop designs for homes to improve survivability in the wildland–urban interface.
- 4 Develop wood-based roofing products robust to hail and fire.
- 5 Develop methods of constructing tornado- or hurricane-safe rooms using all wood materials in modular and prefabricated homes.

### **Durability**

- 1 Investigate the building envelope for water-intrusion potential in relation to design, installation, and maintenance.
- 2 Investigate construction practices and associated moisture loading and mold potential.
- 3 Develop accelerated test protocols that more closely mimic in-use conditions for building materials.
- 4 Investigate processes of moisture accumulation in buildings, including moisture transport from the foundation into the living space.
- 5 Investigate insulation systems that decrease mold and mildew growth.
- 6 Continue research on moisture and thermal movement in walls with subsequent model development and verification.
- 7 Generate or obtain better data on the parameters controlling initiation and rate of decay in wood-frame construction, particularly the effect of localized wetting and fluctuating moisture conditions on colonization by mold and decay fungi.
- 8 Develop a flashing method that is more easily incorporated into the trade-contractor scheduling process to ensure that flashing will consistently be installed properly.
- 9 Research the relationship of and differences from composite performance loss caused by initial moisture sorption and subsequent biological decay.
- 10 Develop whole-house protection by design based on locale.
- 11 Investigate thermal and moisture performance of conventional exterior wall assemblies in different climate zones.
- 12 Develop a definition, specific testing standards, and criteria for air barriers and guidelines for their installation.
- 13 Develop and test more sophisticated durability models for wall systems that take into account moisture transport, permeability, air leakage, exposure, and climate.
- 14 Determine whether moisture-vapor permeable-insulative sheathing is needed or desired to manage wall cavity moisture and enhance durability of wall enclosures.

- 15 Develop an indoor humidity profile for different climates, seasons, and types of houses (age, style, foundation).
  - 16 Research influence of flashing and impermeable membranes on siding durability.
  - 17 Estimate service life of wood–plastic composites and wood composites through lab testing and modeling.
  - 18 Compare performance characteristics of various exterior cladding systems.
  - 19 Define optimum permeability and hydrohead performance criteria for weather-resistive membranes and house wraps for different construction types (brick, stucco, vinyl, or wood siding) and different geographies or hygrothermal regions.
  - 20 Compare various wall sections of differing drainage-plane locations and exterior cladding materials with varying distances between the cladding and drainage planes.
  - 21 Develop large-scale, accelerated testing protocols for large structures correlated to actual in-use conditions and performance.
  - 22 Investigate the influence of wall panels on house performance for components susceptible to weather damage such as fenestrations, joints, cladding transition, etc.
  - 23 Research conditions necessitating sill pans for windows and installation techniques.
  - 24 Develop data on long-term degradation of ultraviolet light on unprotected and protected wood–plastic composites.
  - 25 Develop new treatments and treatment technologies for wood and wood-based composites and investigate the effect of treatments on mechanical properties.
  - 26 Investigate behavior and cold-climate moisture potential of open-celled, sprayed urethane-foam insulation applied directly to the underside of an unvented roof deck.
  - 27 Investigate the mold resistance of exterior wall cavity designs produced by locating wall sheathing just behind drywall.
  - 28 Investigate Formosan termite controls that are alternatives to bait stations and soil termiticides.
  - 29 Research long-term termite resistance to currently permitted pressure-treated wood, sill plate barriers, and untreated kiln-dried lumber adjacent to new-generation treated woods.
  - 30 Investigate the durability of oriented strandboard in seaside applications.
  - 31 Develop natural finishes for longer-lasting decks.
  - 32 Develop interior building materials to be more resistant to moisture exposure.
  - 33 Develop finishing guidelines to prevent damage caused by wood-boring pests.
- Environmental Factors***
- 1 Develop design methods to increase housing energy efficiency, for both new and existing construction, with minimal cost.
  - 2 Investigate how mechanical ventilation complements and augments natural air infiltration, exfiltration, and ventilation, and study specific performance characteristics (energy use, moisture removal, indoor air quality, fresh air distribution) of different ventilation designs.
  - 3 Investigate effects that construction quality, structure design, and material choice have upon actual energy consumption during operation of a home.
  - 4 Design ventilation standards for all climates, house designs, and conditioning systems.
  - 5 Develop better estimates of short-term, long-term, and life-cycle costs for renewable building materials compared with non-renewable and slowly renewed products.
  - 6 Develop value-added products to sell from waste wood and plastic.
  - 7 Compare thermal performance of design criteria of R-value compared with air infiltration.
  - 8 Study regional economics of wood recycling by the home-building industry.
  - 9 Develop a life-cycle analysis tool to contrast building materials by economics, carbon and other greenhouse gas emissions, and inputs of energy, capital, and labor.
  - 10 Investigate attributes of wood compared with concrete in terms of lifespan, resistance to natural disaster, and environmental impact.
  - 11 Develop design criteria for installing HVAC systems that effectively condition an entire residential unit.
  - 12 Compare conventional wood-frame construction to structural-insulated panel construction, insulated concrete-form construction, timber frame, and log construction.
  - 13 Research life cycles of various interior wood finishing products (wood flooring, wood mouldings, etc.), and develop life-cycle analyses for them.
  - 14 Develop and compare energy sources such as solar, wind, and biomass-generating systems for homes and structures removed from utility grids.
  - 15 Explore methods to improve utilization of woody material from U.S. public lands.
  - 16 Investigate whether small-diameter, eastern hardwood, hemlock, or low-grade eastern white pine fiber and material can cost-effectively provide material for engineered wood applications (either panel product, or structural element (I-joint)).



