



Integrating Panels into the Production Homebuilding Process

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Raw materials ready for fabrication into wood-framed wall panels

“Integrating Panels into the Production Homebuilding Process”

Executive Summary

How do builders decide whether to use panelized house systems? What factors come into play when a builder is contemplating making a move to panelized construction? And for what reasons would builders who are inclined to try a new building technology choose not to use panelized construction?

These are some of the questions asked in this study conducted for the U.S. Department of Housing and Urban Development’s PATH (Partnership for Advancing Technology in Housing) program in an effort to understand how builders decide to use panel systems. Twenty-four builders across the U.S. were interviewed, mostly from the Southwest and Southeast parts of the country, where the lion’s share of new housing starts are taking place (according to the latest U.S. Census data). Builders were chosen in a wide range of sizes (from 2 employees to more than 100) and the number of houses produced annually (from 2 to more than 200). The builders studied serve all kinds of markets, from first-time homebuyers and affordable housing for lower-income buyers, to high-end custom homebuyers.

The study found that higher first costs and an inadequate understanding of panelized housing technology appear to be the most common barriers cited by builders who have not used panels. Competition with other builders is not a major factor in deciding to use panels. Some code officials appeared to remain behind the curve of understanding how panel systems work, but most (according to the builders) are accepting of the technology once they are educated about it (supplied in some cases by builders using panels).

Among builders who have elected to use panels, cost savings in the long-term, shorter construction time, and better overall quality are the major deciding factors. Some builders have carved out niche markets in building energy-efficient

homes; they claimed that the energy efficiency of structural insulated panel (SIP) construction helped them to serve this market. Some of the important factors for the successful use of panels cited by the builders were trained crews experienced with the technology and good communication and coordination between the builder and panel supplier.

Ultimately, a bedrock finding of the study is that builders willing to trust in advanced technology are most-times rewarded for their efforts in a variety of ways: lower material costs, lower labor costs, and fewer call-backs.

The findings of this study suggest other areas of fruitful research into panelized construction such as builders’ perceptions of cost; builder psychology as a determinant to technology use; studying consumer attitudes about panelized construction; the perceptions of code officials and building inspectors about the technology; studying panels as a commodity building product; and the development of a guide for builders on the choice of panel systems.



Metal structural insulated panel house under construction in Florida

1. Background of the Research Project

The HUD Office of Policy Development and Research (HUD/PD&R) has focused on supporting research and development of building technology innovation, construction systems, products, standards, regulations, and code issues, all of which affect the affordability, safety, and livability of the nation's housing. As the interrelationships of these areas of inquiry have become more complex, the need to conduct research and demonstrations has become more acute.

HUD's PATH program (Partnership for Advancing Technology in Housing) provides public and private sectors of the U.S. housing industry opportunities to advance state-of-the-art practices in the design and construction of affordable housing by accelerating the process of developing and introducing new and innovative technologies, as well as those technologies proven in the market but not used on a widespread basis. Panel technology is a focus of a number of PATH activities. Several PATH demonstration sites use panelized construction. "Advanced Panelized Construction" is the subject of a PATH Technology Roadmap, outlining the current role of panels in the housing industry. It suggests ways, through further research, barriers to panelized construction can be alleviated. The roadmap provides guidance on a research program to develop advanced building panel design; establish common standards, specifications, and interfaces; and improve production, delivery systems, and site assembly. Recent PATH research has focused on benchmarking panel performance, the design and performance of panel connection systems, and the incorporation of utilities and chases in panel systems.

The PATH program's 2003 study, "The Diffusion of Innovation in the Residential Building Industry," found that production homebuilders were more likely to utilize panelized housing systems than smaller, custom builders—25% of builders producing more than 50 homes annually incorporated panelized construction in some form. It concluded that production builders can better reap the benefits of the production efficiencies of panelized systems because their markets embody

larger economies of scale. The fact that 75% of the larger homebuilder respondents to this study did not utilize the technology suggests that there are other factors involved beyond the economic benefits that either encourage or discourage builders in using panelized technology. This research project was an effort to understand what those factors are, and how builders ultimately make the decision to adopt the use of panelized housing systems.

This research project focuses on understanding how homebuilders decide whether or not to use panelized systems. For the purposes of this research, panel systems are defined as those building components that arrive at the site either partially or fully fabricated, which are joined to other panels to create walls, floors, and/or roofs of a house. The point of studying the behavior of builders regarding panelized construction systems is to understand the deciding factors that lead to the adoption of such systems. Understanding the decision-making process of homebuilders could result in a number of potential benefits:

- Better comprehension on the part of the panelized home industry about the reasons why potential customers decide to use (or not use) its products;
- Identifying areas of misunderstanding on the part of homebuilders regarding panelized technology so that they can potentially be addressed by the industry;
- Assisting panelized system manufacturers and distributors to better serve homebuilders and respond to concerns about using the technology; and
- Identifying further research into builders' adoption and decision-making processes for panels and other technologies, the results of which can be used by industry and government to strategically promote further innovation diffusion.



Wood SIP house under construction in Colorado, with infill partitions and wood-truss roof

2. Research Methodology

The goal of the study was to understand how homebuilders make their decisions about whether or not to use panelized construction. It was decided that the best method of gathering information on the builders' behavior regarding panels was to interview them about their building and business practices, to visit builders on site to see how panelized systems were being used, and to compile comprehensive case studies based on this information which would provide insight into the homebuilder's decision-making process. The case studies would then be analyzed to explore and, if possible, identify patterns and traits common among builders who successfully adopted the use of panels. This work would be contrasted with traits of builders who have not used panels.

Among the types of questions that would be asked of homebuilders were the following:

- What were the technical problems, if any, for panel adoption?
- What were the motivating factors for panel adoption—were they related to cost, competition with other builders, energy performance, etc.?
- If problems existed, were they product related, and (if so) were the problems the result of a particular manufacturer and its product?
- Was it difficult to integrate panels into existing business practices?
- Did the builders overcome the problems, and how did they overcome them?
- If problems were not overcome, was the failure due to technology, business operation, the market, cost, etc.?
- What technical and managerial processes were altered due to adoption of panelized systems?

