

# Development of a Web-Based Revised Whole-House Calculator



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Office of Policy Development and Research

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**Letter from the Secretary:**

# Development of a Web-Based Revised Whole-House Calculator

Prepared for:  
U.S. Department of Housing and Urban Development  
Office of Policy Development and Research  
August 2006

Prepared by:  
Michael O'Brien, Virginia Tech  
With assistance from Mark Nowak, Newport Partners L.L.C. and  
Ron Wakefield, Professor of Construction, Head, School of Property,  
Construction and Project Management, The Royal Melbourne Institute of  
Technology

Web tools developed by Gordon Miller & John Smith, G3 Systems Inc.

### **Acknowledgements:**

The research team would like to acknowledge the support and insight generously provided by the following people who supported this project.

Subrato Chandra, The Florida Solar Energy Commission, Bill Colbourne, at the URS Corporation, Pat Huelman at the University of Minnesota, Mike Mullens, The University of Central Florida and Brad Oberg at IBACOS.

Mike Blanford and Carlos Martin from the HUD Office of Policy Development and Research provided critical discussion and helpful input throughout the project.

Marilyn Cavell from the Center for Housing Research at Virginia Tech provided additional program support and financial oversight throughout the project.

Mark Nowak from Newport Partners L.L.C. authored the Whole House Calculator Critical Review and coordinated the building science experts input into the Performance Score Database which is described in Part Two. The small advances made in this second generation whole house calculator would not have been possible without his candid assessments of the first generation calculator.

Angie Baughman translated the expert meeting proceedings into preliminary logic interactions and translated Seismic, Wind, Precipitation, Cooling and Heating Degree day and Relative Humidity Data from maps to County-Level detailed spreadsheets and Manoj Mishra translated Radon maps to County-Level detailed spreadsheets. They are the significant contributors to this project.

Gordon Miller, John Smith and their team at G3 Systems Inc. developed the web-based tool for knowledge input by the outside systems experts and developed the interface and functionality for the final web-based whole house calculator.

The authors accept responsibility for the report and any shortcomings it may have.

Layout Design: Michael O'Brien  
Program Manager: C. Theodore Koebel

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## **Preface:**

This report documents the activities and outcomes of the primary tasks undertaken to complete contract number 2005-R-00104 titled PATH 13 "Whole House Calculator". The primary charges of this contract were to expand the functionality of the Whole House Calculator developed under contract number C-OPC-22032/CHI-T0002 "Designing Whole House Solutions". The following were the primary assigned tasks:

- Conduct a critical assessment of the calculator methodology, and output developed under C-OPC-22032/CHI-T0002, suggesting and incorporating improvements;
- Fully populating the elements of the Calculator including an attempt to address house location by region;
- Creating a functional Calculator that allows a user to input their house's System Choices, User Values, and house location;
- Testing the Calculator using a number of house specifications including the two original sample houses. An attempt should be made to test scoring differences for houses located in different regions;
- Reporting the findings.

These tasks were accomplished, exceeded in most cases in response to the critical assessment. Effectively a "new" whole house calculator was developed. Even with these improvements, the calculator must be considered a work-in-progress.

While much has been improved, some key questions regarding the expectations of subsystems performance remain. Is a below average score for the superstructure important enough to provoke a failing grade and an alert on the house configuration? The calculator currently fails any house configuration with a below average score for the superstructure system. Is energy inefficiency enough to fail a house? In which climate zones? Is below average moisture management enough to fail a house? Is there enough data from enough experts in the performance database to reduce the impact of bias from any one expert? These and other questions remain open and in need of timely resolution before the calculator can be considered a completed, not a beta-test product.

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## **Executive Summary:**

“A Preliminary Method to Develop a Calculator for Evaluating Physical Design Characteristics and Whole House Performance Scoring” documented the development of the first generation “Whole House Calculator”. Part One of this report contains the critical review of this calculator which pointed out numerous shortcomings including:

1. The extensive knowledge base required to input data;
2. Bias in the performance score database;
3. Lack of definitive research findings regarding the performance of materials and systems, impact of licensed professionals on the quality and performance of the final product and the effect of interactions between local conditions, materials, systems and production processes on overall house performance;
4. Limitations of the subsystems weighting method;
5. Limitations of the interaction scoring method;
6. Excessively complicated computational methods;
7. Lack of a warning notification when encountering a house configuration which may compromise structural integrity;
8. The limited number of houses tested;

These points underscore the difficulty of developing a methodology to aid designers and builders in understanding the impact of decisions and choices upon the performance of the house as a whole in a data-poor environment. The Whole House Calculator was completely rebuilt to address these shortcomings as much as possible within the available resources.

To address the knowledge base, a panel of building science experts proposed, and the GTR agreed, that the calculator should be developed with a professional user in mind.

The bias noted in item 2 was addressed by asking the group of building science experts to “populate” the systems performance database. While not eliminating bias, the larger number and broader disciplinary base of the experts should provide a more balanced view of the performance of various materials and subsystems choices. This expert panel also helped address item 3 by providing input based on their state of the art experience. This is further described in Part Two of the report.

Item 4, provoked a new approach to weighting the importance capable of weighting the performance of the building envelope and thermal systems for a house in Fargo, North Dakota and similarly, adjusting the weighting of the structural system for a house in the Outer Banks of North Carolina. A table of wind, seismic risk, radon risk, relative humidity, heating and cooling degree days was developed at a zip-code level of detail to provide a more rational systems weighting method capable of reflecting to local climatic and geological conditions. This is described in more detail in Part Four of the report.

Similarly, Item 5 provoked a new approach to evaluating the interactions between local climatic and geological conditions and the selected systems choices. The new approach is based on a logic subroutine evaluates the climatic/geological triggering factors with the contributing and mitigating factors involved in a negative system interaction. This is described in more detail in Part Five of this report.

Because of the new approaches to performance scoring, subsystems weighting and interaction scoring, the computation of a whole house score has been significantly simplified to be "Weighted performance x interaction = subsystem score". This is described in more detail in Part Three of the report.

Item 7 has been addressed with a logic statement runs after the superstructure grade is calculated. If the grade for the superstructure scores a "D" or less, the whole house receives a failing grade accompanied by the following notation;

- *"Because the structural system of this house configuration has scored substantially lower than the recommended practices house, the structural integrity of this configuration may be at serious risk. Because of this, the calculator has produced a failing grade for the whole house. Please reconsider some of the selections made in the superstructure tab to improve the performance of the structure for this location."*

This current version of the calculator only implements this check on the superstructure system but is programmed to allow implementation on other systems in future versions of the calculator.

Item 8, testing has been addressed by testing 6 case house configurations in 8 locations representing each of the regional divisions of the U.S.

- Blacksburg, VA 24060 which is in the "central" climate zone
- Fargo, ND 58102 which is in the "north central" climate zone
- Morton Grove, IL 60053 which is in the "north east" climate zone
- Beverly Hills, CA 90210 which is in the "west" climate zone
- Taos, NM 87512 which is in the "southwest" climate zone
- Yakima, WA 98901 which is in the "west" climate zone
- Androscoggin, ME 04210 which is in the "northeast" climate zone
- Alexander, IL 62914 which is in the "central" climate zone

These 48 tests include the two initial case study house configurations and four additional configurations:

- Case 1, two story, systems approach house with full basement high end production builder house
- Case 2, two story, standard approach house with full basement high end production builder house
- Case 3, two story, modular house with full basement "affordable" house.
- Case 4, one story, panelized house on slab, high end custom builder house.
- Case 5, one story slab on grade "affordable" house, high thermal performance design, volunteer labor.
- Case 6, one story over crawl space, "affordable" house, volunteer labor.

Testing revealed that the calculator is largely operating as expected. There is a logic problem which causes slab-on-grade configurations to score lower than they should. This is described in Part Six of this report. Test cases that had subsystems optimized for one geographic location did poorly when tested in a location with extreme climate and geological differences. Structural systems in test cases that excelled in Midwest failed in the seismic zones of the west. Building envelopes that excelled in the Middle-Atlantic states failed in the extreme temperatures of the Southwest. Still, the

calculator is in its early stages of development. There is not an abundance of data in the performance database, the reasoning behind the specific performance ratings is in even shorter supply and therefore has not been fully integrated in the systems interaction scoring, advances in sealed attic design, and timber-framed approaches to house design have not been included, and flood data is not yet part of the systems weighting calculations.

The calculator must be considered a work-in-progress. Some key questions regarding the expectations of subsystems performance remain.

- Is a below average score for the superstructure important enough to provoke a failing grade and an alert on the house configuration? The calculator currently fails any house configuration with a below average score for the superstructure system.
- Is energy inefficiency enough to fail a house? In which climate zones?
- Are below average scores for moisture management enough to fail a house?
- Are below average scores indoor air quality in locations where the heating and cooling degree days suggest occupants would spend much of the year inside enough to fail a house?
- Is there enough data from enough experts in the performance database to reduce the impact of bias from any one expert?

Until these and other open questions remain are resolved the calculator must be considered a beta-test product.

Still the tool functions to provide some insights into “what-if” scenarios so builders and designers can develop a sense of the impact of systems, materials and process choices. The federally-managed website limits the ease use of these “what-if” scenarios because to save a scenario, each user would have to be granted a login account. Should this become possible at some point in the future, it would greatly enhance the user experience, making the tool more relevant in the professional community.

## **Part One: Critical Review of Whole House Calculator**

This part contains the results of a review of the Whole-House Calculator as described in the Phase 2 final report by O'Brien and Wakefield dated April 24, 2005 (*Developing a Calculator for Evaluating Physical Design Characteristics and Whole House Performance: A Preliminary Method*). The objective of the critique is to identify potential oversights, weaknesses, or controversial parts of the whole-house calculator (the calculator) for the purpose of improving it where feasible.

The initial section of this report describes background information and related literature on the calculator and similar tools. This is followed by a discussion of the overall methodology used for the calculator, errors and bias that may be introduced, issues related to inputs or systems that are defined in the calculator, and finally, general comments on the calculator and Phase 2 report.

### **Background discussion**

The calculator is an adaptation of methods used for environmental studies in other fields of study. Thus, some background on these methods and their origins will be helpful in understanding the calculator.

Some of the earliest related work in the area of environmental impact assessment procedures was conducted by L.B Leopold and a team at the U.S. Geological Survey (USGS) in the early 1970s (*A Procedure for Evaluating Environmental Impact*, Leopold, et. al, USGS, Reston , VA., 1971). At the time, the USGS was reacting to congressional mandates in various environmental statutes that required assessment of projects to determine the best possible alternatives. The short time frame in which to develop these tools necessitated the use of expert opinion where the gaps in the knowledge would otherwise require years or decades of research to fill.

The process of developing a methodical approach to evaluating a project that combines scientific principles with expert opinion, usually in terms of scoring different systems or components, continues to be used in various disciplines. In the absence of a specific confirmatory test, the medical community often uses procedures of this type to diagnose conditions based on having a certain number of symptoms consistent with the condition. However, the environmental disciplines seem to have embraced these approaches more often than other disciplines.

Life Cycle Inventory (LCI) or Life Cycle Analysis (LCA) are examples of environmental-related tools that have been developed based on an approach that combines scientific principles with expert judgment to develop a "score" or point of comparison for a particular material, application or option. A good review of these types of tools was prepared as part of PATH's participation the BEES program development with the National Institute of Standards and Technology (*Life Cycle Assessment Tools to Measure Environmental Impact*, HUD, Washington, DC, 2001).

Perhaps more directly-applicable to this project is the work by the Scientific Committee on Problems of the Environment (SCOPE), a group established in 1969 by the International Council of Scientific Unions. The SCOPE 5 report

(*Environmental Impact Assessment: Principles and Procedures*, SCOPE, 1975, available for viewing at [www.icsu-scope.org](http://www.icsu-scope.org)) provides a critical review of a variety of assessment tools, including the Battelle system that the whole-house calculator is based upon (*Environmental Evaluation System for Water Resources Planning, Final Report*, N. Dee, et. al., Battelle Columbus Labs, Columbus, Ohio, 1972). Particular emphasis is placed on problems of uncertainty. The authors conclude with a warning about the proper use of these tools as methods to investigate environmental impact rather than as tools to make specific determinations. This is an important consideration for the whole-house calculator in terms of making sure users know how to interpret the results and, equally important, how not to use the results.

Although the Battelle Environmental Evaluation System (EES) was the basis for the whole-house calculator development, other literature describes similar tools. These include the Sorensen Method (*A Framework for Identification and Control of Resources Degradation and Conflict in the Multiple use of the Coastal Zone*, J.C. Sorensen, University of California Press, Berkeley, CA 1971), the Fisher and Davies Method (*An Approach to Assessing Environmental Impacts*, Fisher and Davies, University of Waterloo, Ontario, Canada, 1973), and similar models.

Other literature offers insight into the limitations and benefits of environmental assessment tools. A 1977 study by VA Tech offers an excellent overview of the various systems including Leopold's approach relative to computerized models (*A computerized Method for Abstracting and Evaluating Environmental Impact Statements*, Martel and Lackey, VA Tech Water Resources Research Center, Blacksburg, VA, 1977). Likewise, other work is proceeding to develop similar tools as the calculator, including an effort at Michigan State University (*Whole-house performance criteria framework and its application*, L. Swarup, Construction Management program at Michigan State University, 2005).

In summary, the calculator methodology is not a unique creation. Rather, it is an adaptation of techniques that have been in use for decades in the environmental assessment field. It shares many of the same pros and cons of those systems, plus a few unique to housing performance and systems interactions.

### **Issues related to the methodology**

The building industry and home buyers could benefit substantially from the ability to assess a home from a whole-house perspective. Tools are clearly needed to access the impact of various changes and interactions between the different systems. Its especially important to be able to assess the impact on performance in regard to new practices or materials. However, the information to address what are typically very complicated interactions does not always exist. Further, it would take decades at current levels of research funding to fill the major gaps.

As described earlier, this is similar to the situation faced in the environmental community over the past several decades. This necessitated the use of expert opinion to fill gaps in the knowledge. This is not unlike the whole-house calculator, where experts are necessary to determine the performance and interaction scores and weights of the subsystems in homes.

Acceptance of a methodology of the type used in the calculator that is built on expert opinion and a scoring or ranking system certainly requires more faith than a methodology that adheres to strict scientific principles. Experts tend to disagree with each other rather frequently. They have also been known to be wrong at times. Conflict in the literature over recommendations for moisture control in various climates is one example where reaching consensus would be difficult. Too many experts have different suggestions on how to control moisture. In the past, experts were certain that ventilation of crawlspaces and attics would prevent moisture problems only to find out later that ventilation may be increasing problems in some climates.

Another issue related to the methodology - also an issue with the environmental assessment tools that have been developed over the years - is the belief that scoring or somehow placing numerical values on a set of variables and manipulating the numbers through a series of mathematical operations will somehow yield meaningful results. Questions arise as to what exactly the final whole-house score signifies. What is a good score? What is a poor one? Is there any way to prove that the results are meaningful? Could a different set of people develop a very different approach that was equally valid or invalid?

Interpreting results from a scoring-based system is even more complicated when multiple scores or values are used. In the calculator, user values and expert weights are first chosen, these are multiplied by performance scores, and then further multiplied by interaction scores. One could question how it was determined that these operations are the most appropriate ones, even if they sound rational or are similar to operations in other accepted tools that are in use. Further, there are errors and biases associated with each scoring or weighting activity that takes place. These become multiplicative when combined in the operations that take place in the calculator. Even small errors in individual step can become significant when multiplied by other multiple small errors.

A final issue related to the methodology was mentioned in the report on the calculator - how are fatal flaws handled? In the calculator, it's very possible that a building with a relatively high score could fail sooner than a lower-scoring building because of some fatal error. This is possible because the methodology allows lower scores in some areas to be balanced out if other areas have higher scores. Also, the calculator limits the score on the negative end of an interaction. It's possible that a negative interaction that results in a structural collapse could have no less of an impact on the whole-house score than water entering the basement because of an omission of drain tile. Clearly, the occupants would view these in a different light.

Given the above issues related to the methodology, what, if anything should be done to the calculator? There is no easy answer to this question. If one takes strict adherence to scientific methods as the standard for evaluating the calculator, then there are likely to be many people who will never be convinced that the methodology is valid. On the other hand, policy makers, designers, and others are forced to make decisions every day based on less than perfect scientific data.

It would be hard to argue that there are not large data gaps in the information necessary to develop a calculator based completely on scientific methods and that at least some opinion is necessary to decide how to best weight, score, and assess interactions of various systems in homes. Although one



can raise some legitimate questions about the methodology and whether it can be “proven” to work, we won’t know how well the calculator actually represent the performance of a whole building until the calculator is applied to enough homes to analyze the meaning of the results.

One key to interpreting the results is how well the calculator differentiates between homes that are not very different in terms of design and construction versus those that are significantly different, and those that are somewhere in between (This relates to the discussion later on errors and bias). Do the operations and scoring reflect differences in buildings that one would expect? At least three scenarios exist:

Homes that differ slightly or not at all – It should be expected that the whole house scores would be the same or at least very similar.

Homes that are known to perform radically different. If the whole house score in this scenario is similar, then one would question the validity of the calculator. If, on the other hand, the scores are significantly different (with “significant” yet to be defined), then the calculator may be a useful tool for identifying homes that fall outside the normal range of housing performance

Homes at various points somewhere between the first two scenarios. If the first two scenarios give results as expected, then this last scenario should show us how discerning the calculator is as one moves closer to or further from the extremes.

It is noted that the calculator compares a subject home score to the best possible score for that home. Although this may prove to be useful, its somewhat of a circular argument since the same methodology is used for the best possible score as is used for the subject home score.

#### **Recommendation 1:**

Run many different types of homes where similar and different results would be expected to evaluate the ability of the calculator to discern similarities and differences. A couple of homes were scored during Phase 2 of the project, but that version of the calculator will undoubtedly change based on input from an expert work group during the current phase. Further, once a user interface is added, it should be easier to score a larger number of homes and assess the results.

Make sure the proper limitations for use of the calculator are disseminated with the calculator. Understanding that the calculator is a tool for relative comparison, at least until more is known about its ability to discern differences in design and construction of homes, is important for users to know. Scoring a single home without knowing how it compares to homes with known performance characteristics will reveal little about the individual home. Users also need to know that they influence the results by assigning weights to certain desired attributes (i.e. user values on attributes such as efficient, flexible, moisture response or safe). Thus, two identical homes could have very different scores if one user values an attribute more or less than a second user.

Build in a warning when a home has known fatal errors. This would address the situation where a house could conceivably receive a “good” score even though, for example, there might be a structural failure that is overlooked because the rest of the home performed exceptionally well. Note that this

was recognized in the final Phase 2 report, but how this is handled needs to be addressed in the calculator.

### **Errors and Bias**

An extensive knowledge base is required to use the calculator. The calculator requires some knowledge across a wide range of disciplines. It is unlikely that even a diverse group of experts would know enough about each system and subsystem's performance and interactions, or at least agree on most of the issues. Builders and consumers would be at a distinct disadvantage if required to score performance and interactions.

Even if the users are removed from the scoring process, the calculator still would present some challenge for the typical consumer or homeowner. Determining which systems and subsystems are in a specific home, without having this information handed to them in a format that is user friendly, is probably not a reasonable expectation for a typical consumer.

### **Recommendation 2:**

As proposed in the next phase of this work, the performance and interactions should be scored by the expert group. However, these scores should be set as optional defaults so that anyone with the knowledge to conduct the scoring on their own can do so.

There is no easy way to provide the knowledge for consumers to be able to properly describe the systems or subsystems in a home. The key may be in properly limiting who uses the calculator, along with a mix of advice on how to obtain the proper information.

Precision and variability associated with the calculator. The calculator results are best used to compare different scenarios or buildings, not to determine how a specific building performs by itself. Thus, the "real" answer or score for a home is not known, only the estimate derived by the scoring process. At this point in time, there is no easy way to assess the accuracy, or other errors associated with the methodology.

The calculator spreadsheets and mathematical operations offer sources of error that could be quantified, but these would be small and limited to errors like rounding functions internal to the software. Human error (entry errors, incorrect house data, or lack of understanding of user values) will also contribute to overall scoring errors. However, these types of errors would mostly be small compared to the variability introduced throughout the scoring process. They are probably not worth the effort to address.

Perhaps the largest variability will result from the bias introduced by the experts or users. It is unlikely that the same person would score a home in the same manner as another person even if their weights or values placed on attributes were the same. On the other hand, not much is known about the variability at this point in time and it is possible that only some of the bias introduced by different scorers would even have much of an impact on the final score.

### **Recommendation 3:**

There is no way to completely eliminate the variance or bias introduced by different users scoring a home with the calculator. Even experts will score a home different than other experts. One possible way to reduce the variance, which is part of the VA Tech plan in Phase 3 of the calculator development, is to limit the input or interaction of users. For example, some variance could be reduced by using a group of experts to reach consensus on the systems weightings, performance scores and the interaction scores. These could then be used as defaults for all users. Thus, the homeowner, builder, or other user would only input a description of the their home (i.e., its systems and subsystems) and distribute the 100 points for the user value ratings.

Limitations of the -3 to +3 range for interaction scores. There will always be questions about the choice of rating parameters for any system of this type. As with the many other issues in this review, the end results are probably the only feasible way to determine how well the system scores correlate with known house performance. However, the decision to limit the lower end of the range of interaction scores to -3 raises a few questions.

Is it reasonable to fix the lower limit of a negative interaction? This relates to other discussions in this critique related to fatal errors in a home. If a significant negative interaction is present, the limit on the bottom of the scoring range (-3) limits the impact of the interaction. Thus, a structural defect that can lead to a catastrophic failure can be given the same impact as use of a low R-value in the thermal envelope.

One can make a similar argument on the positive end of the range of interaction scores. However, items like excess structural capacity or high R-values have diminishing returns as compared to the impact of a catastrophic failure on the negative side of the range of possible interaction scores.

The ratings of -3 to +3 are all also relative in nature (referring to improvements or degradations), but it is not clear exactly what they are relative to. Is it the lack of the item in the factor (ventilated attic vs. no ventilated attic)? Is it another house design?

Interestingly, if interactions are considered very important then it seems like triple, quadruple and higher-level interactions might be important as well, but they are not considered at all in the rating process.

### **Recommendation 4:**

System weighting factors may reduce the impact of the limits on negative scores somewhat. For example, weighting the structural issues greater than other performance issues could help. The other option discussed elsewhere in this critique is to include flags for catastrophic interactions in the calculator. We also recommend some clarification on the basis for the relative comparison implied by the range of scores.

Multiplication of the performance score by the interaction score and normalization of the results. The calculator appropriately applies weighting factors based on user values and system importance to the system

performance scores. This is logical in that it offers an approach for recognizing the higher or lower impact of certain systems on the desired outcome. However, the calculator does nothing to directly weigh the impact between the performance score and the interaction score (Although see discussion below on the normalization process). Should the performance score be given the same weight as the interaction score?

It may also be appropriate to ask why the performance score is used at all to develop a whole house score. This seems to stretch the Battelle method by introducing a second overall objective into the scoring process. It is unclear why the performance score is multiplied by the interaction score, except that it seems like there should be some relationship between these two items.