- 17 Determine the effect of certification standards on use of local wood from small landowners or the forest products industry.
- 18 Develop tools to relate strength properties (MOE, MOR, density, latewood fraction of annual ring in gymnosperms, etc.) to forest-stand and tree predictors.

#### ***Fasteners and Adhesives***

- 1 Develop less corrosive chemical treatments for wood.
- 2 Develop estimated lifespan and reliability of fasteners in natural and engineered wood products, especially those in contact with the new preservative preservatives. Evaluate the effect of different environmental conditions: coastal, high heat and humidity, etc. Also, investigate the effect of moisture content of wood on fastener withdrawal, especially at corners on structural-insulated panels.
- 3 Gather empirical data describing performance of fasteners over time.
- 4 Develop clear information on requirements for fasteners and hangers to be used with copper-based treated wood.
- 5 Research effective ways to bond lumber laminations treated with ACQ or copper azole formulations.
- 6 Develop adhesive formulations and associated design parameters for connecting multiple members, shear walls, and other connections.
- 7 Investigate alternatives for shear walls using staples and adhesives.
- 8 Develop a process for getting variation in nail spacing recognized by code organizations.
- 9 Investigate how adhesively bonding components (bond-line strength and stress transfer) can improve the integrity of housing.
- 10 Develop an understanding of fatigue mechanisms of mode-I fracture testing for bonded-wood systems.
- 11 Develop spring-loaded wedges for a crack-propagation study on wooden double-cantilever beams.

#### ***Inspection***

- 1 Investigate simple nondestructive tests to determine moisture levels within wall cavities.
- 2 Develop nondestructive evaluation techniques for various members and systems.
- 3 Develop technology that will nondestructively assess structural damage to framing and sheathing of stucco and exterior insulation finish systems- (EIFS-) clad buildings.
- 4 Develop nondestructive (ultrasonic) testing to evaluate building performance.
- 5 Investigate T-ray technology for testing materials and structures.

- 6 Develop evaluation methods based on ground-penetrating radar for properly fastening wood members after construction is completed.

#### ***Materials***

- 1 Develop relational models and testing procedures to assess interactions between building products and systems to ensure that new products do not adversely affect overall building performance.
- 2 Investigate weathering characteristics of wood-plastic composites including fade, mold growth, and staining in order to improve performance of these materials.
- 3 Investigate reliability-based design of new composites, including structural capabilities, and marry technologies to produce new composites.
- 4 Rather than adapting current tests, work cooperatively with ASTM to develop and refine meaningful test standards that take into account the anisotropic nature of material.
- 5 Investigate insulation options in various housing assemblies to contrast installation ease, thermal efficiency, air sealing, and cost.
- 6 Develop building materials that are durable and structurally sound but have environmentally friendly properties (such as being easily recycled or biodegradable) when discarded.
- 7 Investigate and compile engineering properties of wood-plastic composites including durability, fire performance, moisture characteristics, creep, and ultraviolet light resistance.
- 8 Develop accurate design models that include the interaction of dissimilar materials, such as structural elements, with finish or aesthetic products. This design performance should include all aspects of function: energy, moisture, durability, and structure.
- 9 Develop a strength-grading system and instrumentation with improved grading accuracy (as compared with traditional bending machines or Dynagrade).
- 10 Investigate biotechnology to produce new composites.
- 11 Investigate the compatibility of wood-plastic composites with current wood preservatives.
- 12 Investigate narrow-faced studs and their effect on energy and sound transfer, raw material requirements, strength characteristics, and installation.
- 13 Investigate the fundamental nature of wood-plastic composites. Understand the effects of mix ratios, wood types and extractives, additive effects and interactions, and model mechanical performance and weatherability.
- 14 Using finite-element software, develop orthogonal constitutive properties for different composite materials so these concepts can be used to analyze new concepts and uses.

- 15 Develop randomly oriented strandboard for normalizing strength, improving dimensional stability, and reducing waste for structural-insulated panel manufacture.
- 16 In cooperation with ASTM, develop a design regime for new applications similar to load and resistance factor design for wood–plastic composites.
- 17 Investigate the influence that kiln-dried logs or lumber used for residential construction has on building quality compared with green logs or lumber. Quality measures include dimensional stability, durability, aesthetics, and insect resistance.
- 18 Develop a structural wood–plastic composite.
- 19 Investigate whether wood fiber from small-diameter trees can be utilized cost-effectively as insulation.

#### ***Operation, Maintenance, and Rehabilitation***

- 1 Determine the best solution for remediating a building that has been contaminated by mold growth or determine the best methods for cleaning and preventing re-growth of mold in buildings.
- 2 Develop rehabilitation and maintenance guidelines for historic structures.
- 3 Develop new technologies and methods for rehabilitating and maintaining historic buildings.
- 4 Research characteristics of wood fillers designed to replace decayed or damaged wood.
- 5 Develop remediation guidelines for damage caused by wood-boring insects.