Selecting Homebuilders for Interviews

It was determined that approximately 24 builder firms would be interviewed for the study. Eighteen of the builders used panel systems on a regular basis; six builders who had decided not to use panels were interviewed to understand why they chose not to use panel technology.

While this total number was not a statistically significant

sample, such a sample would allow detailed information to be collected that could indicate tendencies among homebuilders regarding panel adoption.

Regional variation among the builders selected for study was the first priority in determining the sample. The continental U.S. was divided into five regions, roughly corresponding to those used by the U.S. Bureau of the Census. The regions and their corresponding states for the panel builder interviews were as follows:

- Northeast = NE (CT, MA, ME, NH, NJ, NY, PA, RI, VT)
- Southeast = SE (AL, AR, DE, FL, GA, KY, LA, MD, MS, NC, SC, TN, VA, WV)
- Northwest = NW (ID, MT, OR, WA, WY)
- Southwest = SW (AZ, CA, CO, NM, NV, OK, TX, UT)
- Midwest = MID (IA, IL, IN, KS, MI, MN, MO, ND, NE, OH, SD, WI)



Getting ready to trim a SIP, an on-site operation in Colorado

The mix of the 18 panel builders to be interviewed would reflect the intensity of building activity in the respective regions: six builders each from the Southeast and Southwest (where the greater numbers of housing starts were reported by the census bureau) with two each from the remaining three regions. One builder who had not used panels was selected from each of the regions (with two from the Southwest).

The builders to be interviewed would range in the number of houses built per year (small: <25; medium: 26-100; and large: >100); the type and sophistication of panelized technology used (from simple panel fabrication on-site to the use of completely proprietary, “closed wall” systems that arrive on site virtually ready to erect in place); labor composition (percentage of employees identified as administrative, general contractor, carpenter, laborer); organizational structure (trade subcontractor, contractor, developer); and house types constructed (single-family, row-house, multifamily). A list of approximately 80 builder firms who use panelized technology was compiled, and preliminary telephone interviews were conducted to determine willingness to participate in the study. The final list of builders to interview was derived from this list to attain a varied mix. The names and identities of all selected building firms and individual employees were tracked by location of their headquarters throughout this study and, subsequently, are withheld from this report.

A panel builder “Typology Matrix” was created to record initial information about the builder, including the name and contact number for the main decision-maker in the firm who would be the subject of an in-depth telephone interview (the inquiry form for potential study participants is found in Appendix A).

Interviewing and Visiting Builders

To ensure that builders interviewed would be asked the same questions in the same order, a telephone interview script was developed to be used by the interviewers (a copy of the script is found in Appendix B). The interview script was

structured to collect some additional information about the firm not included on the “Typology Matrix” (such as market served--region and income level [low/affordable, production, custom]; client types--nonprofit developer, affordable housing provider, private; age of company; change in company over the past five years--growth, contraction; whether it is independently owned or franchised; number of fulltime employees; use of other advanced building technology--modular, HUD Code, energy-efficient technologies, OVE-framing; sources of framing labor; sources of panel systems and their proximity to the site; panel types most often used--SIP, open-wall, etc.).



Builder’s own panelized home in Kerrville, Texas

The interview script organizes the main body of questions about the builder's use of panels under four main categories:

- Context of Builder's Practice;
- Pre-Construction Decision Making;
- Construction Decision Making
- Post-Construction and General Decision-Making Processes

The advantage of this structure is that it allows information to be collected about *when* a decision was made, and what the mitigating factors of that decision were. It also allows the interviewer to ask the builder slightly different questions at different points in the interview to verify a certain redundancy in the replies, which helps to build confidence in the accuracy of the information being elicited.

The thrust of the questions focused on key issues regarding how the builders decide to use panels, particularly the role of economics, clients, market, and the availability of framing labor, etc. The variety of questions asked can be abstracted to these essential queries:

- How is a particular panel system chosen?
- Where was information about the panel system obtained and how did it influence the decision to use panels?
- Did proximity to the panel manufacturer factor into the decision to use panels?
- How did cost factor into the decision to use panels?
- How did construction quality factor into the decision to use panels?
- How did construction efficiency factor into the decision to use panels?
- How did energy efficiency factor into the decision to use panels?
- How did competition with other builders in the market influence the decision?
- How did local building codes factor into the decision to use panels?
- How does the use of panels influence a home's design?
- What kinds of problems have been encountered in using panels?

- What factors contribute the most to successful use of panels?
- Did the use of panel systems result in changes to business practices?
- What changes in panel design or fabrication would improve the product?
- Did builders avoid using a particular kind of panel system?

Following the interviews, builders were visited to document the use of various panel systems on-site. The visits were geared toward documenting a variety of panel types used in the field, as well as regional variations, size of operation, markets served, etc. During on-site visits additional information was collected. Projects under construction were visited and photographed, and in some cases it was possible to visit the factory facility of the panelized system manufacturer.

With the completion of builder interviews and site visits, a matrix was designed so that responses to different questions could be compared across the range of builders interviewed. The data was loaded into this matrix according to builder responses to the questions. The matrix could be sorted in a variety of ways, so that builder responses could be compared according to builder size, location, panel type, market, etc. This sorting matrix (the entire matrix of interview results is found in Appendix C, available online at HUDUser.org) became the tool with which the data was analyzed and findings about builder behavior and decision making emerged.



Open-wall panel houses under construction in Newman, Georgia

3. Data Analysis and Findings

Builders using all kinds of panelized systems were represented in the study: simple open-wall panel technology (where panels are delivered to the site with exterior sheathing and open stud walls inside, to receive utilities, insulation, and finishes); sophisticated closed-wall structural insulated panels (SIPs, with two sheets of OSB sandwiching a core of rigid foam insulation); insulated precast concrete panels (delivered to the site with exterior finishes already applied); and SIPs with aluminum, steel, or cement board exterior surfaces. By far, the most popular panel systems used were open wall systems and SIPs—five of the builders studied used open wall panels; nine chose some form of SIP. Four of the builders used insulated precast concrete panels.