Another potential important point is that the performance scores may not be mutually exclusive of the interaction score. Is some double counting occurring?

The calculator also attempts to normalize the interaction scores by taking the reciprocal of one minus the score divided by the variance. The variance is defined as the range between the lowest and highest possible interaction scores. The rationale given for this normalization is to correct for problems created by using an interaction score range of -3 to +3, whereby a negative interaction score could overwhelm an otherwise acceptable performance score by turning it negative. It seems like this is quite a complex number of steps to take and makes one wonder what these operations accomplish. As more and more operations are introduced, the less meaningful the result may be.

The adjustment process that calculates the value of  $(1/(1-(\text{score}/528)))$  converts a score of 264 to an interaction factor of 2.00, and a score of -264 to an interaction factor of 0.667. It seems good to get away from the negative scores, but this procedure is a non-linear adjustment, which may raise other internal consistency issues. Indeed, the whole complex process of using the interaction factor doesn't seem to change things much at all. That is because the "normalized" interaction factors range from about 0.99 to 1.19, while the weighted performance scores range by a factor of 10 or more. Since these scores are ultimately multiplied to arrive at a whole-house score, it appears the normalization process gives the performance scores a much greater impact on the whole-house score than the interaction scores.

#### **Recommendation 5:**

The developers of the calculator should better explain the purpose of the different mathematical operations used in the calculator and why these are the most appropriate. One approach that could be considered is to eliminate the negative interaction scoring system in favor of a 1 to 5 system similar to the performance scoring. This should eliminate the need to "normalize" the interaction scores and more evenly account for them with the performance scores.

House systems or characteristic that have multiple and conflicting impacts on performance. This may be appropriate to discuss in terms of a bias but also as an issue related to inputs (see next section). A good example from the calculator is the scoring related to insulation. Given the choice of none, R-11, R-13, or R-19 in walls, which one performs better? This depends on the attribute being evaluated. With the attribute of "lowers construction costs"

one might give a home with lower or even no insulation a high performance score. On the other hand, the same home would score better relative to the attribute of "efficiency" if the walls had R-19 versus R-11 or none. These scores may in fact cancel each other out in the overall performance score even though most people would agree that R-11 or less is probably not a good idea in modern home construction.

#### **Recommendation 6:**

The way user values are distributed may help address this issue but only to a limited extent. Another option to minimize the impact of these types of issues would be to limit system descriptions to a certain range that might be found in homes. In other words, don't allow inputs that fall below certain standards, like no insulation in walls. Code minimum requirements may be good starting points for performance expectations. This approach may be difficult to implement with older homes, but we already believe the data inputs issues restrict the tool to relatively new homes anyway (see discussion in later section of this critique).

Errors and inconsistencies in the User Input and Performance Score worksheet. A quick look through formulas shows that the owner weighting value for safety (cell D59) is not used elsewhere in the sheets, even though it is set at a value of 15. Presumably this is why the sheet includes question marks near that entry.

The "Municipal Water" column formulas in the systems house spreadsheet (column FA) are erroneous in that the "critical subsystems weighting" variable is not applied as it is with the other columns.

There are occasional system performance rankings of "0" scattered around the spreadsheets even though the report indicates that system choices are ranked from "1" to "5."

#### **Recommendation 7:**

Obviously the safety value needs to be implemented in some way, or else it should be eliminated. Likewise, the critical subsystems weights need to be accounted for in the Municipal Water column formulas.

Although not an error in the spreadsheet itself, the use of "0" values for performance ratings shows that the level of complexity and scope of the calculator can lead to errors on the part of users. It may be possible to restrict entries so that the calculator does not go to the next step unless the inputs are within the allowable range. Further, this technique may be extended to address the situation where a user inadvertently overlooks an entry and leaves it blank.

Incorrect number of interactions in the Interaction and Total Score worksheet. There are 89 factors in the sheet, implying  $89 \times 88 / 2 = 3,916$  interactions, not the 3,872 interactions indicated in the sheet. Since each of the 89 factors can interact with 88 others, the maximum score, minimum score and range of scores are correctly given in the sheet. One interesting thing about this approach is that the complexity introduced with each additional factor increases (in proportion to the number of factors) rather than remaining

constant, so the work to implement the system will inevitably grow faster than the number of factors.

#### **Recommendation 8:**

The Phase 2 report already recognizes the increase in complexity that adding more factors introduces. If possible to do so and still be confident in the results, further reductions in the number of factors would make the calculator much easier to understand and use. The number of interactions in the report should also be corrected, although this is not really much more than an editorial correction since it does not affect the later scores that are developed.

#### **Issues related to inputs and systems defined for the calculator**

Current system choices are a mix of design/management processes and specifications. This raises the question as to whether some undeserved credit is given to homes that employ design or management processes (e.g., use of an engineered HVAC system or other uses of design professionals versus following prescriptive requirements, use of a quality management systems, or safety training). If the performance of the home is the outcome of importance, does it matter how one gets there?

If a home is designed by a professional and therefore gets higher scores than a home that follows a prescriptive or conventional construction path, and that home also get high scores for the actual system or subsystem specifications that were designed, does this give more credit to one home over another even though they may both perform the same in reality? Likewise, if safety is valued by the user, is it appropriate to assume that trained staff will translate into a safer process?

Alternatively, should the calculator only address specifications? This is of particular importance if one wishes to compare an older home to a newer one. Does it really matter if an engineer was used in the design at this point or is actual performance as reflected in the specifications and systems what really matters? This also has implications for builders who use the tool since they would have a tough time determining if systems put in by subcontractors were designed or the subcontractor's staff had been trained in safety issues.

It is also confusing to have procedures as early elements in the list (e.g., use of an architect or engineer) and design features, such as full sheathing, further down the list. Does this distort scores? To illustrate this issue, note that the architect/full sheathing cell has a rating of "1". The architect/engineer rating presumably is higher because they use better construction features, like full sheathing, but then it seems like double counting to give credit for the architect/engineer (because they often use better construction features) and give additional credit for using full sheathing. This might call for including separate cross-ratings in the two directions, which might usually be the same (X improves Y, and Y improves X) but might be different (X improves Y, but Y has no effect on X). Also, maybe it's unrealistic, but it would seem much simpler to limit this list to design features

#### **Recommendation 9:**

If the objective is to score the homes performance, then it may be reasonable to drop the processes as system choices that impact performance. There does not appear to be strong support in the literature that support a relationship between these processes and the building's performance. In fact, HUD sponsored a study of performance of homes after the 1994 Northridge Earthquake in which the authors found that homes built to older prescriptive methods performed very well (*Assessment of Damage to Residential Buildings Caused by the Northridge Earthquake*, July 30, 1994. Prepared for HUD Office of Policy Development and Research Washington, DC ). They found no structural performance differences compared to homes that were designed by a professional.

The system choices are not comprehensive. This may seem somewhat nit-picky given the large number of systems choices that are in the calculator. Further, one could continue to add more choices to the point where the calculator is unwieldy. Like the issues raised over the methodology, determining whether all of the right choices are represented may best be determined by comparing the results. However, there may be some high impact items that are not addressed that may be worth adding to the calculator. Most prominent of the missing choices are climatic or regional issues and building size.

Climatic issues cut across a wide variety of systems from thermal envelopes to structural systems. In a similar fashion, regional issues such as high winds or extreme snow loads affect the performance of multiple systems. As described in the Phase 2 report, the calculator does not directly address climatic or regional issues. Indirectly, the person scoring the performance and the interactions can consider the impact of their scores relative to location or climate.

The size of the home is not as easily addressed, yet it has perhaps the largest impact on performance issues related to environmental impact, cost of construction, construction time, and reduced system part count. The size of homes is a controversial issue in the green building world – no one wants to touch it out of fear that larger homes that are built today may somehow be tagged as poor choices for the environment. Although it may be draw heavy resistance, the building size should be a factor and its absence seems to be an important oversight in the calculator.

#### **Recommendation 10:**

The climate or regional issues could continue to be addressed during the scoring process. However, this makes the scoring process even more subjective without some guidance on which systems are influenced by climate or location. Its also very easy to forget about the climate and regional issues when caught up in the process of scoring a home. Using the expert work group to establish the interactions and performance scores will take some of the subjectivity away from the process.

A second option would be to add climatic factors into the calculator such that they serve as reminders to the user. However, this seems too complicated given the way the scoring matrix is set up.

A third option would be to develop different versions of the calculator for the major climates or regions in the United States. As with the second option, this very well may be impractical given the resources available to develop the calculator.

On the size of the home, it's unlikely that the calculator will be able to fully address the implications that come with this issue. Our suggestion is to handle this in the way the results are presented and compared. For example, ranges of house size could be developed and any home that falls in a specific range should only be compared to other homes in the same range.

Costs are not directly considered in the calculator – From a consumer or builder perspective, the payback or return on investment for a home that performs better (or worse) than another home is important in the decision-making process. The calculator does not address these issues directly. Costs are considered indirectly as part of the home's systems performance relative to attributes like "reduces construction costs" and "reduces construction time."

#### **Recommendation 11:**

The question of whether to include some method for addressing affordability or cost impacts, beyond those attributes already included in the calculator, is really a question of the scope that one prefers for the calculator. The other approaches, such as the Battelle method, take a similar approach on costs as the whole-house calculator – they emphasize performance. Thus, it may not be a fair criticism of the calculator to claim that the lack of emphasis on costs is a shortcoming, but rather a limitation on the scope.

If it is desired to address cost more directly, it may be possible to develop a separate add-on to the calculator in the future. For example, an algorithm could be developed that computes a simple payback associated with moving from one home with a certain score to another with a higher score. Thus, the user of the calculator would have two pieces of information to evaluate their home – the whole house score and a payback analysis.

However, given that the market conditions (supply and demand), especially in a hot housing market, often dwarf other factors that determine the cost of a home, it's possible that the results of such a comparison would be meaningless or confusing. It's not improbable that a lower scoring home in a highly desirable neighborhood could cost much more than a better scoring home in a different location.

Availability of data for older homes – This is an issue that may apply to new homes, but is probably more applicable to older homes. First, it is likely that many of the systems in an older home can't be identified for use in the calculator. Insulation values in walls, presence of a vapor barrier, or even the drainage system are examples of systems that are not visible or easy to identify once the home is built. This could even be a problem in a new home given that detailed record-keeping in the form of as-built plans and/or specifications are not always typical practices in the residential construction industry.



## **Recommendation 12:**

Given the difficulty in using the calculator for existing homes, we suggest that the scope be limited to new construction.

## **General Comments on the First Generation Calculator**

The Phase 2 report describing the calculator is polished and professional. However, the complexity of the calculator as presented, although impressive and probably valuable in terms of its level of detail, is so vast as to make it very hard to get an intuitive understanding of what is going on. We would recommend presenting and discussing a simplified version of the same system (e.g., maybe ten factors and ten House Composition features), then moving on to the more elaborate version. It would also be very helpful to include some diagrams showing how data flows through the analysis.

The current plan with the calculator is to convene a group of experts in January of 2006 to develop critical system weighting factors and to score the systems for performance and interactions. The results will then be used to revise the calculator and fit it into a user-friendly front end. The development of a user-friendly front end suggests that somewhere over the past several months, the program has moved from researching the potential of developing a whole-house calculator to implementing and using the calculator on a broad basis by a general audience.

Convening the experts could very well be a useful exercise in that someone needs to go through the process of scoring the factors and interactions if the calculator is to be developed further. However, developing a polished front-end and releasing the calculator for practical use is premature at this time. The validity of the tool has not yet been established.

Although a three-day workshop is planned for the experts, it may be more fruitful to use some of the funds for the workshop to hire the experts to go through the scoring process. Once the scores are analyzed, a much shorter workshop (maybe one day) could be convened to address the areas where there are large disagreements.

The results of the expert's scoring could be used as defaults for the calculator. Once these are established, it may be more useful to run the calculator on a large variety of homes to assess the variability of the results, rather than focus on the development of a user-friendly front end. This would provide much better information on the calculator's validity and create a decision point before disseminating the calculator to potential users. On the other hand, the presence of a cleaner method to input a home's systems would make it easier to assess a larger group of homes. However, the front-end does not have to be a polished system to accomplish this objective.

## Outcomes of the Critical Review:

The critical review brought up several key weaknesses in the first generation calculator and its underlying methodology. This section will present the impact of the recommendations in the critical review on the development of the second generation whole house calculator.

Recommendation 1 proposes more extensive testing. Testing of the second generation whole house calculator described in Part Six of this report confirms compliance with this recommendation. In addition to testing the two house configurations utilized in the previous report, four additional house types are tested in eight different locations. This recommendation further suggests that the summary report of house configurations containing fatal errors should include a warning of the fatal errors. This functionality has been specifically included for the superstructure system in the second generation whole house calculator. Any superstructure receiving a grade of “D” or less triggers a failing grade for the whole house accompanied by the following text:

*“\*Because the structural system of this house configuration has scored substantially lower than the recommended practices house, the structural integrity of this configuration may be at serious risk. Because of this, the calculator has produced a failing grade for the whole house. Please reconsider some of the selections made in the superstructure tab to improve the performance of the structure for this location.”*

The summary report clearly indicates which subsystems “pass” or “fail” and allows the user to compare detailed scoring of their house subsystem with the recommended practice subsystem.

Recommendation 2 suggests that interaction scoring be accessible to users of the second generation whole house calculator for users who are knowledgeable to score interactions on their own. The second generation whole house calculator does not provide this functionality as it would allow any user to adjust interaction scores to achieve a desired overall grade. The method for arriving at systems interaction scores was completely revised from a static-score approach to a computed-logic-based approach that considers the triggering, contributing and mitigating factors in arriving at an interaction score. This revised method is described in Part Five of this report. Recommendation 2 goes further in pointing out that consumers will not have the knowledge to answer detailed questions about the processes and systems composition of their home to be able to effectively use the calculator. During the expert meeting, the group consensus, affirmed by the GTR, was that the calculator should be developed with the professional user in mind, and be applicable to new construction. This restricted scope of functionality simplified both data input by the building science experts and the design of the web interface for the calculator.

Recommendation 3 points out the bias inherently present in the performance and interaction scores. The recommendation assumes users will have access to and will provide their own performance and interaction scores. This is not the case. The second generation whole house calculator follows the recommendation to populate the performance database with input from industry experts, but also developed a rational basis for arriving at systems weighting based on the magnitude of climatic and seismic forces and risk level of radon exposure in each Zip Code of the United States. This system weighting method is described in Part Four of this report.

Recommendation 4 points out that the net result of the systems weighting factor was to reduce the impact of the negative scores. The recommendation proposes an example where structural concerns would receive greater weighting factors than other performance issues. The revised method for arriving at systems weighting factors described in Part Four of this report provides for a more accurate determination of magnitude and application of system weighting factors as they are determined by the specific exposure of the house to the climatic or geologic phenomenon according to the Zip Code or county location of the house. Testing confirms that a house configuration having superstructure characteristics that earn it an "A" in a low wind zone, low seismic magnitude zone earns "D" or "F" grades when placed in a Zip Code with a high wind or seismic magnitude location.

Recommendation 5 suggests a more extensive rationale for the mathematical operations used in the calculator and goes further to suggest the elimination of negative number scoring values used in the first generation calculator. The calculation method for the second generation calculator has been extensively revised, and is explained in detail in Part Two of this report. Negative number scoring has been eliminated, accepting the recommendation to move to a 1 through X range for performance scoring. Normalization operations have been eliminated from the second generation calculation method.

Recommendation 6 is primarily concerned with the scoring of performance within variable value systems. The example describes insulation choice and notes that R-11 insulation should score higher than R-19 if the performance standard is first cost, while R-19 should score higher than R-11 if thermal performance is the metric. Cost is the most difficult metric to address in the calculator. The industry experts debated this issue at the expert meeting and observed that the range of cost metrics includes first cost to the builder, sales cost to the buyer, operating cost to the occupant, and environmental cost to society. The conclusion from the discussion was to not explicitly address costs in this generation of the calculator. The industry experts were encouraged to input performance scores irrespective of cost. In populating the performance score database, industry experts were asked to indicate the reasoning behind their scoring by marking First Cost, Long Term Cost, Occupant Comfort (Thermal Moisture Acoustic), Occupant Health and Safety, Durability, Structural Behavior and Construction Productivity over a ten point range from Not Applicable, to grades of Disadvantage, Non Issue or Advantage. The quantity of this reasoning data limited its applicability to addressing the variable value system in the second generation calculator.

Recommendation 7 points out the problems that could occur if the user is inputting systems interaction data. The second generation calculator does not allow for user input in the systems interaction factors. The method for arriving at systems interaction scores was completely revised from a static-score approach to a computed-logic-based approach that considers the triggering, contributing and mitigating factors in arriving at an interaction score. This revised method is described in Part Five of this report.

Recommendation 8 is focused on the combination of the design/management processes with systems and materials specifications in the calculator. The concern is whether undeserved credit is given to homes produced using design/engineering/management services versus a home produced using prescriptive methods. The core question asked is "If the performance of a home is the outcome of importance, does it matter how one

gets there?" The value of the contributions made by professionally licensed and non-licensed accountable personnel in the design, coordination, execution and inspection of the complex details weaving discrete materials, subcontracts, and systems into a well-performing whole is largely established by the expert panel members performance scores for these systems choices in the second generation calculator.

Recommendation 9 begins with a continuation with the focus of recommendation 8, pointing out that the HUD-OPDR publication produced by the NAHB Research Center "Assessment of Damage to Residential Buildings Caused by the Northridge Earthquake" observed that homes built to older prescriptive methods performed very well. There is no argument that in the past, prescriptive methods employed by trained builders who understood the local climatic and geologic conditions will perform well. The FEMA assessment of residential structural shortcomings documented numerous instances of errors in installation and inspection leading to catastrophic failure of prescriptively designed residences. There is no definitive research to resolve this question. The second generation calculator continues to value the role of multiple, accountable, licensed and non-licensed professionals who have a stake in the successful execution of the structural, thermal, moisture management systems and air quality of the house as a whole.

Recommendation 9 continues and correctly identifies the wide variations of climate and geologic conditions across the country which have significant impacts on performance of the envelope and thermal systems. This led to the Zip Code-county approach to calculating climatic and geologic systems weighting factors described in Part Four of this report and was a significant influence on the redesign of the method for calculating systems interactions as described in Part Five of this report.

The final point made in recommendation 9 is that the size of the house should be included as a factor in the calculator. This has been included in the second generation whole house calculator but needs further emphasis. It is hoped that if/when a subsequent generation of the calculator is developed that static databases and logic subroutines can be replaced by streaming simulation to provide more customized and accurate predictions of structural, thermal, moisture, air quality, environmental, and perhaps the economics of performance.

Recommendation 10 begins with a continuation of the concern for the climatic and geologic regional differences given the stated Middle-Atlantic perspective of the first generation calculator's performance scoring database. This was the key driver in asking the panel of building science experts to make recommendations on a 1 to 10 scale (1=not recommended, 10=highly recommended) for each of the systems choices in each of the seven regions of the U.S. drawn from the HUD Rehab Advisor climate region map. This substantially challenged the expert panel populating the performance database. Some panel members did not feel qualified to address each region of the country with their recommendations while others were able to address each region. It is hoped that sufficient funding will be available to facilitate annual commissioning of recommendations by building science experts to the performance database. Increasing the number of building science experts providing input, will lower the impact of any one expert's regional or personal bias, improving the balance of the performance scores in the database.

The concern for the impact of local climatic and geologic on the house systems was also addressed by developing the rational basis for arriving at systems weighting based on the magnitude of climatic and geologic forces in each county of the United States. This system weighting method is described in Part Four of this report.

Recommendation 11 begins with a concern for subjectivity in the scoring of performance by the user. No user scoring is required for use of the second generation whole house calculator. Recommendation 11 concludes by pointing out that costs are not considered directly in the calculator. It is hoped that subsequent versions of the calculator might be able to address relative or actual costs via licensing agreements between HUD and data-brokers to provide an analysis of market or location value, first, operating and lifetime costs (including de-commissioning) could be presented to the user for the house and neighborhood in question. The linkage to GIS based public data relevant to determining the impact of location on cost or value is in the early stages of consideration at this time. It is conceivable that within two additional generations of the calculator, the "Whole-House, Whole-Neighborhood" will become the focus of the calculator.

Recommendation 11 continues by pointing out the lack of available process and specification data for older homes. Recommendation 12 suggests that the scope of the second generation calculator be limited to new construction. This was verified during the expert panel discussion and the consensus of the group was that the initial focus should be on new and recently built homes. Thus, the second generation calculator does not contain the data or systems choices needed to describe an older existing home.

## **Part Two: Populating the 2006 version of the Performance Score Database**

The whole house calculator is based on the premise that much of the data necessary to predict whole-house performance does not exist and would take years or even decades to develop. Tens of thousands of potential system and subsystem interactions would need to be investigated. Thus, populating the data for the calculator was approached using expert opinion to fill in the gaps where quantifiable information is missing.

The approach included:

1. Identifying and recruiting appropriate experts
2. Convening the experts to identify the most significant systems, subsystems, and interactions during a two-day workshop in March 2006
3. Developing an internet-based tool for further identification of important systems, subsystems, and interactions
4. Coordinating with the experts in using the internet-based tool to score the importance of the systems and subsystems and their relative level of interaction.
5. Developing the rationale or rules for the calculator and populating tables in the calculator based on the experts' input at the workshop and from the internet-based scoring exercises

### **Expert group participants**

The participants were selected based on their experience and geographical location. The goal was to include an expert knowledgeable in as many of the various climate regions as possible, with particular emphasis on cold, hot-humid, hot-dry, marine, and mixed climates. The experts and others who participated in the workshop and scoring exercises included:

William Colbourne, URS Corporation  
Subrato Chandra, Florida Solar Energy Center  
Pat Heulman, University of Minnesota  
Gordon Miller, G3  
Michael Mullens, University of Central Florida  
Mark Nowak, Newport Partners LLC  
Bradley Oberg, IBACOS  
Michael O'Brien, VA Tech  
Michael Blanford, U.S. Department of Housing and Urban development (HUD)  
Carlos Martin, HUD  
Dave Engel, HUD  
Liza Bowles, Newport Partners LLC (facilitator)

## Workshop

The initial session of the workshop was focused on interactions the experts have identified through their own or others research and experience. The general approach was to identify potential problems or issues with housing. This information was intended to supplement the findings from the literature review and input in earlier phases of the calculator development and to provide the basis for determining priorities that the calculator should address.

In the morning session, the group identified common problems or concerns during normal duty periods and under more extreme or severe duty. Severe duty includes service during hurricanes, earthquakes, fires, and other events where climate and other local conditions place homes at higher risk. Tables 1 and 2 contain the issues in each category.