#### ***Other***

- 1 Investigate stakeholder perceptions, attitudes, and awareness of issues in housing research and technology transfer. (Please note that this needs statement was obtained by combining two identical ones.)
- 2 Compare current inspection tools—Resistograph, IML-Resi, (IML, Inc., Kennesaw, GA) Sibert DDD (Sibert Technology Limited, Guildford, Surrey, England), ThermiCam (FLIR Systems, Boston, MA)—for standing timber to evaluate each tool’s ability to detect fungal decay, beetle attack, or termite destruction.
- 3 Investigate home designs that facilitate easy finishing, remodeling, and wall relocation. These designs could potentially lead to more affordable finance programs that recognize the value of sweat equity.

#### **Ranking of Technology Transfer Needs**

Technology transfer needs were priority-ranked from highest to lowest:

- 1 Investigate all potential areas of moisture accumulation in buildings and materials.
- 2 Investigate moisture-control strategies to decrease mold.

- 3 Develop a new homeowner preventive maintenance program or checklist for homes.
- 4 Develop guidelines for inspection criteria based upon case studies of natural disasters such as hurricanes, tornados, and seismic events.
- 5 Integrate inspection of building materials, assemblies, and entire homes.
- 6 Develop a standard for flashing doors and windows.
- 7 Develop installation guidelines for wood-based siding to facilitate enhanced durability.
- 8 Develop a database of code enforcement rather than construction activity and inspection rate for each state and local jurisdiction.
- 9 Investigate structural performance of engineered wood under seismic, high-wind, and fire conditions.
- 10 Develop economical ways to reduce common air contaminants in homes and educate people how to avoid contaminants.
- 11 Develop inspection guidelines for each stage of construction illustrating compliant and non-compliant examples.
- 12 Develop educational materials aimed at consumers to guide material choice for improved durability.
- 13 Develop systems that more easily integrate connections between wood and non-wood elements such as concrete foundations to wood floor systems.
- 14 Research whether mold and other interior pollutants cause health problems and, if so, develop remediation strategies.
- 15 Extend seismic performance data to include narrow shear walls and portals, and investigate methods for prediction of shear-wall performance based on simple properties such as lateral nail resistance or dowel-bearing strength.
- 16 Develop a program to study and test performance of common nails in steel to wood connections. Develop pullout and shear values.
- 17 Simplify design procedures for lateral-load design in high-wind and seismic regions.
- 18 Develop tools to provide engineering analysis of lateral loads for establishing code compliance.
- 19 Verify through testing the legitimacy of conventional construction provisions in the building code.
- 20 Develop guidance for designing structures with energy-efficient windows for a variety of architectural styles and climates.
- 21 Develop fastening requirements specific to power-drive fasteners.
- 22 Develop educational materials designed to inform consumers that quality means more than countertop and cabinet upgrades.

- 23 Develop a consistent approach to the utilization of perforated shear-wall designs.
- 24 Research performance of perforated shear walls for factors such as wind-, seismic-, and snow-load.
- 25 Develop a tested assembly approach to wall and floor systems to better identify composite action and develop a systems factor for generic assemblies that can be applied over a broad spectrum of dimension lumber sizes, grades, and species.
- 26 Determine a value for the increase in seismic or wind strength when a house is fully sheathed with plywood or oriented strandboard.
- 27 Design connections to transfer moment and beam splices and miscellaneous connections.
- 28 Develop standards for wood-frame construction up to three stories.
- 29 Develop training materials about new construction products for designers and builders.
- 30 Develop exterior engineered wood products designed for structural and aesthetic purposes and robustness to exterior conditions.
- 31 Provide information for consumers and builders about the renewability and other environmental effects of using structural wood products compared with other building materials in home construction.
- 32 Develop a system for code compliance analysis for all new building materials.
- 33 Develop methods to incorporate material installation instructions into the home inspection process.
- 34 Provide guidance on the selection, characteristics, and use of available wood preservatives.
- 35 Analyze market and economic factors that promote adoption of new materials and technologies and processes.
- 36 Develop standards details and prescriptive provisions for attaching wood joists and I-joists to the side or top of a steel beam.
- 37 Develop design guidelines and a suitable list of anchors and bolts for attaching decks to houses.
- 38 Investigate safety in truss design while considering installation errors and improper material handling and storage.
- 39 Develop a straightforward method of calculating strength of diaphragm elements (plywood sheathed floors, walls, roofs).
- 40 Investigate by regions panelized roof, wall, and floor systems including improvement opportunities, supply constraints, installation advantages, and interest by builders.
- 41 Investigate economies-of-scale improvements to deliver more efficiently residential structures that are well received by the market.
- 42 Develop data on long-term degradation of ultraviolet light on unprotected and protected wood.
- 43 Develop a “rule of thumb” guideline showing tolerance levels for fastener placement in shear wall and diaphragm applications.
- 44 To decrease damage done on construction sites, develop practical criteria for handling and storing trusses, engineered floor joists, and parallam beams.
- 45 Investigate whether U.S. forests can sustainably supply existing demand for lumber, whether U.S. forest policy has resulted in economic loss in direct and indirect jobs and the cost of retraining, and whether other countries have had any positive results as they export their lumber to meet our internal demand.
- 46 Research effects that increased use of composite wood products have on sustainability of forests.
- 47 Develop workforce training on the importance and complexities of establishing an effective load path for transferring loads to the foundation of a structure.
- 48 Research the role of fasteners and resistance to seismic loads for plywood and oriented strandboard.
- 49 Investigate the current minimum ratings for oriented strandboard including MOE, MOR, dimensional stability (linear expansion, thickness swelling, water absorption), and creep resistance for adequacy and compliance rate.
- 50 Develop recommendations for prevention of bat, powder post beetle, termite, fungus, and mold infestation.
- 51 Develop a user-friendly guideline for builders that show where joist holes can be located.
- 52 Develop specific guidelines on design and fastening of wood members.
- 53 Investigate the contribution of oriented strandboard to indoor air quality.
- 54 Perform case studies to compare steel and wood (materials, labor, energy, environment ...).
- 55 Design training programs effectively relaying the importance and techniques of temporary bracing.
- 56 Develop guidance for selection, installation, maintenance, and replacement of fiber cement siding.
- 57 Investigate the influence of species mix in oriented strandboard manufacture on structural performance and durability.
- 58 Develop design information for stiffness and strength of steeply sloped roof diaphragms.
- 59 Develop flitch-plate design parameters for wood and steel including engineered wood and fastening requirements for full-load transfer between materials.
- 60 Assess whether structures or assemblies are over-designed as a result of poor installation practices.