The data analysis and findings are organized according to the various issues addressed by the interview questions, which explain how builders decided to use panelized systems, and why they decide to use them (or not). The data collected were “sliced” according to a number of factors in an effort to understand how such factors might influence a builder’s decision to use panels. The data were sliced according to the panel types used, the builder’s region, the number of houses per year produced, the number of staff that the builder employs, the labor source for framing, the type of client that the builder serves, and the source of the panel systems used. Under each key question is a discussion of the study findings based on the information collected in the builder interviews and site visits.

1. How is a particular panel system chosen?

The choice of a particular panel system, according to the research, is driven mostly by what the particular builder wished to achieve through the use of panels. For example, builders who chose to use SIPs usually arrived at that decision due to what they perceived as the energy performance of that

technology. For the builders interviewed who use open-wall panel systems, the proximity of an open-wall panel producer who approached the builder through marketing seemed to spur the use of this technology (the close proximity of the builder to the manufacturer appeared to be a factor in a builder choosing to use a variety of panel types, not just open-wall systems).

Across the board, however, two reasons were mentioned most often: faster construction and better construction quality were the deciding factors for most builders in using panelized technology of any type. Another factor often mentioned by builders was either their own past experience with a panelized system, or the experience of a fellow builder.

For builders who built 100 houses or more a year, the deciding factor most often mentioned in the interviews was savings in cost and construction time. There was no prevailing reason for builders producing 25 to 100 units; better quality, energy performance, cost savings, and past experience with the system were all mentioned as deciding factors. For builders producing 15 or fewer houses a year, energy efficiency was cited most often for choosing to build with panels, along with past experience with the technology. These results seem to indicate that large-scale builders are more price and time sensitive, while smaller builders are influenced by what they identified as better construction quality and performance.



Panelized envelope with site-built front porch

For builders with a large number of employees (20 or more) time and cost savings were cited as the reason for choosing panels, along with better quality. There appeared to be no dominating factor for smaller firms of 20 or fewer employees.

For builders who depended on subcontracted labor for panel erection, past experience was mentioned most often as the deciding factor for panel selection. There appeared to be no dominant reason for choosing a panel system among builders who employed their own framing carpenters, or partly relied on subs. This appears to indicate that the results of sub labor are volatile, and that panelized systems help the builder to mitigate that volatility.

For builders who primarily served the affordable housing market (first-time homebuyers or non-profit developers of affordable housing) energy efficiency was the reason most often cited for using panel systems. Time and cost savings were also mentioned as important factors. Better construction quality, cost savings, and construction speed were all mentioned as important factors by builders who served the production home market. For builders of custom homes, energy efficiency was often cited as a deciding factor, along with better construction quality and cost savings. Decreased construction time did not appear to be as important a factor for these builders. Here, it appears that the primary concerns of potential homebuyers were mirrored in the reasons that builders gave for choosing to use panel systems.

For builders who procured their own panels (that is, who either manufactured their own or served as a distributor for a manufacturer) better construction quality and performance were the over-riding factors in deciding to use a panel system. This seems to indicate builders are willing to assume a greater control over panel quality if performance is the primary motivating factor for using panels.



Open-wall panels stacked in a factory during manufacturing in California

2. Where was information about the panel system obtained and how did it influence the decision to use panels?

Information about panel systems was gathered from a variety of sources according to the builders studied. They cited the internet, panel suppliers, architects and designers, clients, trade shows, and conferences. The Structural Insulated Panel Association (SIPA) was the only professional trade group mentioned by name that builders noted had reliably supplied materials on panel technology. Builders who used open-wall systems most often cited suppliers as an information source, or having to hunt down information on one's own from a variety of sources. A few of the builders mentioned that reliable information on

panelized technology in general was, in their view, scarce. This seemed to indicate that a professional trade group or information source for open-wall panelized systems was needed.

There did not appear to be any variation in information sources by the builder's region, nor did the number of houses produced per year seem to indicate a discernable pattern of information sources. Neither the builder's source of framing labor, number of employees, client type, or sources for panels indicated a pattern for information sources.

Was the information obtained a deciding factor in making the decision to use panels? The builders interviewed showed no dominant pattern here. On open-wall systems, the builders were essentially evenly split (three to two) on the influence of information on making their decisions. Four out of the nine builders using wood or metal SIPs found that the information provided helped them in their decision to use the technology. Only one out of the four builders using insulated precast concrete panels found the information helpful in making the decision. Looking at the data collected across other factors (size, location, sources of framing lumber, client type, source of panels) none emerged as a predictor that a builder would find currently available information as influencing the decision to use panels.

3. Did proximity to the panel supplier factor into the decision to use panels?

According to the information collected, a builder's proximity to the panel supplier factors into the decision to either use or not use a certain panel only in regard to the affect of proximity on cost. None of the builders interviewed mentioned proximity to a supplier has having an affect on the quality of technical assistance or the reliability of panel deliveries. This seems to indicate that the panel manufacturers serving the builders interviewed have worked out their distribution networks and technical assistance programs.



Structural insulated panels stacked prior to delivery; note pre-drilled chases for utilities

Transportation costs are factored into the price of a panel system. Builders reported that if such costs are substantial they can tip the balance against using panels. Builders using open-wall systems seemed to be most influenced by the proximity of the panel supplier—most of them mentioned the impact on cost as a deciding factor in choosing a panel system. Surprisingly, only three out of the nine wood SIPs builders said that proximity was a deciding factor, which indicated that generally SIP suppliers are sufficiently diffused to serve their markets. The same seemed to be true for precast concrete panel builders—only one of three cited proximity as important in the decision to use panels; in this case the decision to use a certain panel system was made because the supplier

was relatively close by, and was the only one that offered this particular panel system.

Generally, supplier proximity was not a factor in the decision to use panels for builders in the Southwest, and was evenly split as a deciding factor for builders in the Southeast. It was not important to builders in the Northeast, and evenly split as a deciding factor for Northwest builders interviewed. The builders surveyed in the Midwest mentioned proximity as a deciding factor.