Table 1 – Normal Duty Issues

Inadequate or no window flashing
Foundation moisture/water entry/poor drainage and grading
Poor indoor comfort
Weatherstripping failure
Deteriorating paint and other coatings
Foundation cracking/settlement
Combustion backdrafting
Poor interior finishes
Excessive floor bounce/inadequate stiffness
Indoor air quality (dust/allergens, VOCs, glue and adhesive outgassing)
Poor energy performance
Bulk water from plumbing
Use of materials/equipment/systems in inappropriate climate or application
Deck/balcony collapse
Inadequate ventilation
Poor control of noise (outside and room to room)
Floor squeaks
Drywall pops and cracking
Uncontrolled air transport across the envelope
Cracking in masonry construction
OSB expansion under shingles (ridging)
Garage air entering house
Moisture redistribution in framing and finish materials
Trade interference with previously completed work
Masonry chimney lining failures
Inadequate wiring/electrical systems (mostly in older homes)
Siding loss
Poor summer humidity control
Pipe corrosion
Plumbing leaks
Poor delivery/supply of hot water
Window failures (stuck windows)
Inadequate termite protection
Inadequate fire protection
Too many roof penetrations (moisture and air leakage)
Too many non-window/door openings (moisture and air leakage)
Poor kitchen and bath ventilation
Oversized HVAC equipment
Oversized ducts

Ground moisture with slab foundations (carpet moisture) Poor dryer venting Indoor odors Soiling/particle deposition on light colored carpets Premature wearing of finishes Multi-level single zone HVAC systems leading to temperature variations Footings settlement/cracking from poor soils Poor drying potential of construction materials Mold Thermal and hygroscopic expansion of materials Pressure imbalances throughout the home Poor placement of heatpumps and AC units Loss of shingles Poor installation of all types of materials and equipment
---

Table 2 – Severe Duty issues

Shingle loss Siding loss Roof sheathing loss Hail damage Corrosion of fasteners in coastal areas Wind-borne debris impact damage Wind driven rain through soffits and roof vents Inadequate concrete design/reinforcement Un-reinforced masonry chimney failures in seismic events Water heater damage in seismic events Poor material selection in wild fire areas Plumbing and electric in breakaway walls Falling trees Rapid structural failure in fires (trusses, engineered products) Impact resistant glazing reducing firefighter emergency access Incomplete/non-continuous load path Copper pin holes/plumbing leaks in aggressive soils or water
---

The group examined the results from Tables 1 and 2 to help identify those issues that are the highest priorities for the calculator to address. Table 3 contains a list of the priorities.

Table 3 – Priority issues

Structural inadequacy of floors (deflection and vibration) Lack of continuous load path Degradation of structural fasteners Ground moisture Wind-driven rain Inadequate ventilation leading to poor indoor air quality (IAQ) Combustion backdrafting (IAQ) Inadequate or oversized HVAC equipment Poor placement and sizing of ducts Inadequate HVAC controls Siding/roofing/cladding loss Uncontrolled air transport across envelope Poor attention to noise (from outside and room to room) Ground moisture affecting carpets on slabs Poor indoor humidity control Poor comfort due to inadequate insulation integrity Poor comfort due to dust/allergens/mold
---



High maintenance requirements of some materials and systems  
 Bulk water intrusion/inadequate flashing and opening protection  
 Foundation settlement  
 Poor site drainage/grading  
 Use of materials in locations where not appropriate (e.g., vinyl wall paper in hot-humid climate)  
 Drywall cracks and pops  
 Interior finish failures  
 Poor energy performance  
 Poor installation quality

In the afternoon session, the group elaborated on the priorities by discussing ways in which the calculator could or should address certain issues. This guidance helped to confirm the approach used in the calculator and identified areas where changes may be necessary.

During the second day, the group discussed limitations on the scope and application of the calculator and reviewed the process for using the internet-based tool to score the inputs for the calculator.

Highlights on the scope and application discussion include the following:

- New homes versus older existing homes present difficulties for users of the calculator who may not have access to the information needed to describe a home. For example, the location or even presence of a vapor barrier in a wall assembly would not be evident to a consumer looking to assess an older existing home. A home where plans and specification are available would be necessary to fully describe a home. The consensus of the group was that the initial focus should be on new and recently built homes.
- Processes such as third party quality assurance or use of a professional designer do not always result in better performance nor do homes built without these processes necessarily show lower performance across the board. However, for many complex systems, the presence of a process designed to increase quality of performance (e.g., Building America or Energy Star programs) increases the chance that negative interactions will be minimized or eliminated. The consensus of the group was that these process issues should indicate a positive impact on the home's performance.
- Installation quality is a large factor in how a system will perform. The group suggested that scorers of different systems and subsystems should consider that standard installation practices have been followed. On a related topic, prefabrication of components should not be considered to offer any performance advantages. Experience with quality improvements due to prefabrication of typical systems used today does not guarantee improved performance.
- Interpreting scores from the calculator requires some care and qualifiers. There is a large experimental component to the development of the calculator. Experience with it is needed to determine how to best interpret and compare scores. Some proof testing on various homes in different climates or exposures is necessary before the scope and limitations can be better defined. This should be viewed as the first iteration of the calculator. Appropriate disclaimers should be applied as the calculator is used and further developed.

- Builders and architects or designers are the primary intended users. As the limitations and capabilities of the calculator are better understood, the target user audience may be expanded to include consumers.

## Scoring exercise

The participants were guided through the scoring tool and given the opportunity to view the screens they would need to score. The participants left the workshop with a log-in name and password to enable them to use the scoring tool from their homes or offices.

During the April to June 2006 timeframe, each participant scored the climate zones they felt most knowledgeable about. Some scored every climate zone while others scored only one or two where they have the most experience.

The scoring exercises included three parts. Part 1 as illustrated in the screen below, Figure 1, was designed to identify the relative importance of 10 systems or inputs to the overall performance of a home in six different climate zones.

Figure 1: Expert Panel Database, Relative Importance of Subsystems.

Whole House Survey: Data Collection Tool

Log Off

Survey Save / Continue >>

Priority Ranking

Rate the importance of these subsystems for each of the six regions of the U.S., where 1 is not important and 100 is extremely important.

☒ Northeast ☒ Central ☒ North Central ☒ Southwest ☒ Southeast ☒ West Save / Next Region

Performance Issues:	Ranking:
Process & Production Design	5
Foundation	25
Superstructure	25
Envelope Systems	75
Interior Partitions & Finishes	5
Millwork & Appliances	5
Utility Distribution	25
Electric Power & Light	5
Sewer & Water	5
Thermal Systems	75

Regions:

Map showing the six regions of the U.S. with color-coded areas: North Central (blue), Northeast (green), Central (yellow), Southwest (orange), Southeast (red), and West (purple).

< Region Region >

start Whole House Survey... 3:54 PM

Part 2 was designed to identify the most and least important systems in a home by rating materials and methods from poor to best performance in each climate zone. Participants entered scores as illustrated in Figure 2, the screen below.

Figure 2. Expert Panel Database, Importance Scoring.

Whole House Survey: Data Collection Tool

Progress:  Log Off

Survey Main Menu Go Save / Continue >>

Survey Questions

Please rate the following subsystem alternatives from least desirable to most desirable for each region. You can navigate to different regions by clicking the appropriate tab, clicking an area of the map, or by using the previous/next region buttons.

Subsystem: Thermal Systems Save / Next Region

☒ Northeast ☒ Central ☒ North Central ☒ Southwest ☒ Southeast ☒ West

Overall Strategies	Ranking:	NA	Poor	Good	Best
All System Options:					
Central system					
Room by room conditioning					
Through the wall units					
Window units					

Heating Strategies	Ranking:	NA	Poor	Good	Best
All System Options:					
Gas fired boiler or water heater					
Oil fired boiler or water heater					
Electric boiler or water heater					
Gas hot air furnace					
Oil hot air furnace					
Electric hot air furnace					
Ground coupled electric heat pump					

Regions:

Map of the United States showing regions: NORTH CENTRAL, NORTHEAST, WEST, SOUTHWEST, SOUTHEAST, CENTRAL.

< Region Region >

The results of Part 2 were compiled by G3 (the calculator software developer) and used in Part 3 to further probe why the participants scored items a certain way. Only the highest and lowest scored systems were further evaluated in Part 3. The items that were rated as neutral, meaning they had little impact on a homes performance, were not addressed in Part 3. A sample screen from Part 3 is shown below.

Figure 3. Expert Panel Database, Reasoning Scoring.

Whole House Survey: Data Collection Tool

Progress:  Log Off

Survey Main Menu Go Save / Continue >>

Survey Questions

Please rate whether the following factors are an advantage, disadvantage or nonissue. You can also provide any additional comments that help explain your rating.

Subsystem: Thermal Systems Save / Next Region

☒ Northeast ☒ Central ☒ North Central ☒ Southwest ☒ Southeast ☒ West

Overall Strategies: Central system	Ranking:	NA	Disadv.	Non Issue	Advantage
System Options:					
First Cost					
Long Term Cost					
Occupant Comfort (Thermal Moisture Acoustic)					
Occupant Health and Safety					
Durability					
Structural Behavior					
Construction Productivity					

Comments:

Cooling Strategies: Central forced air

Ranking:	NA	Disadv.	Non Issue	Advantage
System Options:				
First Cost				
Long Term Cost				
Occupant Comfort (Thermal Moisture Acoustic)				

Regions:

Map of the United States showing regions: NORTH CENTRAL, NORTHEAST, WEST, SOUTHWEST, SOUTHEAST, CENTRAL.

< Region Region >

Comments:

### **Compiling the scoring results**

The information from the scoring exercises was compiled to determine average scores for the systems expected to be found in typical homes in each climatic region of the United States. This information was used with the mitigating factors identified in the March 2006 workshop to develop the reasoning and to populate the calculator. Multiple “proof” runs of the calculator were conducted on a variety of homes and climate regions, as described elsewhere in this report.

### Part Three The Second Generation Whole House Calculator:

Given the critical review and the availability of a group of building science experts, the whole house calculator was completely rebuilt to address the shortcomings of the first generation calculator and take advantage of the available building science expertise.

The key features of the second generation are:

- Simplified mathematics;
- Simplified data input;
- A rational basis for systems weighting (described in Part Four);
- A logic-based method for assessing the impact of complex systems interactions (described in Part Five);
- Elimination of either performance or interaction scoring by the user;
- Results output as a letter grade in a “Report Card” format (described in Part Three);
- Results of a house configured by the user is compared to a “Recommended Practices” house instead of a theoretical perfect score (described in Part Six);
- The tool is now web-deployed, not deployed in excel spreadsheets (described in Part Three).

#### Simplified mathematics:

The previous calculator used mathematical processes that the critical review noted as unnecessarily complicated and produced a set of results that were difficult to verify. This led to an overhaul of the scoring ranges, logic and mathematics of the second generation calculator.

The second and first generation whole house survey tools share a similar conceptual structure. Both tools employ:

- A set of systems choices for the processes, materials and systems used in production homebuilding today;
- A performance database filled with numerical rankings for each of the systems choices;
- An Interaction database.

Beyond this the second-generation calculator is all-new.

The new calculator operates in the following manner:

1. The user inputs a location for the house. This can be in the form of the State and County, or as the Zip Code for the location of the house. This location decision queries the database to extract:
  - a regional set of performance scores,  $\{RP_s\}$ , previously input by the expert panel;
  - a county set of systems weighting factors,  $\{S_w\}$ ;
  - a regional set of systems interaction factors,  $\{I_f\}$ ;
  - and a regional set of recommended practices,  $\{Rp\}$ .
2. The user is now presented with a webpage showing 10 systems tabs containing a total of 476 systems choices. Each tab clicked on allows the user to make selections of systems choices that most closely describe the house they plan to build.

3. Based the systems choices chosen by the user in step 2, the calculator selects the systems choices performance scores  $\{P_s\}$  from the set of regional performance scores,  $\{RP_s\}$ ;
4. Each systems choice is mapped to one to five systems weighting factors. These are:
  - Wind  $S_{w1}$ ;
  - Seismic  $S_{w2}$
  - Radon  $S_{w3}$ ;
  - Relative Humidity;  $S_{w4}$
  - Precipitation  $S_{w5}$ ;
  - Heating Degree Days  $S_{w6}$ ;
  - Cooling Degree Days  $S_{w7}$ .

Please see appendix one for the complete list of systems choices and the weighting factors for each.

Once the users systems choices are made, the performance score for each systems choice is multiplied by the systems weighting factor or factors mapped to that systems choice.

$$WP = (P_s \times S_{w1} \times S_{w2} \times S_{w3} \times S_{w4} \times S_{w5} \times S_{w6} \times S_{w7})$$

The basis for developing each weighting factor is described in Part Four of this report: A Rational Basis for Systems Weighting.

5. These weighted performance scores for each of the systems choices, selected by the user to make up the house configuration, are then checked against regionally specific systems interactions,  $\{I_f\}$ , selected in step 3

At this stage of the calculator development, eleven systems interactions composed of approximately nine-hundred triggering, contributing and mitigating factors have been implemented. These are:

- Seismic collapse
- High wind collapse
- High wind induced water intrusion
- Structural degradation from excessive moisture levels
- Mold Mildew Air Quality concerns from excess moisture levels in Warm Climates
- Benzene/Hydrocarbons in Interiors in High Cooling Degree Day Climates
- Benzene/Hydrocarbons in Interiors in High Heating Degree Day Climates
- EIFS/Framing Interaction in Hot Humid Climates
- Carpet Mold
- Premature Roofing Aging due to Overheating
- Radon Intrusion

These systems interactions are extracted based on the Zip Code or state and county input by the user. They are sets of logic subprograms that check the list of systems choices selected by the user against a series of lists of factors contributing to, mitigating and triggering an interaction between the climatic and geologic characteristics of a region against the set of systems choices making up the house's configuration. This is more fully described in Part Five of this report: A Logic-Based Method to Account for Systems

Interactions. Configuring additional systems interaction subroutines must be a high priority of subsequent iterations of the whole house calculator as this handful, while useful for testing the logic-based approach, is not fully inclusive of important interactions that occur between house systems and the local climatic and geologic conditions.

6. The summary calculation is executed for each systems choice after weighting factors and interaction factors are applied:

Expressed as a formula this would be:

$$T_s = \sum ((P_s \times S_w) + I_f)$$

Where:

$T_s$  Total Score for the house configuration input by the User;  
 $P_s$  Performance score input for the house region;  
 $S_w$  System Weighting for the local (State, County, Zip Code);  
 $I_f$  System Interaction factor(s) for the region;  
 $RP_s$  Recommended Practices house score;  
 $Tg$  Total Grade for house configuration input by the User as a percentage of the Recommended Practices house score, expressed as a letter grade.

7. The resulting score for each subsystem tab is compared to a “Recommended Practices” House configuration for the same region. See Appendix 4 “Recommended Practices House Configurations” for configuration details. The comparison produces a report card with a numerical score for “your house” ( $T_s$ ), a numerical score for the “recommended practices” house, ( $RP_s$ ) and a letter grade for each subsystem and for the house as a whole ( $Tg$ ). The six recommended practices houses (one for each region) were developed largely from principles found in the “Building America Best Practices Series” which can be found at <http://www.eere.energy.gov/buildings/>.

### **Simplified data input;**

The discussion during the expert panel meeting affirmed the potential of the following approach to the revised calculator:

1. The user enters Zip Code or county/state;
2. The database is delimited to the regional performance data, regional systems interaction logic subroutines are selected;
3. The user has the option to select;
  - a. best practice choices for this region (editable);
  - b. enter their own system choices (editable);
4. Based on systems chosen by the user, performance scores are extracted for each system choice;
5. System weighting factors are applied to each applicable systems choice;
6. Regional systems interaction logic subroutines check for number of contributing, mitigating, triggering factors related to regional systems interactions;
7. Interaction logic scoring is applied to performance scores for each applicable systems choice as a multiplication factor;

8. A summary performance (modified by interaction) score is generated for each systems choice;
9. A report card is generated to score each system in comparison to the score generated by the recommended practices house for the same region.

All calculations are conducted behind the web interface, invisible to the user. The only inputs requested from the User are the selection of the house location and the selection of the systems choices making up the house configuration.

The first generation calculator had 543 systems choices to select from in order to assemble the house configuration. This second generation calculator has 476 systems choices arrived at with the consensus of the expert panel. The small reduction in choices was accomplished through the deletion of systems choices found in older homes and by the focus on builders and designers as the primary user group for the calculator. The choices were further reduced by focusing the calculator on new construction of single-family-detached housing as the only use for the calculator.

Clicking on the “About” button on the entry page brings the user to the disclaimer page and additional information contact address included in the “About the Whole House Calculator” page as shown in Figure 4 below.

Figure 4, About the Whole House Calculator.

Whole House Survey: Home Evaluation Calculator	
<a href="#">About</a>	
<p><b>About the Whole House Calculator:</b></p> <p>This Web-based tool was developed with funding from the U.S. Department of Housing and Urban Development, Office of Policy Development and Research. The purpose is to help the housing community evaluate or compare the impact of a process, characteristic or system choice in the context of the house as a whole, the local climate/seismic/radon conditions and recommended practices, a step toward achieving High Performance Housing, i.e., housing that is energy efficient, durable, sustainable and healthy.</p> <p>The Whole House Calculator is designed for the builder considering constructing single-family homes. It depends heavily on data provided by industry experts and federal agencies.</p> <p>The information contained in the Whole House Calculator substantially revises the 2005 HUD Policy Development and Research (PD&amp;R) publication: Developing a Calculator for Evaluating Physical Design Characteristics and Whole House Performance: A Preliminary Method. The Calculator draws on information from the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Energy and the U.S. Environmental Protection Agency. No flood risk considerations are included in the calculations.</p> <p>The results should be used as a guideline to select the processes, characteristics and systems to make a high performing house. If you are a consumer considering building a new house, you are strongly encouraged to seek the advice of an construction or design professional who can provide you with specific information, designs and analysis needed to assess the costs and benefits of various processes, characteristics and systems.</p> <p>This site is best viewed on Windows with Internet Explorer 6.0 or higher or Mozilla/Firefox 1.5 or higher. This site is best viewed on Macintosh using Safari 1.3 or higher or Firefox 1.0 or higher.</p> <p>Please send any questions or comments on the Whole House Calculator to:  <a href="mailto:wholehousesurvey@pathnet.com">wholehousesurvey@pathnet.com</a></p> <p><a href="#">Return to Whole House Calculator.</a></p>	
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To begin the whole house calculation, the user types in a location for the house as either State and County or Zip Code, shown in figure 5.

Figure 5, Beginning Screen.

Whole House Survey: Home Evaluation Calculator

About

Instructions:

The Whole House Calculator allows you to generate a "Report Card" for the key processes, characteristics and systems that make a house behave the way it does in the place its built. It does this by asking you to select the location of the house, then select the processes, characteristics and systems in the house, either starting from the recommended practices for your location, choosing from one of the preconfigured houses, or selecting each process, characteristics and system yourself.

The Calculator then compares your selections with the recommend practice for your location and generates a report card for the overall house and each major subsystem in the house. You can view a more detailed comparison of the items that make up each subsystem to see what items are raising or lowering the grade, compared to the recommended practice for your location.

Site Location: Please enter the location of the house.

State

SELECT YOUR STATE

County

SELECT YOUR COUNTY

--- Or ---

Zipcode

Submit

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Once the location is entered, the systems choice input screens appear with the recommended practices for the region highlighted in light green and one of the recommended practices pre-selected as shown below in Figure 6.

Figure 6, Systems Choice Input Screen.

**Whole House Survey: Home Evaluation Calculator** About

Montgomery, Virginia New Site

**Your System Choices [Turn Debug On]**

➔ Please indicate your choices for each system below. Best practices for your region have been highlighted and preselected.

**Process & Production Design** Previous Next Submit / View Summary

**Process & Design** Foundation Superstructure Envelope Interior Partitions Millwork / Appliances Utility Electrical Sewer & Water Thermal

**1. Design & Engineering Credentials**

All System Options:

- ☒ Architect & engineer
- ☐ Architect only
- ☐ Engineer only
- ☐ Unlicensed Designer
- ☐ Energy rater
- ☐ Part of Building America program
- ☐ Part of Energy Star program
- ☐ Builder / developer
- ☐ None

**2. Design & Engineering Services**

All System Options:

- ☒ Custom design & siting
- ☐ Production design, custom siting
- ☐ Production design, production siting
- ☐ Production siting, production design with prepacked options
- ☐ Purchased design, no siting

**3. Structural Systems**

All System Options:

- ☐ Structural systems
- ☒ Fully engineered
- ☐ Designed integration
- ☐ Engineered by suppliers or installers
- ☐ Components proscriptively described
- ☐ Components traditionally described

These systems choices are grouped under the following ten subsystem headings:

- Process and Production Design;
- Foundation;
- Superstructure;
- Envelope Systems;
- Interior Partitions and Finishes;
- Millwork and Appliances;
- Utility Distribution;
- Electric Power and Light;
- Sewer and Water;
- Thermal Systems.

User testing has shown that approximately 45 – 60 minutes are needed by the designer or builder having the complete process description and specification at their side to make these systems selections. If the pre-

selected recommended practices are all accepted, data entry can be completed by clicking the “submit/view summary” button and viewing the house score in under 30 seconds.

To aid in the selection process, a glossary of terms has been developed and applied to the web-pages such that a user letting the mouse linger over a systems choice will be presented with an explanation of the systems choice. The figure below, Figure 7 shows the glossary explanation that pops up when the mouse lingers over the term “Production design, custom siting”.

Figure 7, Glossary Explanation Pop-Up.

**Whole House Survey: Home Evaluation Calculator** About

Montgomery, Virginia New Site

**Your System Choices [Turn Debug On]**

Please indicate your choices for each system below. Best practices for your region have been highlighted and preselected.

**Process & Production Design** Previous Next Submit / View Summary

**Process & Design** Foundation Superstructure Envelope Interior Partitions Millwork / Appliances Utility Electrical Sewer & Water Thermal

**1. Design & Engineering Credentials**

**All** System Options:

- ☒ Architect & engineer
- ☐ Architect only
- ☐ Engineer only
- ☐ Unlicensed Designer
- ☐ Energy rater
- ☐ Part of Building America program
- ☐ Part of Energy Star program
- ☐ Builder / developer
- ☐ None

**2. Design & Engineering Services**

**All** System Options:

- ☒ Custom design & siting
- ☐ Production design, custom siting
- ☐ Production design, product
- ☐ Production siting, product
- ☐ Purchased design, no siting

**Production design, custom siting**  
A pre-designed home that has been constructed in large numbers but is specifically oriented and located on a specific parcel to meet the needs of a specific owner.

**3. Structural Systems**

**All** System Options:

- ☐ Structural systems
- ☒ Fully engineered
- ☐ Designed integration
- ☐ Engineered by suppliers or installers
- ☐ Components prescriptively described
- ☐ Components traditionally described

Once the user has made selections under each of the subsystems headings and clicks the “Submit / View Summary” button, a report card is generated and presented as seen in Figure 8 below.

Figure 8, Simple Summary View.

Whole House Survey: Home Evaluation Calculator

About

Montgomery, Virginia

New Site

Here is your score based on your system choices.