- 61 Investigate the material used for backfill and its correlation to moisture accumulation for a variety of construction materials.
- 62 Investigate the influences of flange-web joints on performance of wood I-beams.
- 63 Develop span tables for non-load bearing beams that support tray ceilings.
- 64 Develop a prescriptive way of calculating lateral-load requirements that includes elements like drywall.
- 65 Develop guidelines, methods, materials, and training for temporary bracing of house assemblies during construction.
- 66 Provide builders with alternative building techniques that use less wood per square foot of construction and still meet building code requirements.
- 67 Develop a self-supporting laminated roof with insulation, wood skins of high-strength structural foam cores, and lightweight wood reinforcements.
- 68 Develop updated and additional structural use information so that structural fiberboard finds broader code and builder acceptance.
- 69 Develop guidelines for framing to accommodate potential accessibility modifications such as grab bars and railings.
- 70 Investigate structural-insulated panels for exterior corners.
- 71 Develop tables and provisions for sheet steel and steel straps for wood shear walls.
- 72 Develop methods to integrate oriented strandboard manufacturers' online quality assurance programs to the American Plywood Association's product standard PS2 compliance.
- 73 Develop standardized profiles for framing to speed production and reduce errors.
- 74 Create market assessments of sustainably produced forest products by region.
- 75 Develop a building design methodology that begins with form and performance requirements and then specifies material properties.
- 76 Identify and explore alternatives to dimension lumber as a structural material.
- 77 Develop a prescriptive method for a hybrid wood and steel house.
- 78 Develop design and construction methods to optimize home space using fewer materials while retaining marketability.
- 79 Build a demonstration house that incorporates all the best-judged winners from each category of suggestions, such as a house that demonstrates the highest ranked needs in each of the priority areas, such as a house that demonstrates the highest ranked needs in each of the priority areas.

## Ranking of Technology Transfer Needs by Priority Area

In this section, research needs are ranked within their priority area.

### *Construction*

- 1 Verify through testing the legitimacy of conventional construction provisions in the building code.
- 2 Develop educational materials designed to inform consumers that quality means more than countertop and cabinet upgrades.
- 3 Develop training materials about new construction products for designers and builders.
- 4 Develop a straightforward method of calculating strength of diaphragm elements (plywood sheathed floors, walls, roofs).
- 5 Investigate by regions panelized roof, wall, and floor systems including improvement opportunities, supply constraints, installation advantages, and interest by builders.
- 6 Investigate economies-of-scale improvements to deliver more efficiently residential structures that are well received by the market.
- 7 To decrease damage done on construction sites, develop practical criteria for handling and storing trusses, engineered floor joists, and parallam beams.
- 8 Design training programs effectively relaying the importance and techniques of temporary bracing.
- 9 Assess whether structures or assemblies are over-designed as a result of poor installation practices.
- 10 Develop guidelines, methods, materials, and training for temporary bracing of house assemblies during construction.
- 11 Develop a self-supporting laminated roof with insulation, wood skins of high-strength structural foam cores, and lightweight wood reinforcements.
- 12 Investigate structural-insulated panels for exterior corners.

### *Design*

- 1 Extend seismic performance data to include narrow shear walls and portals, and investigate methods for prediction of shear-wall performance based on simple properties such as lateral nail resistance or dowel-bearing strength.
- 2 Simplify design procedures for lateral-load design in high-wind and seismic regions.
- 3 Develop tools to provide engineering analysis of lateral loads for establishing code compliance.
- 4 Develop a consistent approach to the utilization of perforated shear-wall designs
- 5 Research performance of perforated shear walls for factors such as wind-, seismic-, and snow-load.

- 6 Develop a tested assembly approach to wall and floor systems to better identify composite action and develop a systems factor for generic assemblies that can be applied over a broad spectrum of dimension lumber sizes, grades, and species.
- 7 Determine a value for the increase in seismic or wind strength when a house is fully sheathed with plywood or oriented strandboard.
- 8 Develop standards for wood-frame construction up to three stories.
- 9 Investigate safety in truss design while considering installation errors and improper material handling and storage.
- 10 Develop workforce training on the importance and complexities of establishing an effective load path for transferring loads to the foundation of a structure.
- 11 Develop a user-friendly guideline for builders that show where joist holes can be located.
- 12 Develop design information for stiffness and strength of steeply sloped roof diaphragms.
- 13 Develop flitch-plate design parameters for wood and steel including engineered wood and fastening requirements for full-load transfer between materials.
- 14 Develop a prescriptive way of calculating lateral-load requirements that includes elements like drywall.
- 15 Provide builders with alternative building techniques that use less wood per square foot of construction and still meet building code requirements.
- 16 Develop guidelines for framing to accommodate potential accessibility modifications such as grab bars and railings.
- 17 Develop tables and provisions for sheet steel and steel straps for wood shear walls.
- 18 Develop standardized profiles for framing to speed production and reduce errors.
- 19 Develop a building design methodology that begins with form and performance requirements and then specifies material properties.
- 20 Develop a prescriptive method for a hybrid wood and steel house.
- 21 Develop design and construction methods to optimize home space using fewer materials while retaining marketability.