For large builders (100 or more units a year) proximity to a supplier was not a deciding factor in using panelized systems, nor was it a factor for builders producing 15 or fewer houses a year. For five out of the eight mid-sized builders, proximity was identified as a factor. For builders relying solely on subcontracted labor for erecting panel systems, proximity as a factor in decision-making was evenly split between them. It was not a deciding factor for builders with a mix of self and sub labor, nor was it for builders whose labor was in-house. It is not readily apparent why mid-sized builders and those using sub labor would be more sensitive to panel manufacturer proximity.

Among the different client types that builders worked with, there was no discernable pattern of the influence of supplier proximity on the decision to use panels.

Among builders interviewed who had not used panels, a number of them mentioned the lack of a panelized dealer close by as a deciding factor against using panels, plus the fact that no other builders in their region were using panelized systems. It might be case that builders who have never used panels put an over-emphasis on this factor in their decision-making; it is possible that they believe that proximity affects prompt delivery (which was not borne out by the research).



Panelized single-family homes constructed for the affordable housing market in Chicago

4. How did cost factor into the decision to use panels?

Builders in the study who had never used a panel system almost uniformly cited perceived higher costs for panelized systems as the reason they had decided against using them. The cost of panelized systems was not a negative factor for the builders who chose to use them. The reason for this is that panelized builders, at least as they indicated in the study, appeared to view costs on a more long-term basis. For example, builders who used SIP technology admitted to higher first-costs for materials compared to stick framing, but there were cost advantages further along the construction timeline, said the builders. By

choosing SIP technology, builders explained that they could use fewer on-site laborers, at a lower skill level, which reduced costs. Construction time was also shortened, which meant that soft costs could be kept lower. Builders also mentioned the cost of construction waste—hauling it away and paying to dispose of it. With panelized technology the builders surveyed reported that there was far less construction site waste—which was ultimately a cost savings.

Builders surveyed in the Southeastern U.S. predominately used open-wall panel systems. Many of these builders cited less on-site labor as a way of reducing costs—and a reason to use panel systems. Avoiding costly material theft was also a factor in the decision to use panel systems for some builders.

Builders who produced 100 or more houses a year placed an emphasis on value over cost in their decision to use panelized systems. They also cited the benefits of saving time over the course of construction process—so higher first costs did not represent a negative factor to them. For builders who constructed 15 or fewer houses, higher costs for panelized systems were balanced out by lower labor costs, faster construction times, and better quality overall. A number of builders in the mid-range (26 to 100 houses a year) mentioned that the gap in costs of panel systems versus stick-built was closing, in their experience. These builders also appreciated the savings in labor costs as a deciding factor for choosing panel systems. It would appear that small builders with modest labor staff would find a real benefit in reducing on-site labor, which panel systems offered them.

Builders with small staffs (fewer than 10 people) noted a narrowing gap in costs between panel versus stick construction. Larger builders (more than 20 employees) cited labor savings and better quality as balancing against higher first costs for panel systems.



Reducing construction waste can result in a cost savings for builders using panels

Builders who relied on subcontractor labor for framing also saw costs narrowing between site-built and panelized construction. They cited lower labor costs with panel construction as an advantage, and a factor in their decision making. Builders with their own supply of labor most often mentioned reduced construction time as a deciding factor. Builders interviewed with a mix of labor sources (self and sub) appeared to place more emphasis on material quality over material costs, and also mentioned construction speed as an important consideration.

Perhaps the most surprising reaction about the role of costs in making their decision to use panels came from builders who primarily serve the affordable housing market. In the study, these builders either saw little or negligible difference in the cost of panel systems versus stick construction, or cited labor savings as an important factor. Four out of the 10 builders surveyed who serve this market placed an emphasis on quality over first-costs. For builders involved in the production home market, reduced construction times outweighed higher first-costs for panel systems. They also mentioned reduced labor costs as an important factor in choosing panelized systems. Custom builders stressed lower labor costs versus material costs as a deciding factor, along with a better quality product and the energy performance of panelized systems. Again, these builders appeared to be sophisticated in their ability to look beyond the up-front costs of a panel system and to appreciate other kinds of savings (time, labor) that these systems offered. These results also appear to indicate that construction labor costs are escalating at a faster rate than material costs.

Open-wall panel builders see definite labor savings and possibly material savings. Open-wall panel builders also save money on reduced construction waste, waste hauling, and on-site theft of materials. Although SIPs are higher in material costs than stick framing, the higher price ultimately did not discourage the builders' decision to adopt the technology. Again, these builders appear to be weighing the ease and quality of panelized construction against the lower cost of stick construction, and deciding to use panels.

Many builders find that higher up-front panel costs are balanced by shorter construction time, labor savings (when using less skilled assemblers for erection rather than framers), and lower waste-hauling costs. All types of panel systems make it more conducive for a builder to use less skilled labor at a lower cost. This fact is particularly true when using SIPs because of the relatively low skill required for their erection, builders reported.

In general, builders in regions with higher labor costs get a bigger payback

from panelized systems. Cost effectiveness is maximized when house designs are simple and repeated. This would indicate that panelized construction would be attractive to builders construction a large number of homes of either identical or similar design.

5. How did quality factor into the decision to use panels?

While higher costs for panelized systems did not appear to deter the builders surveyed, construction quality was cited as the biggest factor (along with



Insulated precast concrete panel is fabricated in Chicago with a brick exterior

construction efficiency) in deciding to use panels by builders all over the U.S., large and small. Construction quality appeared to be a bigger factor for smaller builders versus larger builders. Many of the builders surveyed who produced 15 or fewer houses a year said that they believed a drop in the number of callbacks was the result of better material quality and a higher quality finished product in using panel systems (particularly SIPs).

Across the range of panelized systems used, there was no variation in the importance of quality as a deciding factor for builders (although one builder out of four using insulated precast concrete panels said that construction quality was not a critical factor in making the decision to use the system). Quality that was judged by these builders as better than stick framing was the “reward” for trusting in the use of panelized technology.