<< System Choices

Your Score Overview Report: ☒ Simple ☐ Detailed

Score			
SubSystem	Your House	Best Practice	Grade
Process & Production Design	180.48	204.39	B+
Foundation	82.88	94.40	B+
Superstructure	82.42	115.17	C+
Envelope Systems	42.50	60.89	C+
Interior Partitions & Finishes	65.61	65.79	A
Millwork & Appliances	19.50	22.38	B+
Utility Distribution	4.71	9.31	D
Electric Power & Light	27.24	33.91	B
Sewer & Water	33.86	37.29	A-
Thermal Systems	30.94	42.21	C+
<b>TOTAL</b>	<b>570.13</b>	<b>685.75</b>	<b>B</b>

Your Location Details

Location: Montgomery, Virginia

Issue	Value	Factor	% Variance
Wind Load (mph)	90	1.3846154	0.90668
Seismic Zone	2	3.325	
Radon Zone	1	1	
Relative Humidity	66-75	1.86	0.85-1.01
Precipitation (inches)	30-40	0.849624	
Heating Degree Days	5001-6000	0.7500938	
Cooling Degree Days	401-0700	0.2059429	

Region: Central

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Each subsystem is scored and compared to the score for a recommended practices house for this region. Note that this house has scored a “D” for the Utility Distribution subsystem. By clicking the radio button next to “Detailed” in the “Your Score Overview Report” line, additional information is shown comparing the scores for the systems choices for the users house with the recommended practices house as seen in Figure 9 below.

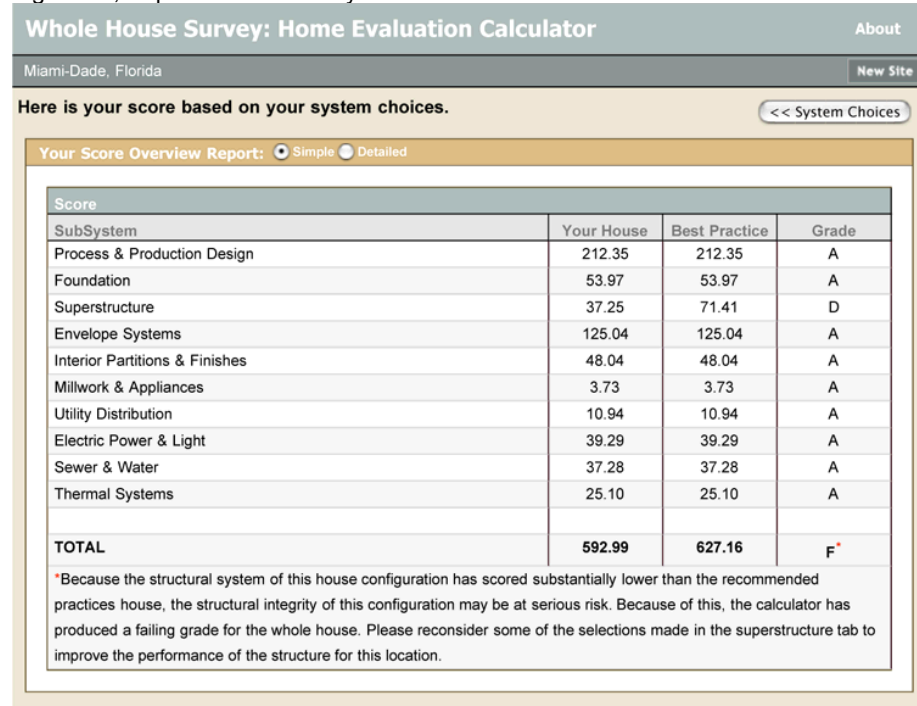
Figure 9, Detailed Summary Screen.

Whole House Survey: Home Evaluation Calculator				About
Montgomery, Virginia				New Site
Here is your score based on your system choices.				<< System Choices
Your Score Overview Report: <input type="radio"/> Simple <input checked="" type="radio"/> Detailed				
Score				
SubSystem	Your House	Best Practice	Grade	
Interior Partitions & Finishes	65.61	65.79	A	
Partition Framing >> Site framed wood	24.55	24.55		
Wall Finish Substrate >> Drywall	10.42	0		
Wall Finish Substrate >> Reduced-cellulose drywall	0	9.76		
Primary Interior Finish at Exterior Wall >> 1 latex primer + 1 finish latex	1.32	1.32		
Primary Wall Finishes (Interior Wall) >> 1 latex primer + 1 finish latex	5.4	5.4		
Subfloor >> Particle board	1.6	0		
Subfloor >> OSB	0	3.56		
Floor Finishes >> Pad and carpet	0.74	0		
Floor Finishes >> Hardwood - solid	0	1.02		
Ceiling Substrates >> Drywall	10.42	0		
Ceiling Substrates >> Reduced-cellulose drywall	0	9.76		
Ceiling Finishes >> 1 latex primer + 1 finish latex	0	10.42		
Ceiling Finishes >> 1 high-build primer / finish coat	11.16	0		
Millwork & Appliances	19.50	22.38	B+	
Countertops >> Plastic laminate	3.25	0		
Countertops >> Stone	0	4.38		
Interior Trim >> Milled wood	0	4.5		
Interior Trim >> Milled or formed wood composite	3.88	0		
Cabinetry >> Prefabricated - milled wood	0	4.75		
Cabinetry >> Prefabricated - engineered wood	3.63	0		
Gas Appliance Venting >> Plumber-installed	4.63	4.63		
Appliance Subcontract Method >> By builder	4.13	4.13		
Utility Distribution	4.71	9.31	D	
Integration Strategies >> Bundled-weaved together based on schedule	1.34	0		
Integration Strategies >> Unbundled-each subsystem has designed place	0	1.53		
Production Strategies >> Site fabricated trunks and feeders	0.82	0		
Production Strategies >> Hybrid, prefabricated trunks, site fabricated distribution	0	0.8		
Ductwork Location >> All in conditioned spaces	0	3.3		
Ductwork Location >> In conditioned and unconditioned spaces	0.29	0		
Air Handling Unit Location >> In unconditioned space	-0.19	0		
Air Handling Unit Location >> In conditioned space	0	3.3		
Ductwork Material >> Site formed ductboard	2.44	0		
Ductwork Material >> Prefabricated metal	0	0.38		

Here the user could see that the decision to site fabricate and weave the systems together have caused some small reduction in the score but most of the reduction in the score has resulted from the decision to place the ductwork in both conditioned and unconditioned space and the air-handling unit in unconditioned space.

Should the superstructure subsystem receive a grade of “D” or less, the house will receive a failing grade and a note explaining the failure will be displayed as shown in Figure 10 below:

Figure 10, Superstructure Subsystem Failure Notice.



At this stage, the user may return to the superstructure page by either clicking the “Back” button on their web browser or by clicking on the “<<System Choices” button which will return them to the ten tab page shown in Figure 11 below where the user can make revise their systems choices, click to resubmit and review the summary page to verify that their changes had a more positive impact on the performance of the Superstructure subsystem and the house as a whole..

Figure 11, Return to Systems Choices Tabs.

Whole House Survey: Home Evaluation Calculator

About

Miami-Dade, Florida

New Site

Your System Choices Turn Debug On

Please indicate your choices for each system below. Best practices for your region have been highlighted and preselected.

Superstructure

PreviousNextSubmit / View Summary

Process & Design

Foundation

Superstructure

Envelope

Interior Partitions

Millwork / Appliances

Utility

Electrical

Sewer & Water

Thermal

1. Floor Framing

All

System Options:

☒ Dimension lumber - site framed

☐ Engineered lumber - site framed

☐ Prefabricated trusses - site assembled

☐ Prefabricated trusses & floor panels - factory assembled

☐ Light gauge steel - site framed

2. Floor Rim / Band Insulation and Vapor Barrier

All

System Options:

☐ Fiberglass batts - faced

☐ Fiberglass batts - unfaced

☒ Fiberglass batts and polyethylene

☐ Spray-on Icylene

☐ Spray-on polyurethane

☐ Interior rigid foam board

☐ Exterior rigid foam board

3. Wall Framing

All

System Options:

☐ Dimension lumber

☐ Engineered lumber

☐ Light gauge steel

☐ Reinforced masonry

☒ Unreinforced masonry

☐ Prefabricated panels

#### **Part Four: A Rational Basis for Systems Weighting:**

The first generation calculator allowed the users to input the Systems Weighting factors based on the house characteristics they valued most. While this allowed users to adjust a house until it performed as desired, this method did not account for the climatic and geologic factors most responsible for house performance.

In an effort to address the concerns of bias related to subsystems weighting factors raised in the critical review, a new approach that develops subsystems weighting factors affecting each subsystem is now based on the intensity of the climatic and geologic characteristics of each county.

This approach provides a finer level of geographic detail in the calculator functioning. A data table was developed listing each state and county with its associated climatic and geologic characteristics. The data for these 3,141 counties are further mapped to 42,192 Zip Codes. A Systems Choices table was developed to map climatic and geologic weighting factors to each systems choice. This map is included as Appendix One of this report.

As discussed in the expert panel meeting, there is no clear method that can be used to group or characterize regions of the United States in the context of whole house performance. Multiple map-standards were discussed including the 8-zone map developed by the Pacific-Northwest National Laboratories (Briggs, Lucas, Taylor 2002). Because these types of maps found in building codes and related climate references were developed either for thermal, moisture, seismic, wind, or radon mitigation purposes, no single map was identified as a source for developing performance-based systems weighting factors. As a result, a data table identifying the following climatic and geologic factors was developed at a county level of detail:

- Wind speeds for 50 year mean recurrence based on data from IRC Figure R301.2(4);
- Seismic risk based on data from 1979 UBC Figure 1 Seismic Zone map; this should be replaced with data based on USGS
- Radon potential based on data from <http://www.epa.gov/radon/zonemap.html>
- Relative humidity <http://cdo.ncdc.noaa.gov/climaps/rh2313.pdf>;
- Precipitation based on data from [http://www.ncdc.noaa.gov/img/documentlibrary/clim81supp3/precipnormal\\_hires.jpg](http://www.ncdc.noaa.gov/img/documentlibrary/clim81supp3/precipnormal_hires.jpg)
- Heating degree days based on data from [http://www.ncdc.noaa.gov/img/documentlibrary/clim81supp3/annualheatingDD\\_hires.jpg](http://www.ncdc.noaa.gov/img/documentlibrary/clim81supp3/annualheatingDD_hires.jpg)
- Cooling degree days based on data from [http://www.ncdc.noaa.gov/img/documentlibrary/clim81supp3/annualcoolingDD\\_hires.jpg](http://www.ncdc.noaa.gov/img/documentlibrary/clim81supp3/annualcoolingDD_hires.jpg)

The data for these 3,141 counties are further mapped to 42,192 Zip Codes as an alternate method of identifying the house location for the user.

The weighting factors for each location were determined by dividing the expected intensity of the natural force for a county by the difference between the high and low value for that same force across all counties of the United States.



For Mobile County, Alabama, the anticipated peak wind speed (50 year recurrence) is 150 mph. The difference between the high value (150) and low value (85) is 65. Mobile's 150 mph design target divided by the national hi-low difference, 65, equals a weighting factor of 2.3076923. This weighting factor is used to multiply the result of the performance scores for all systems choices pertaining to the superstructure of the house to arrive at a weighted importance for the superstructure system. During development and testing, a debug function was included in the calculator to allow manual checking of the calculations. Figure 12 below shows the 2.3076923 weighting factor (highlighted in the blue circle) applied to the floor framing systems choices

Figure 12, Weighting Factor for Wind in Debug Mode.

1. Floor Framing	
All	System Options:
167	Dimension lumber - site framed $[5 * 2.3076923 * 1 * 0.2500313 + 1 + -1 = 2.88497652884495]$
	Weighting Factors: Wind, Seismic, Heat
	Interaction Factors: Wind, Moisture

*Weighting Factor for Wind*

Similarly, the Seismic factor for Mobile County is fairly low, a risk of minor or no damage. Seismic risks are scored on a scale of

- 0 no damage
- 1 Minor damage; distant earthquakes may cause minor damage to structures with fundamental periods greater than 1 second;
- 2 Moderate damage
- 3 Major damage;
- 4 Areas within zone 3 determined by proximity to major fault systems.

These scores were initially developed from data found in the 1979 UBC Seismic Zone map. At the time of this report writing it is clear that the next generation calculator should revise this data table using data from the USGS shaking hazard map found at [http://earthquake.usgs.gov/research/hazmaps/products\\_data/images/nshm\\_us02.gif](http://earthquake.usgs.gov/research/hazmaps/products_data/images/nshm_us02.gif). This map scores the levels of horizontal shaking that have a 1 in 10 chance of occurring in a 50 year period. It has the advantage of a finer graded level of detail and would provide scores ranging from 0 to 32% of the acceleration of a falling object due to gravity (g's). The Seismic weighting factor is highlighted in Figure 13 below.

Figure 13, Weighting Factor for Seismic Risk in DeBug Mode.

1. Floor Framing	
All	System Options:
167	Dimension lumber - site framed $[5 * 2.3076923 * 1 * 0.2500313 + 1 + -1 = 2.88497652884495]$
	Weighting Factors: Wind, Seismic, Heat
	Interaction Factors: Wind, Moisture

*Weighting Factor for Seismic*

Following the Seismic weighting factor is a Heating Degree Day (HDD) factor. The number following the Seismic weighting factor is the HDD factor (.2500313) This is similarly developed as a percentage of the range of Heating Degree Days across the country. It's inclusion as a weighting factor reflects the low number of heating degree days in Mobile County, a way of anticipating the moisture-related interaction described in Part Five of this report, "A Logic-Based Method to Account for Systems Interactions." Including the HDD factor here may be a form of doubling the influence of humidity-related structural degradation and should be reconsidered in any subsequent development of the calculator.

This method of developing systems weighting factors based upon local climate and geologic conditions shows promise. It also addresses a concern for prioritizing structural performance described in the critical review. Since it calculates the hi-low difference in wind speeds across the country, (150 mph hi value – 85 mph low value = 65) is always lower than the lowest wind speed value, the weighting factor related to wind is always above 1. Seismic risk factors, calculated in a similar manner are multiplied by the wind factor to arrive at a structurally conservative overall weighting factor for the structural system of the house.

Given the importance of the structural integrity of the house to the occupants safety. The calculator places an additional priority on structural performance. Any house configuration that scores a “D” or less in the superstructure category automatically causes the house to receive a failing grade. The failing grade is accompanied by the following footnote *“Because the structural system of this house configuration has scored substantially lower than the recommended practices house, the structural integrity of this configuration may be at serious risk. Because of this, the calculator has produced a failing grade for the whole house. Please reconsider some of the selections made in the superstructure tab to improve the performance of the structure for this location.”*

Improvements to this overall approach to systems weighting that should be incorporated into any future versions of the calculator include:

- Replace current seismic values in the data tables with data from USGS Shaking Hazard map;
- Verify accuracy of systems choice mapping to climate and geologic weighting factors;
- Include storm surge and flood hazard data as a systems weighting factor;
- Include snow loading data as a systems weighting factor.

## **Part Five: A Logic-Based Method to Account for Systems Interactions**

The initial version of the calculator used a table filled with static scores input by a single person challenged to hold the possible interactions between all 93 systems choices in their mind over the 40 hour period required to score each of the 8,600+ possible interactions for a single climate zone. The Critical Review rightly points out that this approach is unable to account for the multiple variables and interactions often involved with the performance of systems in the whole house context.

During the expert panel discussions, it was clear that many of the problematic interactions encountered in housing are the result of dozens of discrete decisions on processes, materials and systems being acted upon in a range of climatic and geologic conditions which change dramatically across the country.

There seemed to be very few, perhaps no, “fail-safe” approaches to residential construction that will perform equally well in all climatic and geologic conditions found across the country. But there was agreement that some forms of problematic interactions are well-understood in the building science community and could be anticipated if one knew the pathology of the interaction.

Given this, a new approach to accounting for complex interactions was developed. It takes into consideration the processes, materials, systems making up a house and the local climatic and geologic conditions by logically describing an interaction as a series of logical “if” statements.

The logic begins by searching the set of interaction subroutines for climatic or geologic factors identified as “trigger factors”. A “trigger factor” is defined as a climatic or geologic factor that when absent causes no problematic interactions, but when present, selects more “if” statements for further query. The interaction logic is a list of systems choices characterized as either contributing to a problematic interaction or mitigating a problematic interaction.

Each systems choice making up the house is examined by the interaction logic. When a systems choice in the house configured by the user matches a systems choice characterized as contributing to a problematic interaction, that systems choice is given a value of +1. Similarly, when a systems choice in the house configured by the user matches a systems choice characterized as contributing to the mitigation of the problematic interaction it is given a value of -1. The result is mitigating factors reduce the impact of contributing factors.

An example of this logic interaction is the interaction titled “Structural Degradation from Excessive Moisture Levels”. This interaction is concerned with long term exposure of structural components, in this example the floor framing over a crawl space, to high moisture levels. Continuing with the user configured house in Mobile County, Alabama the calculator assigns a score to the choice of a crawl space type of foundation shown in Figure 14 below.

Figure 14, Interaction Factors for Crawl Space.

15. Foundation Type	
All	System Options:
<input type="radio"/> 82	Slab-on-grade [5.5 * 2.3076923 * 1 * 1 * 1.86 * 1.4511278 * 0.2500313 * 1.0297146 = 8.82003779849172] Weighting Factors: Wind, Seismic, Radon, RelHum, Precip, Heat, Cool Interaction Factors:
<input type="radio"/> 83	Pier - open beneath [5 * 2.3076923 * 1 * 1 * 1.86 * 1.4511278 * 0.2500313 * 1.0297146 + -1 + -1 = 6.01821618044702] Weighting Factors: Wind, Seismic, Radon, RelHum, Precip, Heat, Cool Interaction Factors: Moisture, MoldMildew
<input checked="" type="radio"/> 84	Crawl space - vented [5 * 2.3076923 * 1 * 1 * 1.86 * 1.4511278 * 0.2500313 * 1.0297146 + -1 + -1 + -1 = 5.01821618044702] Weighting Factors: Wind, Seismic, Radon, RelHum, Precip, Heat, Cool Interaction Factors: Moisture, MoldMildew, BenzeneCool

Three interaction factors are identified with this geographic location:

- Structural Degradation from Excessive Moisture Levels (listed above as “Moisture”;
- Mold Mildew Air Quality Concerns from Excess Moisture Levels in Warm Climates (listed above as “Mold Mildew”);
- Benzene/Hydrocarbons in interiors in High Cooling Degree Day Climates (listed as “Benzene Cool”)

The Crawl Space systems choice in the Foundation Type scores a 5.0182 overall, lower than the Open Pier and Slab-on-Grade choices. After the interaction factors, the series of numbers -1, -1 and -1 are scores relating this systems choice to each of the three systems interaction factors listed above.

Having a vented crawl space in this geographic location alone does not cause a problematic interaction, it is one contributing factor. A potentially mitigating factor might be the choice to include a 4 or 6 mil poly vapor barrier. Figure 15 below shows the potential impact of including this vapor barrier.

Figure 15, Vapor Control Impact.

8. Subgrade Water Management Layer (Horizontal)	
All	System Options:
<input type="checkbox"/> 162	4 mil poly sheet [3.8 * 1 * 1.86 * 1.4511278 * 0.2500313 * 1.0297146 + 1 + 1 = 4.6406658708961] Weighting Factors: Radon, RelHum, Precip, Heat, Cool Interaction Factors: Moisture, MoldMildew
<input type="checkbox"/> 163	6 mil poly sheet [6.4 * 1 * 1.86 * 1.4511278 * 0.2500313 * 1.0297146 + 1 + 1 = 6.44743725624607] Weighting Factors: Radon, RelHum, Precip, Heat, Cool Interaction Factors: Moisture, MoldMildew
<input type="checkbox"/> 164	Sand and gravel cushion [5.4 * 1 * 1.86 * 1.4511278 * 0.2500313 * 1.0297146 + -1 + -1 = 1.75252518495762] Weighting Factors: Radon, RelHum, Precip, Heat, Cool Interaction Factors: Moisture, MoldMildew
<input type="checkbox"/> 165	Washed aggregate [5.8 * 1 * 1.86 * 1.4511278 * 0.2500313 * 1.0297146 = 4.030490013473] Weighting Factors: Radon, RelHum, Precip, Heat, Cool Interaction Factors:
<input checked="" type="checkbox"/> 166	None [0.8 * 1 * 1.86 * 1.4511278 * 0.2500313 * 1.0297146 + -1 + -1 = -1.44407034296924] Weighting Factors: Radon, RelHum, Precip, Heat, Cool Interaction Factors: Moisture, MoldMildew

Including a 4 mil poly sheet over the earth would add 4.64 points to the foundation subsystem score, a 6 mil sheet would have added 6.4 points, while the absence of any poly sheet adds only 1.44 points to the foundation subsystem score.

Adding a cold-source such as metal air conditioning ductwork to become a condensing surface is likely to add to the moisture levels in this crawl space. Figure 16 below shows how this systems choice affects the score of the Utility subsystem.

Figure 16, Utility Integration Strategy.

Utility Distribution		Previous	Next	Submit / View Summary					
Process & Design	Foundation	Superstructure	Envelope	Interior Partitions	Milwork / Appliances	Utility	Electrical	Sewer & Water	Thermal
<b>1. Integration Strategies</b>									
All	System Options:								
<input checked="" type="radio"/>	358	Bundled-weaved together based on schedule [4.66666667 * 1.86 * 0.2500313 * 1.0297146 = 2.23476043914101] Weighting Factors: RelHum, Heat, Cool Interaction Factors:							
<input type="radio"/>	359	Unbundled-each subsystem has designed place [5.33333333 * 1.86 * 0.2500313 * 1.0297146 = 2.55401193010482] Weighting Factors: RelHum, Heat, Cool Interaction Factors:							
<input type="radio"/>	360	Hybrid-system trunks in designed places, distribution woven [5.33333333 * 1.86 * 0.2500313 * 1.0297146 = 2.55401193010482] Weighting Factors: RelHum, Heat, Cool Interaction Factors:							
<b>2. Production Strategies</b>									
All	System Options:								
<input checked="" type="radio"/>	361	Site fabricated trunks and feeders [5.33333333 * 0.2500313 * 1.0297146 = 1.37312469360474] Weighting Factors: Heat, Cool Interaction Factors:							
<input type="radio"/>	362	Prefabricated trunks and feeders [5 * 0.2500313 * 1.0297146 = 1.2873044003349] Weighting Factors: Heat, Cool Interaction Factors:							
<input type="radio"/>	363	Hybrid, prefabricated trunks, site fabricated distribution [5.16666667 * 0.2500313 * 1.0297146 = 1.33021454709855] Weighting Factors: Heat, Cool Interaction Factors:							
<b>3. Ductwork Location</b>									
All	System Options:								
<input checked="" type="radio"/>	364	All in unconditioned spaces [2.16666667 * 1.86 * 0.2500313 * 1.0297146 + -1 + -1 + -1 = -1.96243265317045] Weighting Factors: RelHum, Heat, Cool Interaction Factors: Moisture, MoldMildew, BenzeneCool							
<input type="radio"/>	365	All in conditioned spaces [8 * 1.86 * 0.2500313 * 1.0297146 + 1 + 1 + 1 = 6.83101789539666]							

The bottom two lines on the figure above show the score for choosing to locate ductwork in unconditioned spaces is 1.962 because of it's potential to become a condensing surface contributing bulk water adjacent to a wood structural component in a warm climate.

The above example illustrates the way interaction factors increase or decrease the scores of a systems choice. It reveals a potential strength in being able to affect the performance score for a broad array of components across subsystems boundaries, but also illustrates a weakness.