#### ***Disaster***

- 1 Investigate structural performance of engineered wood under seismic, high-wind, and fire conditions.

#### ***Durability***

- 1 Investigate all potential areas of moisture accumulation in buildings and materials.
- 2 Investigate moisture-control strategies to decrease mold.

- 3 Develop a standard for flashing doors and windows.
- 4 Develop installation guidelines for wood-based siding to facilitate enhanced durability.
- 5 Develop educational materials aimed at consumers to guide material choice for improved durability.
- 6 Develop exterior engineered wood products designed for structural and aesthetic purposes and robustness to exterior conditions.
- 7 Provide guidance on selection, characteristics, and use of available wood preservatives.
- 8 Develop data on long-term degradation of ultraviolet light on unprotected and protected wood.
- 9 Develop recommendations for prevention of bat, powder post beetle, termite, fungus, and mold infestation.

#### ***Environmental Factors***

- 1 Develop economical ways to reduce common air contaminants in homes and educate people how to avoid contaminants.
- 2 Research whether mold and other interior pollutants cause health problems and, if so, develop remediation strategies.
- 3 Develop guidance for designing structures with energy-efficient windows for a variety of architectural styles and climates.
- 4 Provide information for consumers and builders about the renewability and other environmental effects of using structural wood products compared with other building materials in home construction.
- 5 Investigate whether U.S. forests can sustainably supply existing demand for lumber, whether U.S. forest policy has resulted in economic loss in direct and indirect jobs and the cost of retraining, and whether other countries have had any positive results as they export their lumber to meet our internal demand.
- 6 Research effects that increased use of composite wood products have on sustainability of forests.
- 7 Investigate the contribution of oriented strandboard to indoor air quality.
- 8 Perform case studies to compare steel and wood (materials, labor, energy, environment...).
- 9 Create market assessments of sustainably produced forest products by region.

#### ***Fasteners and Adhesives***

- 1 Develop systems that more easily integrate connections between wood and non-wood elements such as concrete foundations to wood floor systems.
- 2 Develop a program to study and test performance of common nails in steel to wood connections. Develop pullout and shear values.
- 3 Develop fastening requirements specific to power-drive fasteners.

- 4 Design connections to transfer moment and beam splices and miscellaneous connections.
- 5 Develop standards details and prescriptive provisions for attaching wood joists and I-joists to the side or top of a steel beam.
- 6 Develop design guidelines and a suitable list of anchors and bolts for attaching decks to houses.
- 7 Develop a “rule of thumb” guideline showing tolerance levels for fastener placement in shear-wall and diaphragm applications.
- 8 Research the role of fasteners and resistance to seismic loads for plywood and oriented strandboard.
- 9 Develop specific guidelines on design and fastening of wood members.

### ***Inspection***

- 1 Develop guidelines for inspection criteria based upon case studies of natural disasters such as hurricanes, tornados, and seismic events.
- 2 Integrate inspection of building materials, assemblies, and entire homes.
- 3 Develop a database of code enforcement rather than construction activity and inspection rate for each state and local jurisdiction.
- 4 Develop inspection guidelines for each stage of construction illustrating compliant and non-compliant examples.
- 5 Develop methods to incorporate material installation instructions into the home inspection process.

### ***Materials***

- 1 Develop a system for code compliance analysis for all new building materials.
- 2 Investigate the current minimum ratings for oriented strandboard including MOE, MOR, dimensional stability (linear expansion, thickness swelling, water absorption), and creep resistance for adequacy and compliance rate.
- 3 Develop guidance for selection, installation, maintenance, and replacement of fiber cement siding.
- 4 Investigate the influence of species mix in oriented strandboard manufacture on structural performance and durability.
- 5 Investigate the influences of flange-web joints on performance of wood I-beams.
- 6 Develop updated and additional structural use information so that structural fiberboard finds broader code and builder acceptance.
- 7 Develop methods to integrate oriented strandboard manufacturers’ online quality assurance programs to the American Plywood Association’s product standard PS2 compliance.
- 8 Identify and explore alternatives to dimension lumber as a structural material.

### ***Operation Maintenance and Rehabilitation***

- 1 Develop a new homeowner preventive maintenance program or checklist for homes.

### ***Other***

- 1 Analyze market and economic factors that promote adoption of new materials and technologies and processes.
- 2 Investigate the material used for backfill and its correlation to moisture accumulation for a variety of construction materials.
- 3 Develop span tables for non-load bearing beams that support tray ceilings.
- 4 Build a demonstration house that incorporates all the best-judged winners from each category of suggestions, such as a house that demonstrates the highest ranked needs in each of the priority areas.