A number of builders in the Southwest mentioned the declining quality of stick-framing materials as a factor in their decision to use panel systems. Builders in the Northeast and Midwest cited better quality panels as related to better energy performance and sound attenuation, which for them were deciding factors. In the Southeast, the builders surveyed also mentioned better quality, but for two out of the six builders surveyed it did not appear to be a critical factor in their decision.

Builders producing more than 100 houses per year uniformly cited better quality with panelized systems as a big factor in their decision to use them. Those producing between two and 25 houses a year noted construction quality, in light of the declining quality of stick-framing. They also cited reduced call-backs as an influence on their decision. Mid-range builders echoed these views. The number of employees in a builder’s organization did not seem to have any affect on the builder’s perception of quality as a deciding factor. Builders of all sizes cited better quality as an important aspect in their decision to use panels. Clearly, better construction quality was appreciated across the sample, and indicates it as a bedrock value for builders.



Structural insulated panels are set in place with the aid of a cherry picker on a Chicago site

Labor source did not appear to have an impact on builder responses regarding the importance of quality. Better quality and improved energy performance were important for builders serving the affordable housing market (as well as better acoustical performance in areas where there might be higher ambient sound levels). Custom builders noted fewer callbacks and better energy performance due to better quality, while production builders noted declining quality as a factor in stick-built framing materials—which led them to choose panel technology as a way of reducing callbacks. The feedback from builders indicated

that quality is an over-riding factor in continuing to use panel systems of any type.

Builders using SIPs reported that there are fewer mold problems with the technology because they can get “in the dry” faster. All types of panels offer a hedge against declining lumber quality and the eroding skills of framing subs. In general, all types of panel systems offer better air-tightness; however, SIPs were considered to be the tightest among the builders surveyed that used them.

6. How did construction efficiency factor into the decision to use panels?

For larger builders in the study (constructing from 50 to more than 200 houses a year) open-wall panel systems were the technology of choice. For these builders, construction efficiency (faster construction times with less on-site labor) was a bigger factor than construction quality (although many of the builders also noted that they believed that construction quality was better with panel systems versus stick or masonry building).

Many of the builders surveyed said that construction efficiency was enhanced with an experienced on-site crew, whether this was sub labor well-versed in the panel system, or the builder’s own employees who have used the panel system before. In fact, many of the builders surveyed said that the on-site crew experience was the biggest factor in determining successful use of panels. Builders noted that construction efficiency was greater with fewer subs (which indicates less management necessary by the builder) and that fully fabricated panel systems—pre-designed with window and door locations and cut-outs—further enhanced construction efficiency. House designs that were simple and repeatable on a variety of sites also added to construction efficiency and cost-effectiveness in using panels.

All of the builders using open-wall systems (except for one) cited construction efficiency as important in their selection of the panel system. For builders using

SIPs, construction efficiency appeared to be less important, and hinged upon the construction crew’s experience with the system. Builders using insulated concrete panels noted construction efficiency as an important factor in their choice of a system.

Three out of the eight builders who subcontract out their labor did not identify construction efficiency as being a factor in their choice of panel systems, but the rest agreed that it was an important consideration in their decision. For the majority of builders who supplied their own labor or used a combination of their own labor and subs, construction efficiency was identified as a critical factor. This



Completed wood-framed panelized home in Colorado

seems to indicate that builders depending solely on subs cared less about construction efficiency because it did not directly affect their bottom line (most sub labor contracts are let on a per-house basis, so construction efficiency has virtually no affect on the price for the builder relying solely on subs).

Production builders cited speed in construction efficiency as a motivating factor behind their decision to use panels, while nearly half the builders interviewed who serve the custom market admitted that construction efficiency was not as important in their selection of panelized systems. Six out of ten of the builders serving the affordable market mentioned construction efficiency as an important consideration in their choice.

The biggest determinant in achieving construction efficiency with any panel type is a crew familiar with the erection of the system. Construction efficiency is also a benefit for subs only if they buy into working with the panel technology before construction begins.

Among the different types of panels, builders believed that construction efficiency with SIPs is further enhanced by choosing fully designed and “fully fabricated panels” (with door and window cut-outs), but their initial costs are higher. More experienced SIP builders sometimes choose to field-fabricate these elements from “blank” or “stock panels.”

The construction efficiency of open-wall systems was reported to be less than that of SIPs because more on-site construction is needed to install insulation and finishes (which also means dealing with more subs) according to the builders. Generally, fewer subs to coordinate on a project results in better construction efficiency.



Energy savings of panelized home are touted in Florida

7. How did energy efficiency factor into the decision to use panels?

The promise of better energy efficiency that builders credited to higher quality construction and boosted levels of insulation (particularly in SIPs) was a deciding factor for many builders in the study. Those who operated in parts of the country with extreme climates (either hot or cold) said that they preferred the higher energy efficiency of SIP technology. For builders who cited energy efficiency as an important factor, smaller sized HVAC equipment was an added benefit in adopting SIPs.

All of the builders surveyed in the Southwest mentioned energy efficiency as an important factor in deciding to use panelized construction, and all but one chose SIPs. By contrast, only one builder out of the six surveyed in the Southeast cited

energy efficiency as a deciding factor (that builder was in Florida). Half of the builders in the Southeast opted for open-wall panel systems. All of the SIP builders in the study cited energy efficiency as the deciding factor in choosing this system. The same was true of builders using insulated precast concrete panels. Only one builder out of the five using open-wall systems cited energy efficiency as being an important factor in the decision. This is not surprising, as open-wall systems are generally less energy efficient compared to SIPs, and thus builders using them would not put a value on energy performance.

The bigger the builder (in terms of the number of units produced) the less of a factor energy efficiency played in the choice of using panels. Only half of the builders producing 100 or more units cited energy efficiency as important. This was a marked contrast to the smaller builders. Those producing between two and 25 units unanimously cited energy efficiency as an important factor in choosing to use panelized systems. For three of the five builders who provided their own framing labor, energy efficiency of the system was an important factor. All of the builders who used a combination of self and sub labor said that energy efficiency was important. Five out of the eight builders relying wholly on sub labor cited energy efficiency as a critical factor in their decision.