Many building science experts would propose that in a warm humid climate, combining a traditionally vented crawl space without a poly barrier on the ground and containing air conditioning ducts in the unconditioned crawl space is likely to provide a consistent source of moisture which would make environmental conditions favorable for insects and the formation of mold colonies and decay fungi, exposing the wood structure to a higher risk of decay. But definitive proof that the combination of these factors will *always* result in a level of decay unacceptable to the homeowner does not exist.

For these reasons the systems interactions included in the calculator have been limited to:

- Seismic Collapse;
- High Wind Collapse;
- High Wind Induced Water Intrusion;
- Structural Degradation from Excessive Moisture Levels;

- Mold Mildew Air Quality Concerns from Excess Moisture Levels in Warm Climates;
- Benzene/Hydrocarbons in Interiors in High Cooling Degree Day Climates;
- Benzene/Hydrocarbons in Interiors in High Heating Degree Day Climates;
- EIFS/Framing Interaction in Hot Humid Climates;
- Carpet Mold;
- Premature Roofing Aging due to overheating;
- Radon Intrusion.

The functioning of these interaction subroutines establishes proof of concept for the logical approach to system interaction scoring.

It would not be difficult to suggest interactions to both add and remove from this list. Any future versions of the calculator must include additional expert input specifically on the subject of interactions to build a larger set of more sophisticated logic-based interaction subroutines.

## Part Six: Testing the Second Generation Calculator

The first version of the calculator was only tested on two house configurations for a Mid-Atlantic regional location. Both utilized production builder processes. One was based on traditional design and construction processes, materials and systems and the other was based on a more innovative approach to design and construction processes utilizing extensive prefabrication, and the use of “in-house” production teams responsible for erecting the dried-in “shell” of the house before commencing subcontractor activities. These two houses are described in more detail in the report titled “A Preliminary Method to Develop a Calculator for Evaluating Physical Design Characteristics and Whole House Performance Scoring”. Those same houses were required to be included in the testing of this second-generation calculator.

Recommendation 1 in the critical review calls for the calculator to be tested utilizing a number of different home configurations, tested across a number of geographic locations to ascertain the calculator’s ability to discern similarities and differences.

To address this recommendation, 6 test case house configurations were developed. Each test case contains significant differences such as production method, and foundation type as well as subtler differences such as place in the market, location of mechanical systems and wall construction.

The tests include the two initial case study house configurations and four additional configurations:

- Case 1, two story, systems approach house with full basement high end market production builder house (tested in first version of the calculator);
- Case 2, two story, standard approach house with full basement high end market production builder house (tested in first version of the calculator);
- Case 3, two story, modular house with full basement “affordable” house;
- Case 4, one story, panelized house on slab, high end custom builder house;
- Case 5, one story slab on grade “affordable” house, high thermal performance design, volunteer labor;
- Case 6, one story over crawl space, “affordable” house, volunteer labor.

The full configuration profile for each test case house has been included in Appendix 3 “Test Case Configurations” in this report.

Six separate websites were developed to hold the test configurations to reduce the chances for errors in data input and speed the testing process. As with user-input configurations, the chosen house location (Zip Code or state/county) selects one of the six recommended practices houses appropriate to the house location. These recommended practices

The regional testing recommendation has been addressed by testing the 6 case house configurations in 8 locations representing each of the regional divisions of the U.S.

- Blacksburg, VA 24060 which is in the “central” climate zone

- Fargo, ND 58102 which is in the "north central" climate zone
- Morton Grove, IL 60053 which is in the "north east" climate zone
- Beverly Hills, CA 90210 which is in the "west" climate zone
- Taos, NM 87512 which is in the "southwest" climate zone
- Yakima, WA 98901 which is in the "west" climate zone
- Androscoggin, ME 04210 which is in the "northeast" climate zone
- Alexander, IL 62914 which is in the "central" climate zone

Testing was formally conducted by Ron Wakefield Ph.D., Professor of Construction, Head, School of Property, Construction and Project Management, Design and Social Context Portfolio, The Royal Melbourne Institute of Technology University, Melbourne, Australia. Dr. Wakefield was a Co-Investigator on the first version of the Whole House Calculator and a Co-Author of the report on the first calculator titled "A Preliminary Method to Develop a Calculator for Evaluating Physical Design Characteristics and Whole House Performance Scoring" March 2005. Dr. Wakefield was not provided detailed information on the internal operations of this second generation calculator and was not asked to provide a critical review of the calculator but was charged with evaluating the overall functionality of the web interface and calculated outcomes. Dr. Wakefield's previous experience with the principles of Whole House scoring uniquely qualified him to evaluate the performance of this second generation calculator. Newport Partners L.L.C., authors of the Critical Review of the first calculator conducted additional testing and reported that the second generation calculator appeared to be functioning properly.

Functional testing revealed that the calculator was largely operating as expected. Test cases with subsystems optimized for one geographic location did poorly when tested in a location with extreme climate and geological differences. Structural systems in test cases that excelled in Midwest failed in the seismic zones of the west. Building envelopes that excelled in the Middle-Atlantic states failed in the extreme temperatures of the Southwest. Still, the calculator is in its early stages of development. There is not an abundance of data in the performance database, the reasoning behind the specific performance ratings is in even shorter supply and therefore has not been fully integrated in the systems interaction scoring, advances in sealed attic design, and timber-framed approaches to house design have not been included, and flood data is not yet part of the systems weighting calculations.

The relative impact of a subsystem failure on the whole house scores was one of the key questions emerging from analysis of the test results. While the subsystem performance was weighted according to climatic and geologic factors, each subsystem is not currently equal in importance within the overall calculation. The number of possible points for each subsystem varies with the number of systems choices available to the subsystem. This results in more complex subsystems having more systems choices, which means more possible points. This can be seen in Table 4 below.



Table 4, Point and Systems Choice Distribution Comparison.

<b>Point and Systems Choice Distribution Comparison</b>			
<b>Zip Code</b>	<b>24060</b>		
<b>City</b>	<b>Blacksburg</b>		
<b>State</b>	<b>Virginia</b>		
<b>Region</b>	<b>Central</b>		
<b>Subsystem</b>	<b>Points &amp; Percentage of Total Points in Recommended Practices House</b>	<b>Number of Systems Choices Utilized in Recommended Practices House</b>	<b>Number of Systems Choices available in the Subsystem</b>
Process & Production	204.39 29.98%	49 29.34%	106 22.27%
Foundation	90.4 13.26%	14 8.38%	50 10.50%
Superstructure	115.17 16.89%	12 7.19%	36 7.56%
Envelope Systems	60.89 8.93%	23 13.77%	80 16.81%
Interior Partitions & Finishes	65.79 9.65%	13 7.78%	47 9.87%
Millwork and Appliances	22.38 3.28%	6 3.59%	15 3.15%
Utility Distribution	9.31 1.37%	7 4.19%	18 3.78%
Electric Power & Light	33.91 4.97%	6 3.59%	19 3.99%
Sewer & Water	37.29 5.47%	11 6.59%	27 5.67%
Thermal Systems	42.21 6.19%	26 15.57%	78 16.39%
Total Points	681.74	167	476

One of the factors contributing to high scores in some subsystems and lower scores in others is the number of possible systems choices in each subsystem and the number of systems choices utilized by the recommended practices configurations. The scores for the user's house configuration is compared to the score for the recommended practices house for that region and graded accordingly.

Figure ?? above shows that of the Process and Production subsystem has the largest percentage of systems choices. This is because Process and Production contains both the basic options for the design and construction processes and the basic characteristics of the house itself. This can and perhaps should be changed into two subsystems in future versions of the calculator to avoid the perception that inordinate emphasis is being placed on the role of design or engineering professionals.

The foundation and superstructure subsystems together represent approximately the same percentage of systems choices ( $10.5+7.56=18.06\%$ )

as both the envelope system (16.81%) and the thermal systems (16.39%). This seems to present a balanced opportunity for scoring across the major subsystems of a house.

The Utility Distribution subsystem has about 4% of the total number of systems choices available, but in the recommended practices configuration for Zip Code 24060, affects only 1.37% of the total score. If there is general agreement among the next expert panel convened in subsequent development of the calculator, general strategies (location of ductwork) and specific material systems (metal, ductboard, flexduct) for key subsystems may need to be attached to an additional weighting factor to magnify their impact in the house score overall.

### Test Case 1

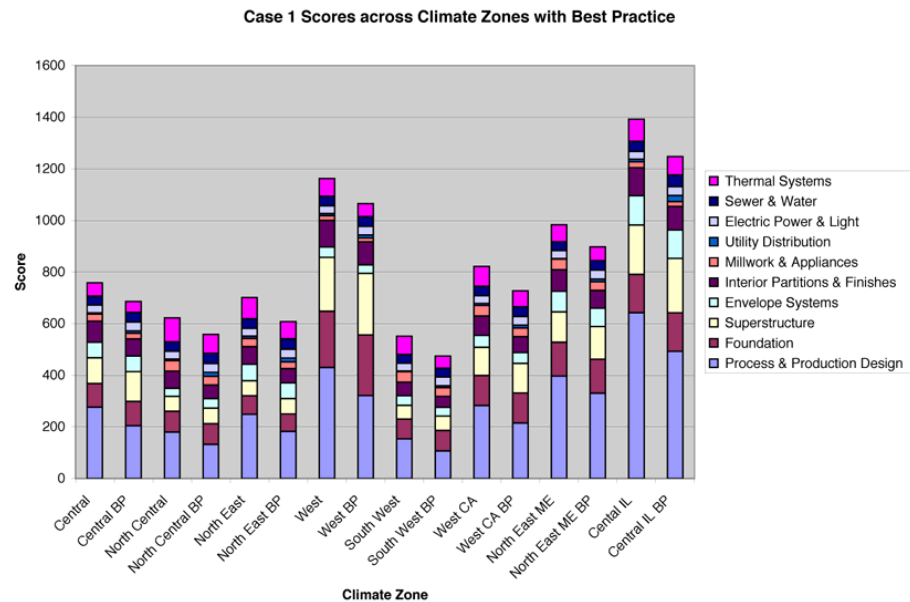
Test Case 1 is a two story, systems approach house with full basement, attached garage high end market production builder house that was tested in the first version of the calculator. This house was designed for the Middle-Atlantic (Central) region of the U.S. Table 5 below shows the overall scoring for each system in the 8 locations included in the test. Note that the utility system scores poorly across all regions. This can be attributed to configuring the house to locate both the air-handling unit and the ductwork in unconditioned spaces which is weighted heavier by the climate data in regions with high quantities of heating and cooling degree days, but is weighted less, thus scoring higher in more moderate climate locations. One can also see the electrical system scoring slightly less than excellent in most locations. This is attributed to the house being configured with all incandescent lighting as compared to compact fluorescent lighting in the recommended practices house. The superstructure scores well in most locations. The SIP panels making up the exterior wall of this model offers additional stiffness that increases performance scoring, while the configuration of the gable roof as an un-braced assembly reduces it's performance in higher wind and seismic regions.

Table 5, Overall Subsystem Scoring for Test Case 1.

Location Zip Code	Blacksburg, VA 24060	Fargo, ND 58102	Morton Grove, IL 60053	Los Angeles, CA 90210	Taos, NM 87512	Yakima, WA 98901	Androscoggin, ME 04210	Alexander, IL 62914
<b>Test Case 1</b>								
Process and Design	A	A	A	A	A	A	A	A
Foundation	A	A	A	A-	A	A	A	A
Superstructure	B+	A	A	B+	A	A	A-	A-
Envelope	A	A	A	A	A	A	A	A
Interior Partitions	A	A	A	A	A	A	A	A
Millwork & Appliances	A	A	A	A	A	A	A	A
Utility	D	F	D+	C+	F-	C+	F-	F+
Electrical	B+	B+	B+	B+	B+	B+	B+	B+
Sewer & Water	A-	A-	A-	A	A	A	A-	B+
Thermal	A	A	A	A	A	A	A	A

Figure 17 below shows Test case 1 in comparison to the recommended practices (indicated by "BP" following the location name) houses across the test locations. Test Case 1, on the whole, outperformed the recommended practices house configuration for each region as shown in Figure 17 below.

Figure 17 Performance of Test Case 1 and Recommended Practices Configurations



## Test Case 2

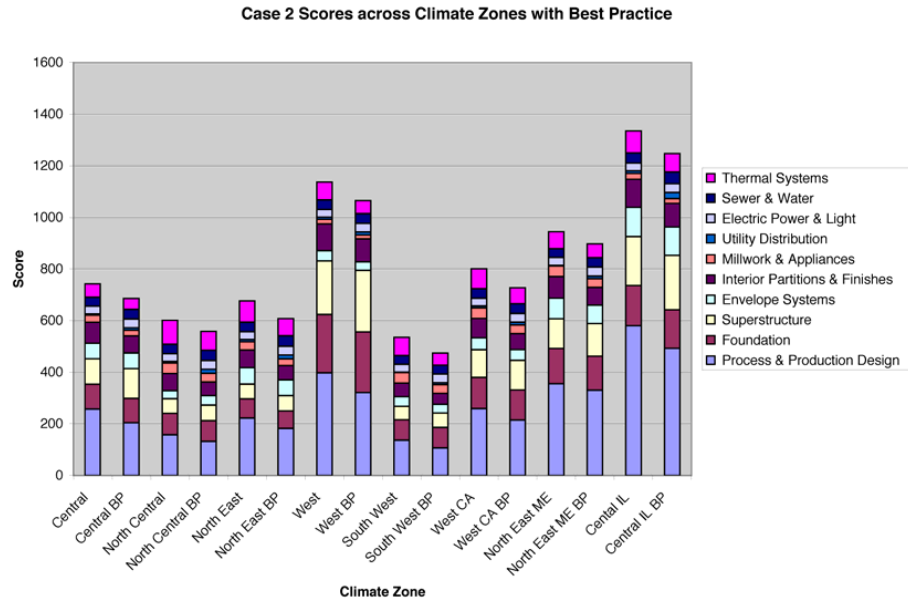
Test Case 2 is a two story, standard light wood frame house with full basement and attached garage for the upper end of the market and is a production builder house tested in first version of the calculator. This house was designed for the Middle-Atlantic (Central) region of the U.S. Table 6 below shows the overall scoring for each system in the 8 locations included in the test. Like Test Case 1, Case 2 scores lower in utility systems because it was configured to locate both the air handling unit and ductwork in unconditioned spaces. Also like Case 1, incandescent lighting reduced the overall electrical system score and the un-braced gable roof assembly slightly reduced the score of the superstructure system.

Table 6, Overall Subsystem Scoring for Test Case 2.

Location	Blacksburg, VA	Fargo, ND	Morton Grove, IL	Los Angeles, CA	Taos, NM	Yakima, WA	Androscoggin, ME	Alexander, IL
Zip Code	24060	58102	60053	90210	87512	98901	04210	62914
<b>Test Case 2</b>								
Process and Design	A	A	A	A	A	A	A	A
Foundation	A	A	A	A	A	A	A	A
Superstructure	B+	A-	A	B+	A-	A-	A-	A-
Envelope	A	A	A	A	A	A	A	A
Interior Partitions	A	A	A	A	A	A	A	A
Millwork & Appliances	A	A	A	A	A	A	A	A
Utility	D	F	D+	C+	F-	C+	F-	F+
Electrical	B+	B+	B+	B+	B+	B+	B+	B+
Sewer & Water	A-	A-	A-	A	A	A	A-	B+
Thermal	A	A	A	A	A	A	A	A

Figure 18 below shows Test case 2 in comparison to the recommended practices (indicated by “BP” following the location name) houses across the test locations. Test Case 2 consistently outperformed the recommended practices house configuration for each region as shown in Figure 18 below.

Figure 18 Performance of Test Case 2 and Recommended Practices Configurations



### Test Case 3:

Test Case 3 is an “affordable” two story, modular house with full walkout basement. This house was designed for the Middle-Atlantic (Central) region of the U.S. Table 7 below shows the overall scoring for each system in the 8 locations included in the test. Case 3 is a partially engineered house, designed by a builder/developer. Test Case 3 scores more points in the Process and Production Design as it’s prefabrication method includes all in-house subcontractors and formal quality checks at each stage of construction. It’s masonry foundation system lacking external water management and insulation reduce the foundation scores in the North-Central and North-East locations. It’s relatively low-performing exterior wall with many windows and low-r value insulation and lack of vapor control similarly reduces scoring for the exterior envelope system in the Northern and Southern locations having more heating and cooling degree-days. Like Test Case 1 and 2, Case 3 locates ductwork in both conditioned and unconditioned spaces and the air handling unit in unconditioned space. The absence of passive or active Radon mitigation strategies contributed to the significantly lower scores in the Maine location.

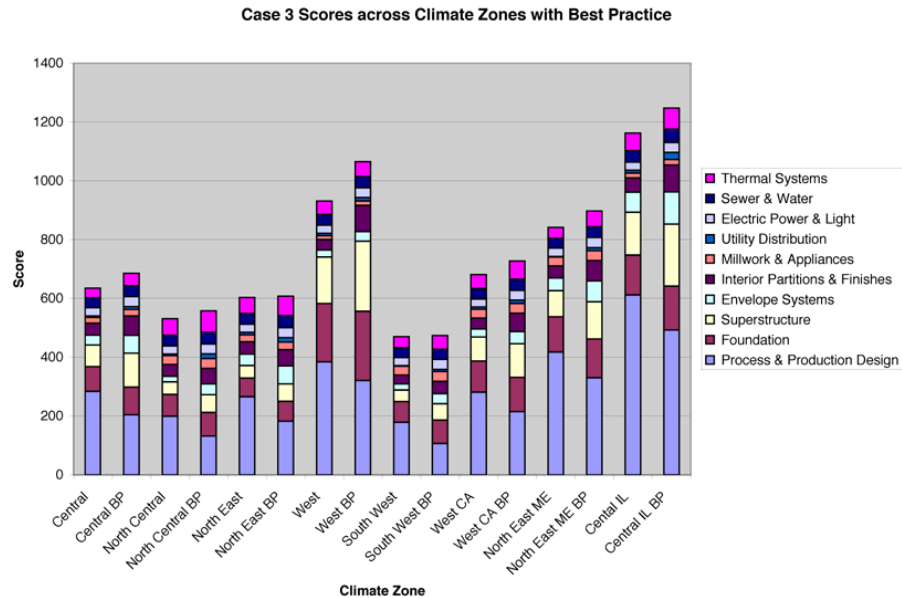
Table 7, Overall Subsystem Scoring for Test Case 3.

Location	Blacksburg, VA	Fargo, ND	Morton Grove, IL	Los Angeles, CA	Taos, NM	Yakima, WA	Androscoggin, ME	Alexander, IL
Zip Code	24060	58102	60053	90210	87512	98901	04210	62914
<b>Test Case 3</b>								
Process and Design	A	A	A	A	A	A	A	A
Foundation	B+	A-	A-	B+	A-	A-	A-	A-
Superstructure	C-	C+	C+	C	C+	C+	C+	C
Envelope	D+	D+	C-	C+	C-	C-	C-	C-
Interior Partitions	C-	B-	B-	F+	C+	C-	D+	D
Millwork & Appliances	A-	A-	A-	A-	A-	A-	A-	A-
Utility	D	F	D+	C+	F-	C	F-	F+
Electrical	B	B	B	B	B	B	B	B
Sewer & Water	A-	A-	A-	A	A	A	A-	B+
Thermal	B-	B-	B	A-	B	B-	C+	B

Figure 19 below shows Test Case 3 in comparison to the recommended practices (indicated by “BP” following the location name) houses across the

test locations. Unlike Test Cases 1 and 2, case 3 only outperforms the recommended practices house in the process and production design, but due to it's toe-nailed wall to plate connections, its mechanical system location in conditioned and unconditioned spaces, lower insulation values and lack of a moisture-managed envelope, it never outperforms the recommended practices house in any of the regions.

Figure 19, Performance of Test Case 3 and Recommended Practices Configurations



#### Test Case 4:

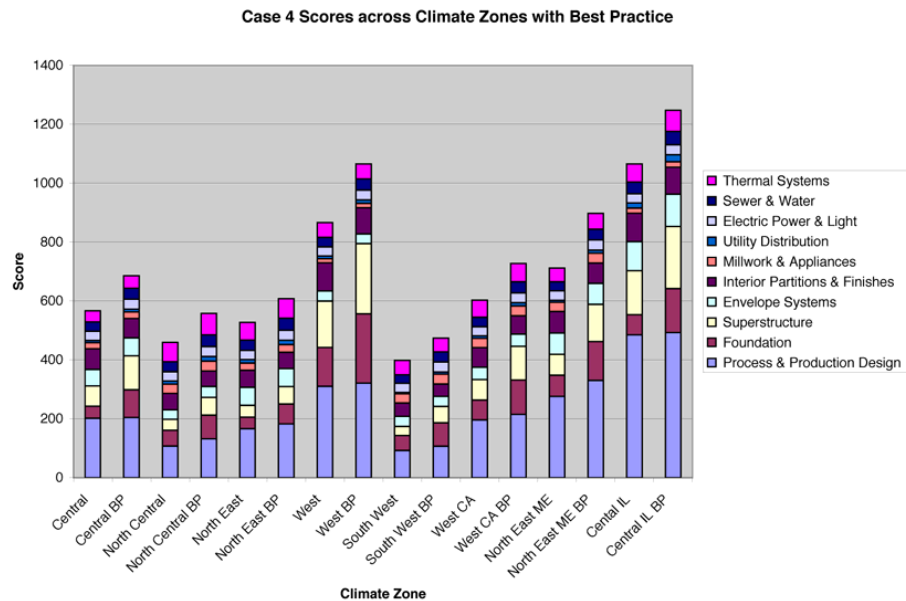
Test Case 4 is a one story, panelized house on a slab-on-grade, with an attached garage containing the homes mechanical system which is distributed through unconditioned spaces. It is considered a rapid-build (less than 14 days) house with a combination of self-supervising subcontractors and volunteer labor and having high end finishes and appliances comparable to a custom builder house; This house was designed for the Middle-Atlantic (Central) region of the U.S. Table below shows the overall scoring for each system in the 8 locations included in the test. The low scores for the superstructure system reflect an inherent error in the calculator's logic. When selecting a slab on grade, the user typically won't make selections in the floor framing categories in the superstructure. This results in 0 scores for floor framing that significantly reduce the scoring for the superstructure system. The foundation system scoring contains a similar error as users selecting a slab-on-grade often assume a "turned-down" edge to act as a footing. The current calculator does not offer this option and thus awards no points for the footing, significantly reducing the foundation systems score. This error will be addressed in future versions of the calculator.

Table 8, Overall Subsystem Scoring for Test Case 4.