### **Analysis of Results**

Overall, topics that dealt with moisture, mold, decay, and preservatives (the latter about both treatment and fastening technology) were ranked the highest. When divided into two groups (research priorities and technology transfer priorities), the research priorities closely followed the overall trends. However, the technology transfer priorities were slightly different with an emphasis on moisture, mold, materials use, and inspection and installation.

### **Concluding Remarks**

The information presented in this study will be used by the Forest Service and other organizations for their programs in housing research and technology transfer. Of course, additional high priority projects may surface as research is completed and used. We consider the process of project identification and prioritization to be dynamic, and additional input will be solicited from interested parties in the future. By freely exchanging information and ideas, we hope that both the effectiveness and efficiency of the completed research will be maximized to provide the greatest national benefit.

## Appendix A—Internet Survey Forms

The screenshot shows a Microsoft Internet Explorer browser window displaying a survey form. The browser's address bar shows the URL: <http://www.nahbrc.org/forums/woodframe/woodframeSwitchboard2.asp>. The page features the NAHB Research Center logo on the left and the TOOLBASE SERVICES logo on the right. The main heading is "Wood-Frame Housing Research Needs Prioritization".

**OVERALL PURPOSE:**

The purpose of the project is to identify, describe, and prioritize housing research needs that will serve as a basis for developing and funding Forest Service research, including cooperative research with universities and other organizations. The results of this project may significantly influence the direction and scope of housing-related research.

Your Background information here:

Stakeholder Identity:

State:

Contact Info:

(email address)

The dropdown menu for "Stakeholder Identity" is open, showing the following options:

- Stakeholder Identity -
- Builder Product Manufacturer
- Builder
- Contractor
- Remodeler
- Code Official
- Academician
- Consultant
- Government Official
- Homeowner/Building Manager
- Professional Association
- Other

The browser's status bar at the bottom shows "Done" and "Internet".


Wood-Frame Housing Research Ranking - Microsoft Internet Explorer

File Edit View Favorites Tools Help


Back Forward Stop Home Search Favorites Media Print Mail News RSS Feeds

Address <http://www.nahbrc.org/forums/woodframe/woodframeSwitchboard2.asp> Go Links

Google Search Web 378 blocked AutoFill Options



## Wood-Frame Housing Research Needs Prioritization



**OVERALL PURPOSE:**

The purpose of the project is to identify, describe, and prioritize housing research needs that will serve as a basis for developing and funding Forest Service research, including cooperative research with universities and other organizations. The results of this project may significantly influence the direction and scope of housing-related research.

**RESEARCH CATEGORIES**

The following categories are meant to roughly organize suggested research ideas. Please submit your ideas under the category or categories that best describe the theme of your submissions.

- **Research Categories:**
  - Materials - research related to individual materials or systems
  - Durability and preservation – research related to durability and preservation of housing materials and/or whole structures
  - Engineering and Design – research related to the engineering and design of residential structures
  - Construction – research related to the actual construction of residential structures
  - Inspection – research related to the inspection of materials or structures
  - Maintenance and Rehabilitation – research related to the operation, maintenance and rehabilitation of existing homes
  - Engineered Systems - research related to engineered housing components including manufactured and modular homes, panelized walls, etc...
  - Economics – research related to economic factors in residential construction
  - Other - research ideas not related to previous categories

Internet



The image is a screenshot of a Microsoft Internet Explorer browser window. The title bar reads "Research Categories: Materials - research related to individual materials or systemsWood-Frame - Microsoft Internet Explorer". The address bar shows the URL "http://www.nahbrc.org/forums/woodframe/woodframeforms.asp?id=1". The browser's toolbar includes buttons for Back, Forward, Stop, Home, Search, Favorites, Media, Print, and other standard functions. The main content area is titled "Wood-Frame Housing Research Needs Suggestion Box". Below the title, it says "Research Categories: >> Materials - research related to individual materials or systems". There are two text input fields: the first is labeled "What is the research subject? (For example, widgets.)" and the second is labeled "What would you like to see accomplished? (For example, accomplishments might be better estimates of widget lifespans, improved application guidelines, etc.)". A "Submit" button is located below the second field. At the bottom left of the form area, there is a link that says "Return to Research Categories". The browser's status bar at the bottom shows "Done" on the left and "Internet" on the right.

Research Categories: Materials - research related to individual materials or systemsWood-Frame - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Forward Stop Home Search Favorites Media Print

Address http://www.nahbrc.org/forums/woodframe/woodframeforms.asp?id=1 Go Links

Google Search Web 378 blocked AutoFill Options

### Wood-Frame Housing Research Needs Suggestion Box

Research Categories: >> Materials - research related to individual materials or systems