For builders serving the affordable housing market, and for those building high-end custom homes, energy efficiency was a factor. For builders who produced production houses, energy efficiency was less of a factor in deciding to use panels. All of the builders who were either retailers of the panel systems that they used or the fabricators of the panel system cited energy efficiency as an important factor in the panel's use. This seems to indicate that builders particularly sensitive to the needs of lower-income potential homebuyers would express a preference for energy-efficient technologies.

8. How did competition with other builders in the market influence the decision?

Generally, builders do not appear to base the decision to use panels on what their peers are doing, but choose panels for their added benefits, which (they claim) make the product more attractive to homeowners. In fact, among builders who chose not to use panels, several commented that they based their decision on the fact that other builders in their market area did not use panels.

The consensus among the builders surveyed was that the choice of panels was not made in an effort to compete with other builders in a market or region.



Panels set on bottom plates, anchored with bolts and straps in Georgia

Several builders mentioned that homebuyers do not register a visual difference in a stick-built or masonry home versus a panelized home—they essentially appear the same. However, several builders surveyed mentioned that better energy performance (particularly with SIPs) helped them to compete by being able to serve a niche market of homebuyers interested in energy savings and lower utility bills. Other builders mentioned that they believed that the savings in construction time and labor costs helped them to compete with builders who did not use panels. This was particularly true for the builders in the study who constructed 100 or more houses a year, all of whom cited competition as a factor. Clearly, the competitive stakes are higher for these larger builders.

All but one of the builders who used open-wall panel systems cited competition as an influence on their decision to use them. These builders believed that lowering costs and reducing construction time made them more competitive. None of the builders using insulated precast concrete panel systems mentioned competition as a factor in their decision to use the technology. Among builders who use SIPs, seven out of the nine builders said that competition was not a factor. However, SIPs builders found that they can capture the growing “energy efficient” niche market.

Only one of the builders that depended on subcontractor labor said that the decision to build panelized homes was made for competitive reasons. Most of the builders with their own labor force said that competition was not a factor in their decision. Those using a mix of labor admitted that competition with other builders was factored into their decision, but only slightly.

Client type served did not appear to be influential in terms of predicting whether a builder was influenced by competition in their decision to use panels.



Finished panelized home in Northern California

9. How did local building codes factor into the decision to use panels?

Some resistance (or at least begrudging acceptance) of panelized systems from local code officials and buildings inspectors was encountered by about half the builders in the study who use panels. Among these builders, the negative reaction from the local officials was not enough to discourage them from using the technology. In fact, a number of builders reported such resistance as a challenge they were happy to meet by educating building inspectors, either on their own or with the assistance of the panel manufacturer or trade groups.

Resistance on the part of building inspectors and code officials did not seem to be more pronounced for one panel technology compared to the others—builders using open-wall, wood SIPs, and cement-board SIPs all reported some

resistance. However, builders using insulated precast concrete panels reported no resistance.

The experience of the builders interviewed in the Southwest seemed to indicate a higher level of resistance to panel systems by code officials and building inspectors than in other parts of the country. In contrast, Southeast builders appeared to have met the least resistance. Perhaps this indicates the level of vigor in the regulatory community in the respective regions of the country.

The size of the builder, the number of houses built, the client served, and the composition of the builder's labor did not appear to have any determining influence on how panel technologies were received by code officials and building inspectors.

Builders reported that those who use panels for the first time in a locale where the technology has not made a big impact on the market should expect to spend some time educating the building inspector about the panelized system. Builders noted that if using panels for the first time, it is best to check with the local building officials early in the project. Builders reported that they often found they had to educate local code officials on the technology if the official has no prior experience with it; panel manufacturers will usually work with local building officials to gain their acceptance. However, builders reported that once familiar with the systems, building inspectors are not a barrier to the technology's use. In fact, one builder noted that local building inspectors now prefer panel systems because they are easier to inspect and construction quality is higher.

10. How does the use of panels influence a home's design?

Builders using open-wall panel systems reported that the design of the home had little if any impact on the applicability of the technology and vice versa. Designs for stick-frame houses were easily adaptable to open-wall panel systems. Builders using SIPs reported that, for the most part, the panel design fabrication



Window and door cutouts, along with angled profiles, can be made in the SIP plant

had little impact on a home's design. Users of insulated precast concrete panel systems reported that simple designs lend themselves best to the use of this technology.

Simple and repeatable designs result in the most cost-effective use of panels—this was particularly true for builders serving the production home market. Custom builders reported that the variety of panel technologies they chose to use had little if any impact on home designs.

Some builders advised that designs should standardize window and door openings and locations to the panel's 4-foot module, which allows them to use stock or blank SIPs. SIP roofs offer the advantage of conditioned attic space or

cathedral ceilings, but are generally more costly than comparable roofing systems. Builders using SIPs reported that panelized roofs may have span limitations because they are typically internally self supporting (not requiring trusses or framing).

11. What kinds of problems have been encountered in using panels?

Fabrication errors, miscommunications with the panel manufacturer, late delivery, resistance from such subs as electricians and plumbers, and the need to train installation crews were the most common problems mentioned by builders in using panel systems. According to the builders surveyed, fabrication errors in open-wall panels and SIPs can usually be corrected on-site, or the manufacturer usually supplies a new panel. However, builders noted that mistakes in concrete panels are not easily remedied on site.

Many of the builders surveyed noted that good communication with the fabricator—detailed drawings and careful management of any changes in house design—is essential in heading off problems on-site. Builders reported that resistance from other subs is common among those who have never worked with panelized systems. Several builders mentioned that once familiar with panel technology (even one house) resistance on the part of the sub dissipates.

Builders who used open-wall systems mentioned fabrication errors as the most common in their experience—generally having to do with the location of window and door openings (errors could usually be corrected on-site). SIP builders most often mentioned resistance on the part of sub trades, such as plumbers and electricians. Such resistance was traced to the sub’s unfamiliarity with the panel technology. Utilities’ interface with the panel system was also mentioned as a recurring problem.