Location Zip Code	Blacksburg, VA 24060	Fargo, ND 58102	Morton Grove, IL 60053	Los Angeles, CA 90210	Taos, NM 87512	Yakima, WA 98901	Androscoggin, ME 04210	Alexander, IL 62914
<b>Test Case 4</b>								
Process and Design	A	B	A-	A	B+	A-	B	A
Foundation	F+	C	D+	D+	C-	D+	D	D-
Superstructure	C-	C-	C	C	D+	C-	D+	C+
Envelope	A-	A	A	A	A	A	A	A-
Interior Partitions	A	A	A	A	A	A	A	A
Millwork & Appliances	A-	A-	A-	A-	A-	A-	A-	A-
Utility	B	C+	B	B-	D+	B-	C	C+
Electrical	A-	A-	A-	A-	A-	A-	A-	A-
Sewer & Water	B+	B+	B+	B+	B	B+	B+	B+
Thermal	A-	A-	A-	A	A	A-	B+	B+

Figure 20 below shows Test case 4 in comparison to the recommended practices (indicated by “BP” following the location name) houses across the test locations. Test case 4 never outperforms the recommended practices house configurations for any region. It’s mildly reinforced slab on grade structure lacking vertical insulation diminishes the performance score for the foundation system in all test locations. It’s 2x6 R-19 insulated wall panels help the envelope system score favorably if not a bit higher in the Northern locations.

Figure 20, Performance of Test Case 4 and Recommended Practices Configurations



### Test Case 5:

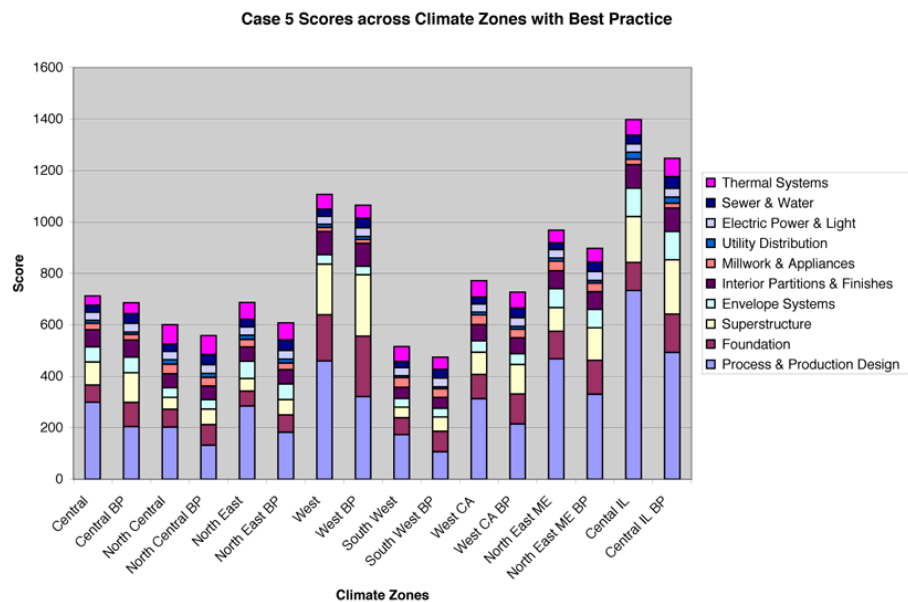
Test Case 5 is a one story, slab on grade “affordable” house, designed for high thermal performance, constructed by volunteer labor. This house was designed for the Great Plains (North-Central) region of the U.S. Table below shows the overall scoring for each system in the 8 locations included in the test. Case 5 is a fully designed and engineered house constructed with a Building America partnership. The low scores for the superstructure system reflect an inherent error in the calculator’s logic. When selecting a slab on grade, the user typically won’t make selections in the floor framing categories in the superstructure. This results in 0 scores for floor framing that significantly reduce the scoring for the superstructure system. The foundation system scoring contains a similar error as users selecting a slab-on-grade often assume a “turned-down” edge to act as a footing. The current calculator does not offer this option and thus awards no points for the footing, significantly reducing the foundation systems score. This error will be addressed in future versions of the calculator.

Table 9, Overall Subsystem Scoring for Test Case 5.

Location Zip Code	Blacksburg, VA 24060	Fargo, ND 58102	Morton Grove, IL 60053	Los Angeles, CA 90210	Taos, NM 87512	Yakima, WA 98901	Androscoggin, ME 04210	Alexander, IL 62914
<b>Test Case 5</b>								
Process and Design	A	A	A	A	A	A	A	A
Foundation	C+	B+	B+	B-	B	B	B	C+
Superstructure	B-	B-	B	B	C+	C+	C+	B+
Envelope	A	A	A	A	A	A	A	A
Interior Partitions	A	A	A	A	A	A	A	A
Millwork & Appliances	A	A	A	A	A	A	A	A
Utility	A	A	A	A	A	A	A	A
Electrical	A-	A-	A-	A-	A-	A-	A-	A-
Sewer & Water	C+	C+	C+	C+	C	C	C+	B-
Thermal	B+	A	A	A	A	A	A-	B

Figure 21 below shows Test case 5 in comparison to the recommended practices (indicated by “BP” following the location name) houses across the test locations. Even though it is an “affordable” house, Case 5 consistently outperforms the recommended practices house across all test locations

Figure 21, Performance of Test Case 5 and Recommended Practices Configurations



### Test Case 6

Test case 6 is a one story over crawl space, “affordable” house, constructed by volunteer labor and designed for the Middle Atlantic (Central) region of the U.S. Table 10 below shows the overall scoring for each system in the 8 locations included in the test.

The low scores for the foundation system can be attributed to the house being configured with an exposed earth crawl space instead of a basement with slab and no horizontal water vapor management components.

The superstructure earns slightly higher grades but are lower due to the configuration not including metal strap connectors between the stud wall and roof joists and not including any bracing for the gable roof. This contributes to average or below in locations where wind speeds and seismic concerns are more heavily weighted.

The envelope scores are average to below in the zone of origin (Blacksburg) reflecting the simplicity of the face-sealed approach to managing water in the exterior wall, the use of a non-woven, non-perforated air barrier, the absence of insulation chutes at the roof/wall intersection, and the absence of dedicated flashing at door and window openings. The very low scores for the

utility subsystem are attributed to locating both the ductwork and air handling unit in unconditioned spaces.

Electrical systems are lowered primarily because the house is configured with incandescent lighting and secondarily due to the absence of an integrated approach to wiring communication systems.

Sewer and water scores are reduced primarily due to the location of water supply lines in unconditioned spaces, not insulating both hot and cold water supply lines, and the absence of filtration systems and rainwater cisterns.

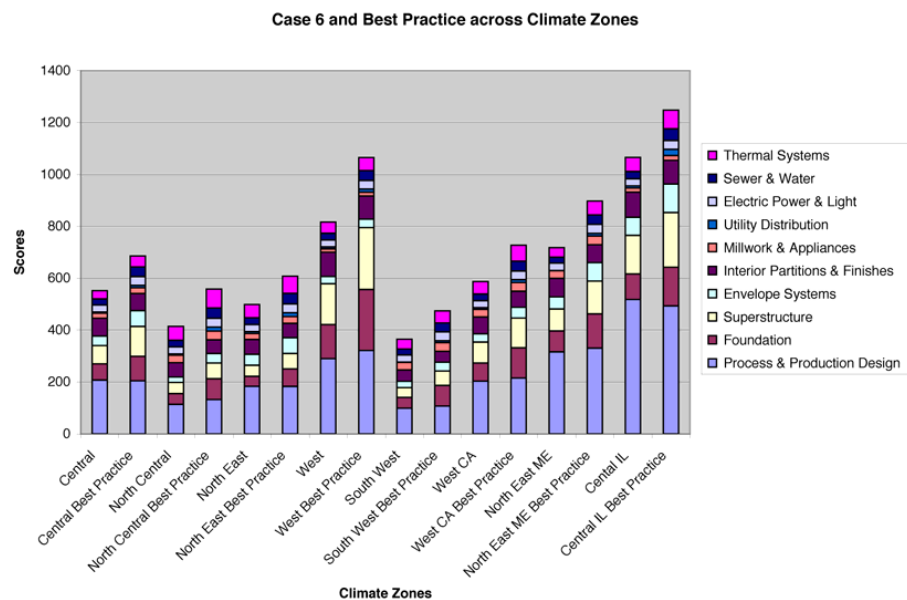
Thermal systems scores are higher where humidity control is less of an issue (Los Angeles, CA) and lower where humidity control is a greater concern (Fargo, ND, Androscoggin, ME) This thermal system score is also affected by the absence of an active radon ventilation system in Androscoggin, ME and the absence of a fireplace.

Table 10, Overall Subsystem Scoring for Test Case 6.

Location Zip Code	Blacksburg, VA 24060	Fargo, ND 58102	Morton Grove, IL 60053	Los Angeles, CA 90210	Taos, NM 87512	Yakima, WA 98901	Androscoggin, ME 04210	Alexander, IL 62914
<b>Test Case 6</b>								
Process and Design	A	A	A	A	A-	A	A	A
Foundation	C	D	D+	D+	D	C-	C-	C
Superstructure	C-	C+	C+	C	C	C+	C	C+
Envelope	C-	C	C	B	C+	B-	C	C-
Interior Partitions	A	A	A	A	A	A	A	A
Millwork & Appliances	B+	B+	B+	B+	B+	B+	B+	B+
Utility	F+	F-	D	C-	F-	C-	F-	F-
Electrical	B	B	B	B	B	B	B	B
Sewer & Water	C-	C-	C	C	C	C	C-	C-
Thermal	B-	C+	B-	B+	B	B-	C	B-

Figure 22 below shows Test case 6 in comparison to the recommended practices (indicated by “BP” following the location name) houses across the test locations. Case 6 never approaches the scores for the best practices house in any of the test locations.

Figure 22, Performance of Test Case 6 and Recommended Practices Configurations





After Dr. Wakefield's initial testing was completed we discovered an oversight. No tests were conducted for the "southeast" region. To address this, a separate series of tests were conducted using:

- Miami, FL, 33101 which is in the "Southeast" climate zone.

The results of this test are included separately in Table 11 below. The results are consistent with those reported in the individual Test Cases described above. The slab-on-grade foundation system errors appear in Test Cases 4 and 5 and affects the superstructure score as described in Test Case 4 and 5. The masonry crawl-space foundation in Case 6 without vapor control reduces the foundation score as it did in the other test locations. The absence of steel connections between the roof trusses and wall framing in Cases 3, 4 and 6 combined with absent gable roof bracing contributed to lower superstructure scores. Face-sealed exterior walls and a lack of door and window flashing used in Cases 3 and 6 similarly reduced envelope scores. Test Case 5, the Building America partner house, performed highest in utility system scoring largely due to its configuration having the ductwork and air-handling unit within conditioned spaces, while those configurations having ducts and air-handling units in unconditioned spaces scored failing grades in the utility subsystem.

Table 11, Test Configurations 1 through 6 in Miami, FL.

<b>Miami, FL</b>	<b>33101</b>								
<b>Test Case 1</b>									
Process and Design	Foundation	Superstructure	Envelope	Interior Partitions	Millwork & Appliances	Utility	Electrical	Sewer & Water	Thermal
<b>A</b>	<b>A</b>	<b>B-</b>	<b>A</b>	<b>A</b>	<b>A</b>	<b>F-</b>	<b>A-</b>	<b>B+</b>	<b>A</b>
<b>Test Case 2</b>									
Process and Design	Foundation	Superstructure	Envelope	Interior Partitions	Millwork & Appliances	Utility	Electrical	Sewer & Water	Thermal
<b>B+</b>	<b>A</b>	<b>B-</b>	<b>A</b>	<b>A</b>	<b>A</b>	<b>F-</b>	<b>A-</b>	<b>B+</b>	<b>A</b>
<b>Test Case 3</b>									
Process and Design	Foundation	Superstructure	Envelope	Interior Partitions	Millwork & Appliances	Utility	Electrical	Sewer & Water	Thermal
<b>A</b>	<b>A-</b>	<b>C</b>	<b>D</b>	<b>B</b>	<b>A-</b>	<b>F-</b>	<b>B</b>	<b>B+</b>	<b>A-</b>
<b>Test Case 4</b>									
Process and Design	Foundation	Superstructure	Envelope	Interior Partitions	Millwork & Appliances	Utility	Electrical	Sewer & Water	Thermal
<b>C</b>	<b>D-</b>	<b>C</b>	<b>A-</b>	<b>A</b>	<b>A-</b>	<b>C</b>	<b>A-</b>	<b>B+</b>	<b>B</b>
<b>Test Case 5</b>									
Process and Design	Foundation	Superstructure	Envelope	Interior Partitions	Millwork & Appliances	Utility	Electrical	Sewer & Water	Thermal
<b>A</b>	<b>B-</b>	<b>B</b>	<b>A</b>	<b>A</b>	<b>A</b>	<b>A</b>	<b>A</b>	<b>C+</b>	<b>B+</b>
<b>Test Case 6</b>									
Process and Design	Foundation	Superstructure	Envelope	Interior Partitions	Millwork & Appliances	Utility	Electrical	Sewer & Water	Thermal
<b>B-</b>	<b>C-</b>	<b>C-</b>	<b>D</b>	<b>A</b>	<b>B+</b>	<b>F-</b>	<b>B</b>	<b>D+</b>	<b>B-</b>

## Part Seven: Limitations and Next Steps

Regardless of the more-polished appearance and sizeable climatic, geologic and performance databases underpinning this second generation Whole House Calculator, it must be considered as a product-in-development rather than a completed product.

Only the small number of experts supported by this project have provided performance data and insight into contributing and mitigating factors in systems interactions. Future work on the calculator must focus on additional data input. More data from more experts will reduce the influence or bias of any single expert.

Any future versions of the calculator must also include additional expert input specifically on the subject of interactions to build a larger set of more sophisticated logic-based interaction subroutines.

Additional systems interaction subroutines must be developed as a high priority in subsequent iterations of the whole house calculator. The handful of interaction subroutines included in this second-generation calculator, while useful for testing the logic-based approach, is not fully inclusive of important interactions that occur between house systems and the local climatic and geologic conditions.

The following should be considered high-priority interaction developments:

- Combustion backdrafting
- Bulk water leakage from plumbing
- Deck/balcony collapse
- Uncontrolled air transport across the envelope
- Footing settlement/cracking from poor soils
- Corrosion of fasteners in coastal areas
- Fastener corrosion in treated lumber
- Un-reinforced masonry chimney failures in seismic events
- Poor material selection in wild fire areas
- Falling trees
- Rapid structural failure in fires
- Incomplete/non-continuous load path
- Copper pin holes/plumbing leaks in aggressive soils or water

Revisions to the current calculator should include:

- Introduce more locally recognized recommended practices houses. This second generation calculator has only one recommended practice house per region. This is artificially enhancing the score of the recommended practices house as it is being configured to cover the range of conditions found in, for example the Central U.S. region which extends from the hot/humid/hurricane-exposures of the North Carolina and Virginia Coast to the cold/humid/seismic-exposure of Southern Missouri.
- Revise the data table for seismic risk using data from the USGS shaking hazard map found at [http://earthquake.usgs.gov/research/hazmaps/products\\_data/images/nshm\\_us02.gif](http://earthquake.usgs.gov/research/hazmaps/products_data/images/nshm_us02.gif). This map scores the levels of horizontal shaking that have a 1 in 10 chance of occurring in a 50 year period. It has the advantage of a finer graded level of detail and would provide scores

ranging from 0 to 32% of the acceleration of a falling object due to gravity (g's).

- Reconsider the Heating Degree Day (HDD) weighting factor that is being mapped to the superstructure system. Including the HDD factor here may be a form of doubling the influence of humidity-related structural degradation and should be reconsidered in any subsequent development of the calculator.
- Revise the systems choices to accept the slab-on-grade as a form of first floor framing. The low scores for the superstructure system reflect an inherent error in the calculator's logic. When selecting a slab on grade, the user typically won't make selections in the floor framing categories in the superstructure. This results in 0 scores for floor framing that significantly reduce the scoring for the superstructure system. The foundation system scoring contains a similar error as users selecting a slab-on-grade often assume a "turned-down" edge to act as a footing. The current calculator does not offer this option and thus awards no points for the footing, significantly reducing the foundation systems score.
- Add snow loading to the systems weighting factors.
- Add flood zone information to Zip Code database of systems weighting factors.
- Develop a way of allowing for quantity or proportional input of window area, door area, areas of exterior and interior finishes and areas or proportion of cathedral type ceilings to flat ceilings. This would provide the data needed for the development of a uncontrolled air leakage interaction subroutine.

Should the calculator be developed with consumers in mind, the following items should be addressed:

- Introduce visual interface for existing housing stock configuration connected to editable systems choices for each house type and era of construction.
- Introduce a visual glossary for systems choices

It is hoped that if/when a subsequent generation of the calculator is developed that static databases and logic subroutines can be replaced by streaming simulation to provide more customized and accurate predictions of structural, thermal, moisture, air quality, environmental, and perhaps the economics of performance.

## Appendix One: Systems Choices Mapped to Weighting Factors

	WIND	SEISMIC	RADON	HUMIDITY	PRECIP	HEATING DEGREE DAYS	COOLING DEGREE DAYS
Process & production design							
2.1 Design & Engineering Credentials							
Architect & Engineer	X	X	X	X	X	X	X
Architect Only	X	X	X	X	X	X	X
Engineer Only	X	X	X	X	X	X	X
Unlicensed Designer	X	X	X	X	X	X	X
Energy rater	X	X	X	X	X	X	X
Part of building america program	X	X	X	X	X	X	X
Part of energy star program	X	X	X	X	X	X	X
Builder/developer	X	X	X	X	X	X	X
None	X	X	X	X	X	X	X
2.2 Design & Engineering Services							
Custom Design & Siting	X	X	X	X	X	X	X
Production Design, Custom Siting	X	X	X	X	X	X	X
Production Design, Production Siting	X	X	X	X	X	X	X
Production Siting, Production Design with	X	X	X	X	X	X	X
Purchased Design, no siting	X	X	X	X	X	X	X
2.3 Specific System Design Applications							
Structural Systems							
Fully Engineered	X	X					
Designed integration	X	X					
Engineered by suppliers or installers	X	X					
Components prescriptively described	X	X					
Components traditionally described	X	X					
2.4 Thermal Energy Systems			X	X	X	X	X
Fully Engineered			X	X	X	X	X
Designed integration			X	X	X	X	X
Engineered by suppliers or installers			X	X	X	X	X
Components prescriptively described			X	X	X	X	X
Components traditionally described			X	X	X	X	X
2.5 Water, Sewer & Gas Systems							
Fully Engineered							
Designed integration							
Engineered by suppliers or installers							
Components prosriptively described							
Components traditionally described							
2.6 Electric Power and Light							
Fully Engineered							
Designed integration							
Engineered by suppliers or installers							
Components prosriptively described							
Components traditionally described							

	WIND	SEISMIC	RADON	HUMIDITY	PRECIP	HEATING DEGREE DAYS	COOLING DEGREE DAYS
<b>2.7 House Design Characteristics</b>							
Presence of overhangs > 1 foot				X	X	X	X
Presence of ventilated attic				X	X	X	X
Presence of attic ridge vents				X	X	X	X
Presence of attic soffit vents				X	X	X	X
Presence of attic gable vents				X	X	X	X
Grading designed to slope away from fdn				X	X	X	X
Landscape design integration				X	X	X	X
Minimal exterior corners < 8				X	X	X	X
Minimal wall envelope penetrations < 16				X	X	X	X
Minimal roof envelope penetrations < 6				X	X	X	X
OVE framing				X	X	X	X
<b>2.8 House plan form (with garage)</b>							
Square	X	X					
Rectangle	X	X					
Ell "L"	X	X					
Tee "T"	X	X					
"U"	X	X					
<b>2.85 House size</b>							
< 1,000 s.f.				X	X	X	X
1,001 – 1,500				X	X	X	X
1,501 – 2,000				X	X	X	X
2,001 – 3,000				X	X	X	X
3,001 – 4,000				X	X	X	X
> 4,000				X	X	X	X
<b>2.86 Garage</b>							
attached	X	X				X	X
detached	X	X				X	X
below	X	X				X	X
beside	X	X				X	X
<b>2.87 Garage attachment condition</b>							
attached w/ shared wall (garage beside)						X	X
attached w/ shared ceiling/floor (garage under)						X	X
attached w/ shared wall and ceiling/floor (garage under and beside)						X	X
attached w/ shared floor/ceiling (garage over)						X	X
<b>2.9 House height</b>							
one story	X	X				X	X
one and one-half story	X	X				X	X
two story	X	X				X	X
three story	X	X				X	X
four story	X	X				X	X

	WIND	SEISMIC	RADON	HUMIDITY	PRECIP	HEATING DEGREE DAYS	COOLING DEGREE DAYS
2.95 Roof type							
Flat	X	X		X	X		
Hip	X	X		X	X		
Gable	X	X		X	X		
Shed	X	X		X	X		
Mansard	X	X		X	X		
Gambrel	X	X		X	X		
2.96 Roof Slope							
< 2:12	X	X		X	X		
3:12 – 4:12	X	X		X	X		
5:12 – 7:12	X	X		X	X		
8:12 – 12:12	X	X		X	X		
>12:12	X	X		X	X		
2.97 Foundation Type							
Slab-on-grade	X	X	X	X	X	X	X
Pier - open beneath	X	X	X	X	X	X	X
Crawl space - vented	X	X	X	X	X	X	X
Crawl space - conditioned	X	X	X	X	X	X	X
Basement - full	X	X	X	X	X	X	X
Basement - daylight or lookout	X	X	X	X	X	X	X
Basement - walkout	X	X	X	X	X	X	X
3.1 Production Design Construction Method (panel, stick)							
Traditional stick frame wood	X	X		X	X	X	X
Traditional stick frame light gauge steel	X	X		X	X	X	X
Panelized stick frame wood	X	X		X	X	X	X
Panelized stick frame light gauge steel	X	X		X	X	X	X
SIPS Panels	X	X		X	X	X	X
Prefabricated Modular (IRC Compliant)	X	X		X	X	X	X
Masonry	X	X		X	X	X	X
ICF	X	X		X	X	X	X
Precast concrete panels	X	X		X	X	X	X
3.2 Construction Method (min/max subs)							
In-house superintendent, all external sub	X	X	X	X	X	X	X
In-house superintendent, In-house shell	X	X	X	X	X	X	X
All in-house personnel	X	X	X	X	X	X	X
All subcontract - self supervision	X	X	X	X	X	X	X
3.3 Construction Quality System Design							
Quality check of personnel training	X	X	X	X	X	X	X
Quality check of work as increments are	X	X	X	X	X	X	X
Commissioning of performance of the co	X	X	X	X	X	X	X
Fit & Finish check at the end of the proje	X	X	X	X	X	X	X
3.4 Construction Safety System Design							
Safety training for personnel at project start							
Daily safety briefings							
Daily safety inspections for rigging, trenching temp structures							
Tooling and materials designed for safety (label, cg, edges, switches, falls)							
Safety a personal decision							