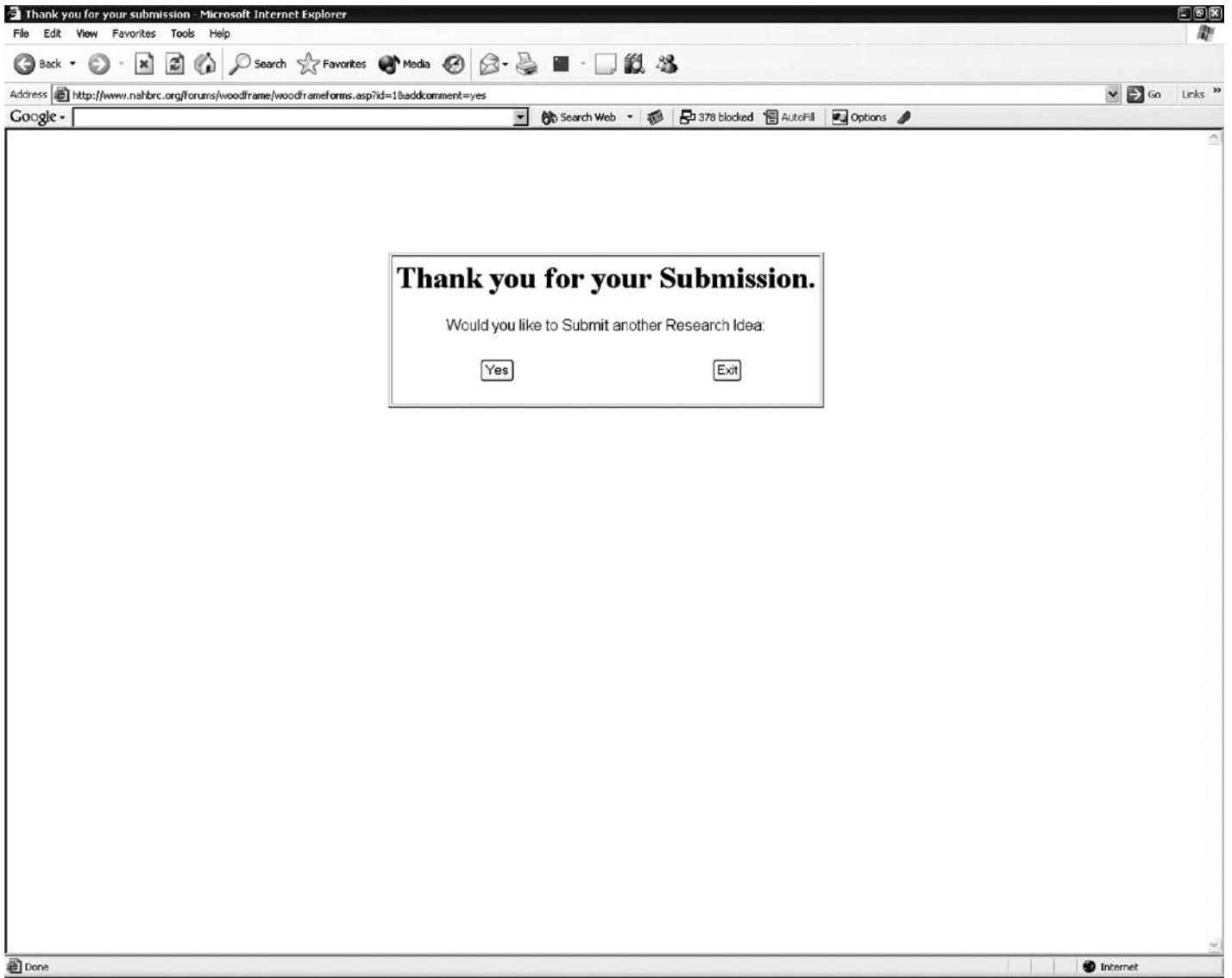
**What is the research subject?**  
(For example, widgets.)

**What would you like to see accomplished?**  
(For example, accomplishments might be better estimates of widget lifespans, improved application guidelines, etc.)

Submit

[Return to Research Categories](#)

Done Internet



## Appendix B—Initial Mailing

Dear Housing Professional:

Please respond by July 23, 2004, to help us determine the direction of a significant effort in wood-frame housing research!

Please participate in this online suggestion box that can take as little as 5 minutes. The NAHB Research Center is conducting an independent survey for the USDA Forest Service, Forest Products Laboratory (FPL) Advanced Housing Research Center and the Coalition for Advanced Housing and Forest Products Research in the area of wood-frame housing research. The primary objective of this survey is to identify, describe, and prioritize research needs. Your input will help shape the blueprint of the research effort for the FPL, universities, industry, government agencies, and other partners.

To facilitate your input, we ask that you state your research needs in any of the following categories:

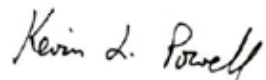
- Materials
- Durability and preservation
- Engineering and Design
- Construction
- Inspection
- Maintenance and Rehabilitation
- Engineered systems
- Economics
- Other categories to be suggested by you

Feel free to submit as many ideas, in as many research categories as you see fit, or to suggest new ones. The categories shown encompass a broad range to encourage your unrestricted input. The information we receive will be compiled and prioritized for developing a 5-year research program. Some may remember a similar survey performed about wood transportation structures research. For more information on that effort, go to <http://www.fpl.fs.fed.us/wit>.

To access the suggestion box, click the following link to the host web site [www.nahbrc.org/fpl](http://www.nahbrc.org/fpl). The login user name is “woodframe” and the password is “house”.

We need your input by July 23, so please respond now to ensure your input in developing the research agenda for wood-frame residential structures. Also, feel free to pass this announcement to others you know that have a stake in housing research.

Respectfully,



Research Analyst and Wood Products Specialist

NAHB Research Center, Inc.

## Appendix C—Second Mailing

Dear Housing Professional:

There is still time to prioritize submitted ideas for housing research!