As might be expected, builders who relied on their own in-house labor reported fewer problems in terms of technically knowledgeable crews than those builders



Electrician wiring a structural insulated panel house in Texas

who subbed the work to an outside labor force, which could change from job to job. In cases where the crews changed on a frequent basis, builders cited having to train new crews as a frustration with panelized construction. Builders interviewed who had never used panelized systems cited the lack of installer expertise as the reason they had decided not to use panels.

12. What factors contribute the greatest to successful use of panels?

Many builders reported that having experienced crews, either on staff or as sub labor, is the key factor in making a panelized project a success. This was usually attained simply by experience (learning on-site in the process of building a

panelized house for the first time) or through crew training by the panel manufacturer. Suppliers often send a representative to the site to help a crew through the building process—several builders noted that this was a big factor in using panels successfully. Technical support by the supplier was cited by several builders as an important factor for continued use of a particular system.

Other factors for success with panel systems mentioned by builders included close coordination and scheduling with the manufacturer/supplier and good shop drawings that are carefully checked. Some builders mentioned that repeatable home designs also helped in the success of projects allowing all the bugs to be worked out both in the panel factory and on-site.

Builders of more than 100 homes a year reported that the biggest factors for success in using panels were careful planning and coordination, review of shop drawings, and repeatable designs. For builders at the opposite end of the spectrum (constructing 15 or fewer house per year) experienced crews, training, technical support from the manufacturer, and coordination were cited as critical to success. Among these smaller builders, however, education and training were the key factors. This was also the case for mid-sized builders (producing between 25 and 100 houses per year). These builders most often mentioned training and education for crews as the biggest key to the successful use of panels.

For builders serving the affordable and production home markets, repeatable design and technically knowledgeable crews were mentioned most often as keys to success. Custom builders cited training and crew experience as the key factors.

13. Did the use of panel systems result in changes to business practices?

The study found that the use of panels required virtually no change on the part of builders in terms of their overall business model or practices. Several builders



Insulated precast concrete panel plant in Chicago

reported that, if anything, the use of panels made their business easier to run because it resulted in dealing with fewer subs. Some builders switched from sub framing labor to in-house erection crews.

A result of using panelized housing systems, some builders reported, was the expansion of their business into new areas. Some builders have become distributors for the panel manufacturer. Other builders have expanded into panel fabrication themselves. A few builders in the study manufactured their own panel systems from scratch. Another affect that a few of the builders reported was that they became more savvy about marketing and education. This appears to be due to the necessity to educate potential customers and code officials about panelized construction technology.

14. What changes in panel design or fabrication would improve the product?

The builders interviewed for the study offered a number of suggestions on how the panel systems they are using could be improved. One builder suggested that a standardized system for labeling panel components be considered, which would make it easier to use panels across different systems. Also suggested was a standard by which different panels across proprietary systems could be compared. One builder mentioned that more attention should be focused on connection systems—making it easier to put panels together with lower skill levels. An open-wall system builder suggested that thicker sheathing on the exterior should be used to give the walls greater strength. A SIP builder offered the idea that panels could be sold with structural gypsum board on the interior surfaces instead of OSB (a product like this is already on the market), and that panels be treated for termite resistance (this is also currently available).

A number of builders suggested that panelized construction systems should be less proprietary, and should move into the market as a “commodity.” As a commodity, panels in standard sizes (such as 4-foot widths) would be sold in outlets such as Home Depot. These panels could be easily connected using generic connection technology. A builder using SIPs suggested that entire walls could be assembled in a warehouse from smaller components, then transported to the site and erected as one large section of the house.

15. Did builders avoid using particular types of panel systems?

The reactions to this question seemed to indicate that the builders chose the panel systems that they use for carefully considered reasons, and they were not likely to switch between panel types.

Builders who have a comfort level with using open-wall systems said that they would not use SIPs because they like the flexibility they perceived in open-wall

technology. They also believed that installing utilities and services in SIPs was “complicated.” In contrast, builders using SIPs said they would not use open-wall systems because they did not perceive them as being as high quality as SIPs. Some SIP builders preferred components that were more “generic,” not part of a packaged design, which allowed them more flexibility during on-site assembly. Two builders noted that they had stopped using SIPs with urethane foam cores because of the perceived environmental shortcomings and health effects of the material. Instead they chose to use panels with expanded polystyrene (EPS) foam cores. Two

builders in Florida avoided wood SIPs and instead opted for other materials: a metal-skinned SIP because one builder believed that it had better resistance to termites; the other builder chose a cement-board-clad SIP for the same reason.

4. Further Research and Additional Action

The study’s interviews and site visits in this study shed considerable light on how builders make the decision to use (or not use) panelized housing construction systems. The findings suggest other areas of research and outreach actions on the part of PATH that might lead to greater use of panelized construction systems.



Utilities stubbed into an open-wall panel system

Builder Perceptions

In the interviews with builders that had little if any experience with using panel systems, it became apparent that some of the builders had a very limited knowledge of panel technology, which translated into misconceptions about the technology. A follow-up study to this one might probe deeper into the perceptions (or misconceptions) of builders who have not used panels and how they have formulated these ideas.

Innovation Profiles of Homebuilders

One measure of the builders' decision-making that was not taken into account in this study was a comparative profile of those builders who embrace new technology, and those who do not. Specifically, this could include studying how and why certain builders are more willing to trust in advanced building technology consistently, and whether they possess certain psychographic traits that promote adoption of innovation in other decisions as well. Developing indicators for builders' perceptions and behavior, or similar psychographic profiles, might reveal a predisposition among certain builders for technology adoption. Researchers may be able to identify a contrasting trend among builders with different psychographic profiles. It might be worthwhile to overlay such a test onto the sample of builders in this study, or other builders who have adopted advanced building technologies. By comparing panel builders with builders using other kinds of advanced technology, such a study might also indicate characteristics of panel technologies themselves that may or may not address those builder traits.