	WIND	SEISMIC	RADON	HUMIDITY	PRECIP	HEATING DEGREE DAYS	COOLING DEGREE DAYS
<b>3.5 Disaster Safety Strategies</b>							
Blow out panels in floodable first floor	X						
120 mph resistant shutters at openings	X						
"Safe room", "strong room" for high wind	X						
Braced garage doors	X						
High impact windows/glazing	X						
Building elevated on piles or columns at	X						
<b>Foundation</b>							
<b>4.1 Subgrade Systems - Footing</b>							
Treated Wood	X	X					
Site cast concrete	X	X					
Crushed rock	X	X					
Pilings	X	X					
None – see slab on grade	X	X					
<b>4.2 Foundation</b>							
Masonry	X	X					
Site cast concrete	X	X					
Precast concrete	X	X					
Insulated Concrete Formwork (ICF)	X	X					
Permanent Wood	X	X					
<b>4.3 Slab on Grade</b>							
Glass Strand reinforcing	X	X	X				
Wire mesh reinforcing	X	X	X				
Rebar reinforcing	X	X	X				
Post tension strand reinforcing	X	X	X				
Combination of the above	X	X	X				
None	X	X	X				
<b>4.4 Subgrade Insulation - horizontal</b>							
Expanded Polystyrene (EPS)						X	X
Extruded Polystyrene (XPS)						X	X
Sprayed on Icylene						X	X
Fiberglass Board						X	X
Fiberglass Batts						X	X
Mineral fiber blockfill						X	X
Foam Beads						X	X
None						X	X
<b>4.45 Subgrade Insulation - vertical</b>							
Expanded Polystyrene (EPS)						X	X
Extruded Polystyrene (XPS)						X	X
Sprayed on Icylene						X	X
Fiberglass Board						X	X
Fiberglass Batts						X	X
Mineral fiber blockfill						X	X
Foam Beads						X	X
None						X	X

	WIND	SEISMIC	RADON	HUMIDITY	PRECIP	HEATING DEGREE DAYS	COOLING DEGREE DAYS
4.46 Subgrade Insulation - Location							
Interior						X	X
Exterior						X	X
Integral						X	X
Both sides						X	X
None						X	X
4.5 Subgrade Water Management Layer (Vertical)							
Brush-on cementitious				X	X	X	X
Brush-on asphaltic				X	X	X	X
Trowel-on asphaltic				X	X	X	X
Spray-on bitumen				X	X	X	X
Sheet-applied bituthene				X	X	X	X
Drain Board/Panel/Sheet				X	X	X	X
Washed Aggregate				X	X	X	X
None				X	X	X	X
4.6 Subgrade Water Management Layer (Horizontal)							
4 mil poly sheet			X	X	X	X	X
6 mil poly sheet			X	X	X	X	X
Sand and gravel cushion			X	X	X	X	X
Washed Aggregate			X	X	X	X	X
None			X	X	X	X	X
Superstructure							
6.1 Floor Framing							
Dimension lumber - site framed	X	X				X	
Engineered lumber - site framed	X	X				X	
Prefabricated trusses - site assembled	X	X				X	
Prefabricated trusses & floor panels - fac	X	X				X	
Light gauge steel - site framed	X	X				X	
6.15 Floor Rim/Band Insulation and vapor barrier							
Fiberglass Batts - faced						X	X
Fiberglass Batts - unfaced						X	X
Fiberglass Batts and Polyethylene						X	X
Spray-on Icynene						X	X
Spray-on polyurethane						X	X
Interior rigid foam board						X	X
Exterior rigid foam board						X	X
6.2 Wall Framing							
Dimension lumber	X	X		X			X
Engineered lumber	X	X		X			X
Light gauge steel	X	X		X			X
Reinforced masonry	X	X		X			X
Unreinforced masonry	X	X		X			X
Prefabricated panels	X	X		X			X
Structural Insulated Panels - SIPS	X	X		X			X
Insulated Concrete Formwork - ICF	X	X		X			X



	WIND	SEISMIC	RADON	HUMIDITY	PRECIP	HEATING DEGREE DAYS	COOLING DEGREE DAYS
<b>6.3 Shear Framing</b>							
Shear panels at corners only	X	X					
Let-in "T" bracing	X	X					
Fully sheathed in structure panels	X	X					
Prefabricated shear panels (eg strongwall)	X	X					
Light gauge steel	X	X					
<b>6.4 Roof Framing</b>							
Dimension lumber	X	X		X		X	X
Engineered lumber	X	X		X		X	X
Prefabricated wood trusses	X	X		X		X	X
Prefabricated light gauge steel trusses	X	X		X		X	X
<b>6.5 Roof to Wall connection</b>							
Toe nail	X	X					
Clips	X	X					
Single plate wrap	X	X					
Double plate wrap	X	X					
<b>6.6 Roof Bracing (if gable)</b>							
Braced in vert and sloped plane	X	X					
Braced in vert plane only	X	X					
Unbraced	X	X					
<b>7.1 Envelope Systems</b>							
Sawn wood siding	X	X			X	X	X
Plywood siding	X	X			X	X	X
Composition board siding	X	X			X	X	X
Cement board siding	X	X			X	X	X
Masonry veneer	X	X			X	X	X
Vinyl siding	X	X			X	X	X
Metal siding	X	X			X	X	X
Acrylic-stucco, Exterior insulation and Finish	X	X			X	X	X
Traditional 3 coat stucco	X	X			X	X	X
Economy 2 coat stucco	X	X			X	X	X
<b>7.2 Bulk Moisture Management</b>							
Water managed wall with rainscreen	X				X		
Face-sealed wall	X				X		
Water managed wall without rainscreen	X				X		
<b>7.3 Air Barrier</b>							
Non-woven, non, perforated Housewrap	X			X	X	X	X
Perforated Housewrap	X			X	X	X	X
Woven Housewrap	X			X	X	X	X
Water managing housewrap	X			X	X	X	X
Asphalt-impregnated building paper	X			X	X	X	X
Kraft paper	X			X	X	X	X
Sealed exterior gypsum sheathing	X			X	X	X	X

	WIND	SEISMIC	RADON	HUMIDITY	PRECIP	HEATING DEGREE DAYS	COOLING DEGREE DAYS
<b>7.4 Wall Insulation</b>							
Glass batt in stud cavity-unfaced				X		X	X
Glass batt in stud cavity-foil faced				X		X	X
Glass batt in stud cavity-paper faced				X		X	X
Glass batt in stud cavity with extruded polystyrene board sheat				X		X	X
Glass batt in stud cavity with foil faced polyiso board sheathing				X		X	X
Sprayed on Icynene				X		X	X
Mineral fiber batt or fill				X		X	X
Spray-on polyurethane				X		X	X
Blown-in Fiberglass				X		X	X
Dense-pack cellulose				X		X	X
<b>7.5 Water Vapor Management</b>							
Poly sheet barrier				X		X	X
Vapor-retarding latex paint				X		X	X
Vinyl wall covering				X		X	X
Kraft paper				X		X	X
Smart vapor retarder				X		X	X
none				X		X	X
Manage with xps or polyiso sheathing							
<b>7.6 Opening Flashing</b>							
Field applied bituthene sheet	X				X		
Field fabricated metal	X				X		
Prefabricated metal	X				X		
Prefabricated plastic	X				X		
Tape-sealed nailing flange	X				X		
None	X				X		
<b>8.1 Roof</b>							
Primary membrane							
Asphalt shingles	X				X		
Wood shingle	X				X		
Prefinished metal	X				X		
Clay or cement tile	X				X		
Single-ply membrane	X				X		
Built-up roofing	X				X		
<b>8.2 Eave/valley ice dam protection</b>							
Bituthene sheet					X		
Hot-mopped roofing felt					X		
Building paper					X		
None					X		
<b>8.3 Secondary Membrane</b>							
Bituthene sheet	X				X		
Hot-mopped roofing felt	X				X		
Building paper	X				X		
None	X				X		

	WIND	SEISMIC	RADON	HUMIDITY	PRECIP	HEATING DEGREE DAYS	COOLING DEGREE DAYS
<b>8.4 Insulation - Attic</b>							
Blown fiberglass				X		X	X
Blown mineral fiber				X		X	X
Blown cellulose				X		X	X
Glass batts				X		X	X
Mineral fiber batts				X		X	X
<b>8.5 Insulation - Cathedral (sloped rafter/joist)</b>							
EPS SIP				X		X	X
XPS SIP				X		X	X
Polyiso SIP				X		X	X
Glass batts				X		X	X
Mineral fiber batts				X		X	X
Sprayed on Icylene				X		X	X
<b>8.6 Ventilation - Attic</b>							
Eave to ridge - no chutes	X			X	X	X	X
Eave to ridge - preformed chutes	X			X	X	X	X
Power vents - temperature controlled	X			X	X	X	X
Gravity vent	X			X	X	X	X
Gravity vent cold roof	X			X	X	X	X
Power vent	X			X	X	X	X
None	X			X	X	X	X
<b>8.7 Roof Flashing</b>							
Prefabricated metal					X		
Site - formed - membrane					X		
Site fabricated metal					X		
Preformed plastic					X		
<b>9.1 Floor insulation</b>							
Glass batts				X		X	X
Mineral fiber batts				X		X	X
Blown fiberglass				X		X	X
Blown mineral fiber				X		X	X
Sprayed on Icylene				X		X	X
Spray-on polyurethane				X		X	X
None				X		X	X
<b>Interior Partitions and Finishes</b>							
<b>10.1 Partition Framing</b>							
Site framed wood	X	X					
Prefabricated wood	X	X					
Site framed light gauge steel	X	X					
Prefabricated light gauge steel	X	X					
Masonry	X	X					

	WIND	SEISMIC	RADON	HUMIDITY	PRECIP	HEATING DEGREE DAYS	COOLING DEGREE DAYS
10.2 Wall Finish Substrate							
Plaster				X			
Drywall				X			
Reduced-cellulose drywall				X			
Drywall over engineered wood (SIPS, OSB, plywood)				X			
Masonry				X			
ICF							
10.3 Primary interior finish at exterior wall							
1 latex primer + 1 finish latex				X	X	X	X
1 latex primer + 2 finish latex				X	X	X	X
Vinyl wall covering				X	X	X	X
Wood veneer paneling				X	X	X	X
Ceramic tile				X	X	X	X
None							
10.4 Primary wall finishes (int. wall)							
1 latex primer + 1 finish latex							
1 latex primer + 2 finish latex							
Vinyl wall covering							
Wood veneer paneling							
Ceramic tile							
None							
11.1 Subfloor							
Particle board	X	X				X	X
OSB	X	X				X	X
Plywood	X	X				X	X
Cement board	X	X				X	X
Concrete	X	X				X	X
Self-leveling gypsum topping	X	X				X	X
11.2 Floor finishes							
Pad and carpet						X	X
Direct-glued carpet						X	X
Vinyl sheet goods						X	X
Vinyl tile						X	X
Ceramic tile						X	X
Hardwood-solid						X	X
Hardwood-veneer						X	X
Plastic laminate						X	X
12.1 Ceiling substrates							
Plaster				X			
Drywall				X			
Reduced-cellulose drywall				X			
Wood deck or panel				X			
None				X			

	WIND	SEISMIC	RADON	HUMIDITY	PRECIP	HEATING DEGREE DAYS	COOLING DEGREE DAYS
12.2 Ceiling finishes							
1 latex primer + 1 finish latex				X			
1 high-build primer / finish coat				X			
Lay-in tile				X			
None				X			
13.1 Countertops							
Plastic laminate						X	
Stone						X	
Cultured stone						X	
Soild cast arylc-plastic						X	
Ceramic tile						X	
Metal						X	
Concrete						X	
Millwork & Appliances							
13.2 Millwork & Appliances							
Interior trim							
Milled wood						X	
Milled or formed wood composite						X	
PVC						X	
Other plastic						X	
13.3 Cabinetry							
Prefabricated - milled wood						X	
Prefabricated - engineered wood						X	
Custom fabricated - milled wood						X	
Custom fabricated - engineered wood						X	
14.1 Gas Appliance Venting							
Plumber-installed						X	
Builder-installed						X	
Owner-installed						X	
Third-party-tested						X	
14.2 Appliance Subcontract Method							
By builder						X	
By owner						X	
Utility distribution							
15.1 Utility Distribution							
Integration Strategies				X		X	X
Bundled-weaved together based on schedule				X		X	X
Unbundled-each subsystem has designed place				X		X	X
Hybrid-system trunks in designed places, distribution woven				X		X	X
15.2 Production Strategies							
Site fabricated trunks and feeders						X	X
Prefabricated trunks and feeders						X	X
Hybrid, prefabricated trunks, site fabricated distribution						X	X

	WIND	SEISMIC	RADON	HUMIDITY	PRECIP	HEATING DEGREE DAYS	COOLING DEGREE DAYS
15.3 Ductwork Location							
All in unconditioned spaces				X		X	X
All in conditioned spaces				X		X	X
In conditioned and unconditioned spaces				X		X	X
15.35 Air handling unit location							
In unconditioned space				X		X	X
In conditioned space				X		X	X
In garage				X		X	X
15.4 Ductwork Material							
Site formed metal				X		X	X
Site formed ductboard				X		X	X
Flexduct - insulated				X		X	X
Flexduct - uninsulated				X		X	X
Prefabricated metal				X		X	X
Prefabricated ductboard				X		X	X
Elec power & light							
18.1 Electrical wiring strat (conduit, romex)							
Conduit							
Romex							
Wiring harness							
18.2 Communication wiring strat (cat5, sep)							
Category 5/6							
Separate wiring for each system							
18.3 Electric Power & Light							
Generation Types	X						
On grid	X						
Self - PV generation	X						
Self - wind generation	X						
Self - gas or propane generator	X						
Hybrid on-grid and self-generation	X						
18.4 Lighting Design Types							
Designed by lighting engineer							
Designed by electrical engineer							
Designed by architect							
Designed by supplier							
Designed by installer							
18.5 Primary Lighting Types							
Incandescent							
Compact fluorescent							
Low Voltage							

	WIND	SEISMIC	RADON	HUMIDITY	PRECIP	HEATING DEGREE DAYS	COOLING DEGREE DAYS
Sewer & water							
16.1 Water Piping Location							
All in conditioned spaces				X		X	X
In conditioned and unconditioned spaces				X		X	X
16.2 Water Piping Material							
Copper				X		X	X
Polyisobutylene				X		X	X
PVC				X		X	X
CPVC				X		X	X
PEX				X		X	X
16.3 Water Piping Insulation Strategy							
All insulated				X		X	X
Hot water only insulated				X		X	X
No insulation				X		X	X
17.1 Sewer Piping Location							
Within partitions							
Directly to subgrade							
17.2 Sewer Piping Material							
PVC							
Iron							
19.1 Water & Sewer							
Source Strategies							
Municipal							
Private well							
Purchased service							
19.2 Treatment Strategies							
None							
Filtered							
Softened							
19.3 Storage Strategies							
None							
Cistern							
19.4 Disposal Strategies							
Municipal							
Septic system							
Storage tank							
Greywater recovery							

	WIND	SEISMIC	RADON	HUMIDITY	PRECIP	HEATING DEGREE DAYS	COOLING DEGREE DAYS
Thermal systems							
20 Overall Strategies							
Central System				X		X	X
Room by Room conditioning				X		X	X
Through the wall units				X		X	X
Window units				X		X	X
20.1 Heating Strategies							
Gas fired boiler or water heater				X		X	X
Oil fired boiler or water heater				X		X	X
Electric boiler or water heater				X		X	X
Gas hot air furnace				X		X	X
Oil hot air furnace				X		X	X
Electric hot air furnace				X		X	X
Ground coupled electric heat pump				X		X	X
Air source electric heat pump				X		X	X
Straight cooling w/ electric baseboard heat				X		X	X
20.15 Cooling Strategies							
Central forced air				X		X	X
Split system				X		X	X
Window unit				X		X	X
Through wall unit				X		X	X
Whole house exhaust fan				X		X	X
20.16 Filtration Strategies							
Fiberglass filter				X		X	X
Pleated filter				X		X	X
Deep pleated media				X		X	X
Electronic				X		X	X
None				X		X	X
20.17 Radon mitigation Strategies							
Under slab barrier			X				
Foundation/sump sealing			X				
Passive ventilation			X				
Active sub-slab depressurization			X				
None			X				
20.18 Dehumidification strategy							
Stand-alone unit				X		X	X
Whole house				X		X	X
None				X		X	X
20.2 Distribution medium Strategies (water, air, radiant)							
Radiant slab water				X		X	X
Hot water radiator				X		X	X
Ducted air distribution				X		X	X
Non-ducted air distribution				X		X	X



	WIND	SEISMIC	RADON	HUMIDITY	PRECIP	HEATING DEGREE DAYS	COOLING DEGREE DAYS
20.3 Domestic Hot water Integration Strategies (dhw & hvac)							
Integrated hot water and furnace						X	X
Stand alone hot water heat and storage						X	X
Tankless electric hot water source heaters						X	X
Tankless gas hot water source heaters						X	X
Solar hot water heat and storage						X	X
Heat pump water heater						X	X
21.1 Supply Strategies (loc, vel, diff, char)							
Perimeter diffuser locations				X		X	X
Core diffuser locations				X		X	X
21.15 Control Strategies							
Zoned				X		X	X
Programmable thermostat				X		X	X
Time delay relay				X		X	X
21.2 Air Velocity							
Low velocity				X		X	X
High velocity				X		X	X
Ultra high velocity				X		X	X
21.3 Diffuser Characteristics							
Pressure-reducing				X		X	X
Point				X		X	X
Linear				X		X	X
21.4 Return Strategies							
Fully ducted returns from each space				X		X	X
Central ducted return				X		X	X
Ducted return for each floor served				X		X	X
Panned joist return duct				X		X	X
Wall cavity return duct				X		X	X
21.5 House Ventilation Strategies							
Continuous supply ventilation				X		X	X
Supply vent only when ahu runs				X		X	X
Exhaust-driven makeup air				X		X	X
Balanced with heat recovery				X		X	X
Balanced with no heat recovery				X		X	X
Balanced with energy recovery				X		X	X
Timed supply ventilation				X		X	X
Timed exhaust ventilation				X		X	X

	WIND	SEISMIC	RADON	HUMIDITY	PRECIP	HEATING DEGREE DAYS	COOLING DEGREE DAYS
21.6 Fireplace Strategies							
Masonry on exterior wall				X		X	X
Masonry on interior wall				X		X	X
Metal on exterior wall				X		X	X
Metal on interior wall				X		X	X
21.6 Fireplace venting Strategies							
Chimney above roof						X	
Vented through wall						X	
Ventless gas						X	
Ventless alcohol						X	
Ventless electric						X	
21.7 Kitchen Ventilation							
Hood - recirculating						X	
Hood - exhausting						X	
Downdraft						X	
21.7 Central Vacuum							
Present						X	
None						X	

## Appendix Two, Systems Interactions:

interaction name						
contributing systems choice heading						
contributing systems choice						
mitigating systems choice factors						
triggering factor						
seismic collapse		seismic location 3 or 4	poss negatives	26		
2.1 Design & Engineering Credentials			poss positives	30		
Unlicensed Designer						
Energy rater						
Part of building america program						
Part of energy star program						
Builder/developer						
None						
Architect & Engineer						
Architect Only						
Engineer Only						
2.3 Specific System Design Applications						
Components prescriptively described						
Components traditionally described						
Fully Engineered						
Engineered by suppliers or installers						
2.7 House Design Characteristics						
Minimal exterior corners <8						
Minimal wall envelope penetrations <16						
2.8 House plan form (with garage)						
EII "L"						
Tee "T"						
"U"						
Square						
Rectangle						
2.86 Garage						
below						
detached						
beside						
2.9 House height						
two story						
three story						
four story						
2.97 Foundation Type						
Basement - full						
Basement - daylight or lookout						
Basement - walkout						
3.1 Production Design Construction Method (panel, stick)						
Traditional stick frame wood						
Panelized stick frame wood						
Traditional stick frame light gauge steel						
Panelized stick frame light gauge steel						
SIPS Panels						
Prefabricated Modular (IRC Compliant)						
ICF						
3.2 Construction Method (min/max subs)						
In-house superintendent, all external subs						
All subcontract - self supervision						
In-house superintendent, In-house shell crew, minimal subs						
All in-house personnel						
3.3 Construction Quality System Design						
Quality check of work as increments are completed						
4.1 Subgrade Systems - Footing						
Site cast concrete						
4.3 Slab on Grade						
Post tension strand reinforcing						
Combination of the above						
6.1 Floor Framing						
Prefabricated trusses - site assembled						
Prefabricated trusses & floor panels - factory assembled						
Dimension lumber - site framed						
Engineered lumber - site framed						
6.3 Shear Framing						
Light gauge steel - site framed						
Shear panels at corners only						
Let-in "T" bracing						
Fully sheathed in structure panels						
Prefabricated shear panels (eg strongwall)						
6.5 Load Path Connections (previously Roof to Wall connection)						
Toe nail						
Clips						
Double plate wrap						

interaction name						
<b>contributing systems choice heading</b>						
<b>contributing systems choice</b>						
<b>mitigating systems choice factors</b>						
<b>triggering factor</b>						
<b>high wind collapse</b>		<b>wind exposure &gt;=100</b>				
2.1 Design & Engineering Credentials				poss negatives		40
Unlicensed Designer				poss positives		
Energy rater						
Part of building america program						
Part of energy star program						
Builder/developer						
None						
	Architect & Engineer					
	Architect Only					
	Engineer Only					
2.3 Specific System Design Applications						
	Components prescriptively described					
	Components traditionally described					
	Fully Engineered					
	Engineered by suppliers or installers					
2.7 House Design Characteristics						
	Presence of overhangs>1 foot					
	Minimal exterior corners <8					
	Minimal wall envelope penetrations <16					
2.86 Garage						
	attached					
	beside					
	below					
	detached					
2.87 Garage attachment condition						
	attached w/ shared wall (garage beside)					
	attached w/ shared wall and ceiling/floor (garage under and beside)					
	attached w/ shared ceiling/floor (garage under)					
2.9 House height						
	two story					
	three story					
	four story					
2.95 Roof type						
	Gable					
	Shed					
	Mansard					
	Gambrel					
	Flat					
	Hip					
2.96 Roof Slope						
	8:12 – 12:12					
	>12:12					
	< 2:12					
	3:12 – 4:12					
	5:12 – 7:12					
3.1 Production Design Construction Method (panel, stick)						
	Traditional stick frame wood					
	Panelized stick frame wood					
	Traditional stick frame light gauge steel					
	Panelized stick frame light gauge steel					
	SIPS Panels					
	Prefabricated Modular (IRC Compliant)					
	ICF					
3.2 Construction Method (min/max subs)						
	In-house superintendent, all external subs					
	All subcontract - self supervision					
	In-house superintendent, In-house shell crew, minimal subs					
	All in-house personnel					
3.3 Construction Quality System Design						
	Quality check of work as increments are completed					