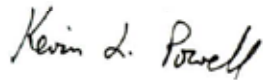
The research needs for housing have been submitted and recorded. Now we need you to assign a value to them. The NAHB Research Center is conducting an independent survey for the USDA Forest Service, Forest Products Laboratory (FPL) Advanced Housing Research Center and the Coalition for Advanced Housing and Forest Products Research in the area of wood-frame housing research. The primary objective of this survey is to identify, describe, and prioritize research needs. Your input will help shape the blueprint of the research effort for the FPL, universities, industry, government agencies, and other partners.

Each idea has been assigned to a category and has a value scale along side. Look through the categories and ideas, and then provide your value to those that interest you. The values will be tabulated to assist with selecting the ideas to pursue.

To access the suggestion box, click the following link to the host web site [www.nahbrc.org/fpl](http://www.nahbrc.org/fpl). The login user name is “woodframe” and the password is “house”.

We need your input so please respond now to ensure your input in developing the research agenda for wood-frame residential structures. Also, feel free to pass this announcement to others you know that have a stake in housing research.

Respectfully,



Kevin L. Powell

Research Analyst and Wood Products Specialist

NAHB Research Center, Inc.

## Appendix D—Internet Survey Tool for Priority Ranking

The screenshot shows a Microsoft Internet Explorer browser window displaying a survey tool. The browser's address bar shows the URL: <http://www.nahbrc.org/forums/woodframe/woodframeSwitchbd/Favorites>. The page features the NAHB Research Center logo on the left and the TOOLBASE SERVICES logo on the right. The main heading is "Wood-Frame Housing Research Needs Prioritization".

**OVERALL PURPOSE:**

The purpose of this project is to identify, describe, and prioritize housing research needs that will serve as a basis for developing and funding research through the USDA Forest Service, Forest Products Laboratory, including cooperative research with universities, industry, government agencies, and other organizations. When complete, the results of this project will help shape wood-frame housing research for the next 5-year period.

---

Your Background information here:

Stakeholder Identity:

State:

Contact Info:  (email address)

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The browser's taskbar at the bottom shows the Windows Start button, several application icons, and the system tray with the time 11:13 AM.

The screenshot shows a Microsoft Internet Explorer browser window. The address bar contains the URL: <http://www.nahrc.org/forums/woodframe/woodframeSwitchboard.asp>. The page features the NAHB Research Center logo on the left and the TOOLBASE SERVICES logo on the right. The main heading is "Wood-Frame Housing Research Needs Prioritization".

**OVERALL PURPOSE:**

The purpose of this project is to identify, describe, and prioritize housing research needs that will serve as a basis for developing and funding research through the USDA Forest Service, Forest Products Laboratory, including cooperative research with universities, industry, government agencies, and other organizations. When complete, the results of this project will help shape wood-frame housing research for the next 5-year period.

**RESEARCH CATEGORIES**

This constitutes the second of a two-part survey effort to list and prioritize potential research projects. Suggested ideas have been collected and placed into research and technology transfer categories. Please prioritize the ideas under each category.

- **Research Categories:**
  - [Construction - Methods and Techniques - quality, modular, site built, manufactured, SIPS](#)
  - [Design - affordability, cost, codes, Universal Design, composite system, structural loads and resistance](#)
  - [Disaster - fire, seismic, wind](#)
  - [Durability - wood preservatives, air barriers, weather barriers, moisture management, biological attack](#)
  - [Environmental Factors - indoor environmental quality, forestry, recycling, life cycle analysis, deconstruction](#)
  - [Fasteners and Adhesives](#)
  - [Inspection - construction, codes, methods, hardware](#)
  - [Materials - wood, non-wood, sawn, engineered, products, adhesives, performance specifications, material interaction](#)
  - [Operation, Maintenance, and Rehabilitation](#)
  - [Other](#)
- **Technology Transfer:**
  - [Construction - Methods and Techniques - quality, modular, site built, manufactured, SIPS](#)
  - [Design - affordability, cost, codes, Universal Design, composite system, structural loads and resistance](#)
  - [Disaster - fire, seismic, wind](#)
  - [Durability - wood preservatives, air barriers, weather barriers, moisture management, biological attack](#)
  - [Environmental Factors - indoor environmental quality, forestry, recycling, life cycle analysis, deconstruction](#)
  - [Fasteners and Adhesives](#)
  - [Inspection - construction, codes, methods, hardware](#)
  - [Materials - wood, non-wood, sawn, engineered, products, adhesives, performance specifications, material interaction](#)
  - [Operation, Maintenance, and Rehabilitation](#)
  - [Other](#)

The browser's taskbar at the bottom shows the Windows Start button, several application icons, and the system tray with the time 11:13 AM.

Research Categories: Disaster - fire, seismic, wind - Microsoft Internet Explorer

Address: <http://www.nslrc.org/forums/woodframe/woodframeRankings.asp?id=3>

### Wood-Frame Housing Research Needs Prioritization

Research Categories: >> Disaster - fire, seismic, wind

- Develop methods of constructing tornado or hurricane safe rooms using all wood materials in modular/prefabricated homes.  
low high
- Investigate the performance of I-beams under fire.  
low high
- Develop recommendations for ways to easily retrofit existing buildings to enhance their structural performance against seismic or high-wind events  
low high
- Develop designs for homes to improve survivability of houses in the wildland-urban interface.  
low high
- Develop wood-based roofing products robust to hail and fire  
low high

Done

start | WJ... | Pat... | In SQL... | frm... | Disc... | Wo... | G.le... | Wo... | Internet | 11:17 AM | Wednesday | 2/2/2005