Builder Perceptions of Cost

This study revealed that even though panelized construction often has a higher material cost, certain builders choose to use the technology based on the belief that higher first-costs for panelized systems translate into cost savings further down the construction sequence (in lower labor costs and faster construction times, for example). Customer satisfaction and long-term quality and energy

benefits were also included in the equation used by these builders to calculate cost. In contrast, other builders place greater emphasis on first costs as the sole deciding factor in whether to use a technology or not. Either perception can be valid based on the builder's particular business practices, but the variation in perceptions of cost indicates that the level and depth of cost analysis are a critical decision-making criterion that deserves further attention. A literature review of builder perceptions of cost and implementation of cost analysis might reveal an additional behavioral distinction between those builders that adopt new building technology regardless of actual costs, even when first costs are higher. Research might reveal how builders in general perceive costs; why, for example, do builders less prone to innovation adoption employ certain analyses (i.e., simplistic) and have certain inherent cost beliefs (e.g., that first-cost savings always translate into full project savings)? Certain perceptions of cost and cost analysis might be more likely to dovetail with a builder's willingness to trust in technology. A comparison of how panelized builders perceive and assess costs versus how stick-builders perceive and assess costs might also be illuminating in understanding how to promote time- and resource-efficient panelized building systems, as well as innovations of other kinds.

Regulatory Barriers

Several builders in this study reported that they are still meeting resistance to panelized construction by code officials and building



Foam cores drilled with utility chases for SIPs

inspectors. Usually, such resistance can be overcome with some education. Research into the perceptions of code officials could shed light on what misconceptions they have about the technology, why they hold onto such misconceptions, and how the industry might work to overcome resistance by these officials. Such research would explore how these officials have formed their opinions about panelized construction, what they know about the technology, and what forms of education and outreach—or institutional changes—might best serve to counteract this resistance.

Technical Specifications

For panelized construction to make a bigger impact on the homebuilding industry, it appears that making the technology less proprietary and more of a commodity would help its market penetration. Several builders in this study mentioned that they would like to be able to go into a Home Depot or Lowe's and purchase panelized wall components. Understanding the generic performance qualities of panel technology is a focus of several PATH research activities at the moment. Recent PATH research has focused on benchmarking panel performance, the design and performance of panel connections, and the incorporation of utilities and chases in panel systems. Taking such research further, what developments could make panelized systems more of a building commodity? Research might explore different types of panelized housing systems, which systems might lend themselves better to commodification, and changes in the technology that might be necessary to make the systems more generic and interchangeable. Such research would also need to focus on codes, labor training, consumer outreach, utilities interface, and generic connection techniques.

Builder Guide to Panels

As more of an operational activity than research program, the development of a decision-making tool that could be manipulated by builders to determine whether panelized construction might also be helpful. Such a tool could function by region where they build, the types of customers they serve, the size of the

company, the size of the workforce, the number of houses constructed annually, etc. By answering such questions, the builder might be led to a conclusion about whether panels are a good choice, and if so, what particular kind of panel technology might work best. Either PATH, the panel industry, or a combination of resources could be employed to create and disseminate this tool.

5. Conclusion

Panelized building technology is an important part of the history of housing construction in North America. In fact, panelized technology is among the oldest forms of systematized housing in the U.S., dating back to the 1600s, when panel houses were imported in knock-down form via ships from England. Panelization predates wood-framed construction using dimensional lumber, which started in the 1830s. The first American factory-produced panelized homes were developed in the 1890s. The building pioneer Albert Bemis in 1926 founded the Bemis Research Foundation and developed the Cubical Modular Methods of Building Layout and the four-inch module. Bemis's son, John, founded Acorn Structures in Acton, Massachusetts, a renowned producer of panelized wood-framed homes. After World War II the population boom and the shortage of resources gave way to many more wood-framed panelized organizations.

The Schuette Lumber Co. (now Wausau Homes) developed open- and closed-wall panel systems and at its peak in the 1970s produced 25 homes a day in a plant in Wausau, Wisconsin. Stressed-skin panels were developed at the Forest Products Laboratory,



SIP house with stick construction infill

Madison, Wisconsin, in the 1930s, and structural insulated panels (SIPs) entered the U.S. homebuilding market in 1952, when Alden B. Dow, son of the founder of the Dow Chemical Company, began designing SIP homes. Stressed-skin panels led to the development of honeycomb-core stressed skin panels, an offshoot of the airplane construction industry (in which aluminum honeycomb cores were adhered to aluminum skins to form the fuselage). Impregnated paper (for added stiffness) forms the walls of honeycomb cores, which are glued to skins of metal, drywall or hardboard to form exceptionally strong panels. Concrete panels are now becoming more common in the industry.

From the very beginning of the PATH program, panel technology has been a research focus. Several PATH demonstration sites utilize panelized construction. "Advanced Panelized Construction," a PATH Technology Roadmap outlines the current role of panels in the housing industry. The roadmap provides guidance on a research program to develop advanced building panel design; establish common standards, specifications, and interfaces; and improve production, delivery systems, and site assembly.

This current study indicates that builders willing to trust in advanced technology are rewarded in a number of ways. By using various panelized housing technologies, these builders report that they can reduce the amount of time spent on site, reduce labor costs, can improve the quality of the homes they build (which results, according to the builders surveyed, in fewer costly call-backs to correct problems), and can offer builders a niche market in meeting the desires of potential homebuyers looking for energy-efficient homes.

Across the board, however, two "rewards" most often mentioned by builders were faster construction and better construction quality. These were the deciding factors for most builders in using panelized technology of any type. All of these "rewards" translate into motivational "triggers" or "tipping points" that help builders to make the decision to use the technology. This study provides insight into the motivation of builders to use advanced technology, which could help

panel manufacturers orienting their product in the marketplace and communicating to builders the essential qualities or "rewards" to be gained through the technology's use.

Clearly, both this study and historical precedent show that the decision-making processes of individual builders play as significant a role in adoption as technical innovation, if not more so. Further research and activity should address both.



Panelized house with stone cladding under construction in Texas

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