<i>interaction name</i>						
<b>contributing systems choice heading</b>						
<b>contributing systems choice</b>						
<b>mitigating systems choice factors</b>						
<b>triggering factor</b>						
3.5 Disaster Safety Strategies						
			120 mph resistant shutters at openings			
			Braced garage doors			
			High impact windows/glazing			
4.1 Subgrade Systems - Footing						
		Treated Wood				
		Crushed rock				
			Site cast concrete			
			Pilings			
4.2 Foundation						
		Permanent Wood				
			Site cast concrete			
			Precast concrete			
			Insulated Concrete Formwork (ICF)			
6.1 Floor Framing						
		Prefabricated trusses - site assembled				
		Prefabricated trusses & floor panels - factory assembled				
			Dimension lumber - site framed			
			Engineered lumber - site framed			
			Light gauge steel - site framed			
6.2 Wall Framing						
		Dimension lumber				
		Unreinforced masonry				
			Light gauge steel			
			Reinforced masonry			
			Structural Insulated Panels - SIPS			
			Insulated Concrete Formwork - ICF			
6.3 Shear Framing						
		Shear panels at corners only				
			Let-in "T" bracing			
			Fully sheathed in structure panels			
			Prefabricated shear panels (eg strongwall)			
			Light gauge steel			
6.4 Roof Framing						
		Prefabricated wood trusses				
			Dimension lumber			
			Engineered lumber			
			Prefabricated light gauge steel trusses			
6.5 Load Path Connections (previously Roof to Wall connection)						
		Toe nail				
		Clips				
			Double plate wrap			
6.6 Roof Bracing (if gable)						
		Unbraced				
			Braced in vert and sloped plane			

<b>interaction name</b>							
<b>contributing systems choice heading</b>							
<b>contributing systems choice</b>							
<b>mitigating systems choice factors</b>							
<b>triggering factor</b>							
<b>high wind induced water intrusion</b>	<b>wind exposure &gt;=100</b>						
2.1 Design & Engineering Credentials							
Unlicensed Designer							
None							
	Architect & Engineer						
	Architect Only						
	Part of building america program						
2.2 Design & Engineering Services							
Purchased Design, no siting							
	Custom Design & Siting						
	Production Design, Custom Siting						
	Production Design, Production Siting						
	Production Siting, Production Design with prepacked options						
2.7 House Design Characteristics							
	Minimal wall envelope penetrations <16						
	Minimal roof envelope penetrations < 6						
2.86 Garage							
attached							
below							
beside							
	detached						
2.87 Garage attachment condition							
attached w/ shared wall (garage beside)							
attached w/ shared ceiling/floor (garage under)							
attached w/ shared wall and ceiling/floor (garage under and beside)							
attached w/ shared floor/ceiling (garage over)							
2.9 House height							
two story							
three story							
four story							
2.95 Roof type							
Gable							
Shed							
Mansard							
Gambrel							
	Hip						
2.96 Roof Slope							
8:12 – 12:12							
>12:12							
	3:12 – 4:12						
	5:12 – 7:12						
3.2 Construction Method (min/max subs)							
In-house superintendent, all external subs							
All subcontract - self supervision							
	In-house superintendent, In-house shell crew, minimal subs						
	All in-house personnel						
3.3 Construction Quality System Design							
109	Quality check of work as increments are completed						
3.5 Disaster Safety Strategies							
118	120 mph resistant shutters at openings						
120	Braced garage doors						
121	High impact windows/glazing						
6.2 Wall Framing							
192	Insulated Concrete Formwork - ICF						
7.1 Envelope Systems							
209	Sawn wood siding						
210	Plywood siding						
211	Composition board siding						
212	Cement board siding						
214	Vinyl siding						
215	Metal siding						
216	Acrylic-stucco, Exterior insulation and Finish System (EIFS)						

<i>interaction name</i>						
<b>contributing systems choice heading</b>						
<b>contributing systems choice</b>						
<b>mitigating systems choice factors</b>						
<b>triggering factor</b>						
213		Masonry veneer				
217		Traditional 3 coat stucco				
218		Economy 2 coat stucco				
7.6 Opening Flashing						
249	Tape-sealed nailing flange					
251	None					
245		Field applied bituthene sheet				
246		Field fabricated metal				
247		Prefabricated metal				
248		Prefabricated plastic				
8.1 Primary Roof membrane						
251	Asphalt shingles					
256		Built-up roofing				
8.3 Secondary Membrane						
259	Building paper					
260	None					
	257	Bituthene sheet				
	258	Hot-mopped roofing felt				

<b>interaction name</b>						
<b>contributing systems choice heading</b>						
<b>contributing systems choice</b>						
<b>mitigating systems choice factors</b>						
<b>triggering factor</b>						
<b>structural degradation from excessive moisture levels</b>						
			<b>Ave Relative Humidity &gt;65</b>			
2.1 Design & Engineering Credentials						
4	Unlicensed Designer					
8	Builder/developer					
9	None					
1		Architect & Engineer				
5		Energy rater				
6		Part of building america program				
7		Part of energy star program				
2.2 Design & Engineering Services						
14	Purchased Design, no siting					
10		Custom Design & Siting				
11		Production Design, Custom Siting				
12		Production Design, Production Siting				
13		Production Siting, Production Design with prepacked options				
2.7 House Design Characteristics						
37	Presence of ventilated attic					
38	Presence of attic ridge vents					
39	Presence of attic soffit vents					
40	Presence of attic gable vents					
41		Grading designed to slope away from fdn				
36		Presence of overhangs>1 foot				
2.97 Foundation Type						
89	Pier - open beneath					
90	Crawl space - vented					
91		Crawl space - conditioned				
3.2 Construction Method (min/max subs)						
104	In-house superintendent, all external subs					
107	All subcontract - self supervision					
105		In-house superintendent, In-house shell crew, minimal subs				
106		All in-house personnel				
3.3 Construction Quality System Design						
109		Quality check of work as increments are completed				
4.6 Subgrade Water Management Layer (Horizontal)						
172	None					
170	Sand and gravel cushion					
168		4 mil poly sheet				
169		6 mil poly sheet				
6.1 Floor Framing						
173	Dimension lumber - site framed					
174	Engineered lumber - site framed					
175	Prefabricated trusses - site assembled					
176	Prefabricated trusses & floor panels - factory assembled					
177		Light gauge steel - site framed				
6.4 Roof Framing						
198	Dimension lumber					
199	Engineered lumber					
200	Prefabricated wood trusses					
201		Prefabricated light gauge steel trusses				
7.1 Envelope Systems						
216	Acrylic-stucco, Exterior insulation and Finish System (EIFS)					
209		Sawn wood siding				
210		Plywood siding				
211		Composition board siding				
212		Cement board siding				
213		Masonry veneer				
214		Vinyl siding				
215		Metal siding				
217		Traditional 3 coat stucco				
218		Economy 2 coat stucco				
7.2 Bulk Moisture Management						

interaction name							
<b>contributing systems choice heading</b>							
<b>contributing systems choice</b>							
<b>mitigating systems choice factors</b>							
<b>triggering factor</b>							
220	Face-sealed wall						
219		Water managed wall with rainscreen					
221		Water managed wall without rainscreen					
7.3 Air Barrier							
222	Non-woven, non, perforated Housewrap						
223		Perforated Housewrap					
224		Woven Housewrap					
225		Water managing housewrap					
226		Asphalt-impregnated building paper					
227		Kraft paper					
7.4 Wall Insulation							
238	Dense-pack cellulose						
7.5 Water Vapor Management							
239	Poly sheet barrier						
241	Vinyl wall covering						
242		Kraft paper					
243		Smart vapor retarder					
7.6 Opening Flashing							
249	Tape-sealed nailing flange						
250	None						
245		Field applied bituthene sheet					
246		Field fabricated metal					
247		Prefabricated metal					
248		Prefabricated plastic					
8.6 Ventilation - Attic							
276	Eave to ridge - no chutes						
278	Power vents - temperature controlled						
279	Gravity vent						
280	Gravity vent cold roof						
281	Power vent						
277		Eave to ridge SEALED - preformed chutes					
282		None					
9.2 Floor/ceiling Water Vapor Management							
294	Poly sheet						
296	None						
295		Building paper					
10.3 Primary interior finish at exterior wall							
310	Vinyl wall covering						
11.2 Floor finishes							
328	Vinyl sheet goods						
329	Vinyl tile						
333	Plastic laminate						
15.3 Ductwork Location							
371	All in unconditioned spaces						
373	In conditioned and unconditioned spaces						
372		All in conditioned spaces					
15.35 Air handling unit location							
374	In unconditioned space						
375		In conditioned space					
15.4 Ductwork Material							
377	Site formed metal						
379	Flexduct - insulated						
381	Prefabricated metal						
378		Site formed ductboard					
379		Flexduct - insulated					
382		Prefabricated ductboard					
16.1 Water Piping Location							
403	In conditioned and unconditioned spaces						
402		All in conditioned spaces					
20.18 Dehumidification strategy							
460	None						
459		Whole house					



<b>interaction name</b>							
<b>contributing systems choice heading</b>							
<b>contributing systems choice</b>							
<b>mitigating systems choice factors</b>							
<b>triggering factor</b>							
<b>Mold Mildew Air Quality concerns from excess moisture levels</b>							
<b>Warm Climates</b>							
2.1 Design & Engineering Credentials						<b>Ave Relative Humidity &gt;65</b>	
						<b>Ave CDD &gt;1500</b>	
4	Unlicensed Designer						
8	Builder/developer						
9	None						
1		Architect & Engineer					
5		Energy rater					
6		Part of building america program					
7		Part of energy star program					
2.2 Design & Engineering Services							
14	Purchased Design, no siting						
10		Custom Design & Siting					
11		Production Design, Custom Siting					
12		Production Design, Production Siting					
13		Production Siting, Production Design with prepacked options					
2.7 House Design Characteristics							
37	Presence of ventilated attic						
38	Presence of attic ridge vents						
39	Presence of attic soffit vents						
40	Presence of attic gable vents						
41		Grading designed to slope away from fdn					
36		Presence of overhangs>1 foot					
2.97 Foundation Type							
89	Pier - open beneath						
90	Crawl space - vented						
91		Crawl space - conditioned					
3.2 Construction Method (min/max subs)							
104	In-house superintendent, all external subs						
107	All subcontract - self supervision						
105		In-house superintendent, In-house shell crew, minimal subs					
106		All in-house personnel					
3.3 Construction Quality System Design							
109		Quality check of work as increments are completed					
4.6 Subgrade Water Management Layer (Horizontal)							
172	None						
170	Sand and gravel cushion						
168		4 mil poly sheet					
169		6 mil poly sheet					
7.1 Envelope Systems							
216	Acrylic-stucco, Exterior insulation and Finish System (EIFS)						
209		Sawn wood siding					
210		Plywood siding					
211		Composition board siding					
212		Cement board siding					
213		Masonry veneer					
214		Vinyl siding					
215		Metal siding					
217		Traditional 3 coat stucco					
218		Economy 2 coat stucco					
7.2 Bulk Moisture Management							
220	Face-sealed wall						
219		Water managed wall with rainscreen					
221		Water managed wall without rainscreen					
7.3 Air Barrier							
222	Non-woven, non, perforated Housewrap						
223		Perforated Housewrap					
224		Woven Housewrap					
225		Water managing housewrap					
226		Asphalt-impregnated building paper					
227		Kraft paper					
7.4 Wall Insulation							

interaction name							
contributing systems choice heading							
contributing systems choice							
mitigating systems choice factors							
triggering factor							
238	Dense-pack cellulose						
7.5 Water Vapor Management							
239	Poly sheet barrier						
241	Vinyl wall covering						
242		Kraft paper					
243		Smart vapor retarder					
7.6 Opening Flashing							
249	Tape-sealed nailing flange						
250	None						
245		Field applied bituthene sheet					
246		Field fabricated metal					
247		Prefabricated metal					
248		Prefabricated plastic					
8.6 Ventilation - Attic							
276	Eave to ridge - no chutes						
278	Power vents - temperature controlled						
279	Gravity vent						
280	Gravity vent cold roof						
281	Power vent						
277		Eave to ridge SEALED - preformed chutes					
282		None					
9.2 Floor/ceiling Water Vapor Management							
294	Poly sheet						
296	None						
295		Building paper					
10.3 Primary interior finish at exterior wall							
310	Vinyl wall covering						
11.2 Floor finishes							
328	Vinyl sheet goods						
329	Vinyl tile						
333	Plastic laminate						
15.3 Ductwork Location							
371	All in unconditioned spaces						
373	In conditioned and unconditioned spaces						
372		All in conditioned spaces					
15.35 Air handling unit location							
374	In unconditioned space						
375		In conditioned space					
15.4 Ductwork Material							
377	Site formed metal						
379	Flexduct - insulated						
381	Prefabricated metal						
378		Site formed ductboard					
379		Flexduct - insulated					
382		Prefabricated ductboard					
16.1 Water Piping Location							
403	In conditioned and unconditioned spaces						
402		All in conditioned spaces					
20.18 Dehumidification strategy							
460	None						
459		Whole house					

<b>interaction name</b>							
<b>contributing systems choice heading</b>							
<b>contributing systems choice</b>							
<b>mitigating systems choice factors</b>							
<b>triggering factor</b>							
<b>Benzene/Hydrocarbons in interiors in High Cooling Degree Day Climates</b>							
				<b>Ave Relative Humidity &gt;65</b>			
				<b>Ave CDD &gt;1500</b>			
2.1 Design & Engineering Credentials							
4	Unlicensed Designer						
8	Builder/developer						
9	None						
1		Architect & Engineer					
2		Architect Only					
3		Engineer Only					
5		Energy rater					
6		Part of building america program					
7		Part of energy star program					
2.2 Design & Engineering Services							
14	Purchased Design, no siting						
10		Custom Design & Siting					
11		Production Design, Custom Siting					
12		Production Design, Production Siting					
13		Production Siting, Production Design with prepacked options					
2.4 Thermal Energy Systems							
23	Engineered by suppliers or installers						
24	Components prescriptively described						
25	Components traditionally described						
21		Fully Engineered					
2.6 Garage							
64	attached						
66	below						
67	beside						
65		detached					
2.67 Garage attachment condition							
68	attached w/ shared wall (garage beside)						
69	attached w/ shared ceiling/floor (garage under)						
70	attached w/ shared wall and ceiling/floor (garage under and beside)						
71	attached w/ shared floor/ceiling (garage over)						
2.97 Foundation Type							
90	Crawl space - vented						
92	Basement - full						
93	Basement - daylight or lookout						
94		Basement - walkout					
91		Crawl space - conditioned					
3.2 Construction Method (min/max subs)							
104	In-house superintendent, all external subs						
107	All subcontract - self supervision						
105		In-house superintendent, In-house shell crew, minimal subs					
106		All in-house personnel					
3.3 Construction Quality System Design							
109		Quality check of work as increments are completed					
110		Commissioning of performance of the completed house					
15.3 Ductwork Location							
371	All in unconditioned spaces						
373	In conditioned and unconditioned spaces						
372		All in conditioned spaces					
15.35 Air handling unit location							
376	In garage						
374	In unconditioned space						
375		In conditioned space					
Thermal systems							
20 Overall Strategies							
430	Central System						
431		Room by Room conditioning					
432		Through the wall units					
433		Window units					

<i>interaction name</i>						
	<b>contributing systems choice heading</b>					
	<b>contributing systems choice</b>					
	<i>mitigating systems choice factors</i>					
	<i>triggering factor</i>					
20.1 Heating Strategies						
437	Gas hot air furnace					
438	Oil hot air furnace					
439	Electric hot air furnace					
440	Ground coupled electric heat pump					
441	Air source electric heat pump					
442	Straight cooling w/ electric baseboard heat					
434	Gas fired boiler or water heater					
435	Oil fired boiler or water heater					
436	Electric boiler or water heater					
20.15 Cooling Strategies						
443	Central forced air					
444	Split system					
445	Window unit					
446	Through wall unit					
21.5 House Ventilation Strategies						
487	Continuous supply ventilation					
488	Supply vent only when ahv runs					
489	Exhaust-driven makeup air					
490	Balanced with heat recovery					
491	Balanced with no heat recovery					
492	Balanced with energy recovery					
493	Timed supply ventilation					
494	Timed exhaust ventilation					

<b>interaction name</b>							
<b>contributing systems choice heading</b>							
<b>contributing systems choice</b>							
<b>mitigating systems choice factors</b>							
<b>triggering factor</b>							
<b>Benzene/Hydrocarbons in interiors in High Heating Degree Day Climates</b>							
		<b>Ave HDD &gt; 7000</b>					
2.1 Design & Engineering Credentials							
4	Unlicensed Designer						
8	Builder/developer						
9	None						
1	Architect & Engineer						
2	Architect Only						
3	Engineer Only						
5	Energy rater						
6	Part of building america program						
7	Part of energy star program						
2.2 Design & Engineering Services							
14	Purchased Design, no siting						
10	Custom Design & Siting						
11	Production Design, Custom Siting						
12	Production Design, Production Siting						
13	Production Siting, Production Design with prepacked options						
2.4 Thermal Energy Systems							
23	Engineered by suppliers or installers						
24	Components prescriptively described						
25	Components traditionally described						
21	Fully Engineered						
2.66 Garage							
64	attached						
66	below						
67	beside						
65	detached						
2.67 Garage attachment condition							
68	attached w/ shared wall (garage beside)						
69	attached w/ shared ceiling/floor (garage under)						
70	attached w/ shared wall and ceiling/floor (garage under and beside)						
71	attached w/ shared floor/ceiling (garage over)						
2.97 Foundation Type							
90	Crawl space - vented						
92	Basement - full						
93	Basement - daylight or lookout						
94	Basement - walkout						
91	Crawl space - conditioned						
3.2 Construction Method (min/max subs)							
104	In-house superintendent, all external subs						
107	All subcontract - self supervision						
105	In-house superintendent, In-house shell crew, minimal subs						
106	All in-house personnel						
3.3 Construction Quality System Design							
109	Quality check of work as increments are completed						
110	Commissioning of performance of the completed house						
15.3 Ductwork Location							
371	All in unconditioned spaces						
373	In conditioned and unconditioned spaces						
372	All in conditioned spaces						
15.35 Air handling unit location							
376	In garage						
374	In unconditioned space						
375	In conditioned space						
Thermal systems							
20 Overall Strategies							
430	Central System						
431	Room by Room conditioning						
432	Through the wall units						
433	Window units						

<i>interaction name</i>							
<b>contributing systems choice heading</b>							
<b>contributing systems choice</b>							
<b>mitigating systems choice factors</b>							
<b>triggering factor</b>							
20.1 Heating Strategies							
437	Gas hot air furnace						
438	Oil hot air furnace						
439	Electric hot air furnace						
440	Ground coupled electric heat pump						
441	Air source electric heat pump						
442	Straight cooling w/ electric baseboard heat						
434	Gas fired boiler or water heater						
435	Oil fired boiler or water heater						
436	Electric boiler or water heater						
20.15 Cooling Strategies							
443	Central forced air						
444	Split system						
445	Window unit						
446	Through wall unit						
21.5 House Ventilation Strategies							
487	Continuous supply ventilation						
488	Supply vent only when ahu runs						
489	Exhaust-driven makeup air						
490	Balanced with heat recovery						
491	Balanced with no heat recovery						
492	Balanced with energy recovery						
493	Timed supply ventilation						
494	Timed exhaust ventilation						

<b>interaction name</b>							
<b>contributing systems choice heading</b>							
<b>contributing systems choice</b>							
<b>mitigating systems choice factors</b>							
<b>triggering factor</b>							
<b>EIFS/Framing interaction in hot humid climates Climates</b>							
				<b>Ave HDD &lt; 3000</b>		<b>Low end extraction of hdd range</b>	
				<b>Ave CDD &lt; 2000</b>		<b>Low end extraction of CDD range</b>	
				<b>AVE RH &gt; 65%</b>		<b>Should be greater than 65%</b>	
2.1 Design & Engineering Credentials							
4	Unlicensed Designer						
8	Builder/developer						
9	None						
1		Architect & Engineer					
2		Architect Only					
3		Engineer Only					
5		Energy rater					
6		Part of building america program					
7		Part of energy star program					
2.4 Thermal Energy Systems							
23	Engineered by suppliers or installers						
24	Components prescriptively described						
25	Components traditionally described						
21	Fully Engineered						
2.7 House Design Characteristics							
36	Presence of overhangs>1 foot						
44	Minimal wall envelope penetrations <16						
2.9 House height							
73	one and one-half story						
74	two story						
75	three story						
76	four story						
72	one story						
3.1 Production Design Construction Method (panel, stick)							
95	Traditional stick frame wood						
97	Panelized stick frame wood						
99	SIPS Panels						
100	Prefabricated Modular (IRC Compliant)						
101	Masonry						
102	ICF						
103	Precast concrete panels						
96	Traditional stick frame light gauge steel						
98	Panelized stick frame light gauge steel						
3.2 Construction Method (min/max subs)							
104	In-house superintendent, all external subs						
107	All subcontract - self supervision						
105	In-house superintendent, In-house shell crew, minimal subs						
106	All in-house personnel						
3.3 Construction Quality System Design							
109	Quality check of work as increments are completed						
110	Commissioning of performance of the completed house						
6.2 Wall Framing							
185	Dimension lumber						
186	Engineered lumber						
190	Prefabricated panels						
191	Structural Insulated Panels - SIPS						
187	Light gauge steel						
188	Reinforced masonry						
189	Unreinforced masonry						
192	Insulated Concrete Formwork - ICF						
7.1 Envelope Systems							
Wall Exterior Finish							
216	Acrylic-stucco, Exterior insulation and Finish System (EIFS)						
209	Sawn wood siding						
210	Plywood siding						
211	Composition board siding						
212	Cement board siding						

interaction name						
contributing systems choice heading						
contributing systems choice						
mitigating systems choice factors						
triggering factor						
213	Masonry veneer					
214	Vinyl siding					
215	Metal siding					
217	Traditional 3 coat stucco					
218	Economy 2 coat stucco					
7.5 Water Vapor Management						
239	Poly sheet barrier					
240	Vapor-retarding latex paint					
241	Vinyl wall covering					
242	Kraft paper					
243	Smart vapor retarder					
244	none					
7.6 Opening Flashing						
249	Tape-sealed nailing flange					
250	None					
245	Field applied bituthene sheet					
246	Field fabricated metal					
247	Prefabricated metal					
248	Prefabricated plastic					
10.3 Primary interior finish at exterior wall						
309	1 latex primer + 2 finish latex					
310	Vinyl wall covering					
308	1 latex primer + 1 finish latex					
21.1 Supply Strategies (loc, vel, diff, char)						
471	Perimeter diffuser locations					
472	Core diffuser locations					

interaction name						
contributing systems choice heading						
contributing systems choice						
mitigating systems choice factors						
triggering factor						
<b>Carpet Mold</b>				<b>Precipitation &gt;15</b>	<b>Low End extraction from precip range</b>	
				<b>Floor Slab-On-Grade</b>		
				<b>Carpet on Slab</b>		
2.7 House Design Characteristics						
36	Presence of overhangs>1 foot					
41	Grading designed to slope away from fdn					
42	Landscape design integration					
2.97 Foundation Type						
88	Slab-on-grade					
92	Basement - full					
93	Basement - daylight or lookout					
94	Basement - walkout					
3.3 Construction Quality System Design						
108	Quality check of personnel training					
111	Fit & Finish check at the end of the project					
109	Quality check of work as increments are completed					
Foundation						
4.1 Subgrade Systems - Footing						
124	Site cast concrete					
127	None -- see slab on grade					
125	Crushed rock					
4.4 Subgrade Insulation - horizontal						
146	None					
139	Expanded Polystyrene (EPS)					
140	Extruded Polystyrene (XPS)					
4.6 Subgrade Water Management Layer (Horizontal)						
172	None					
168	4 mil poly sheet					
169	6 mil poly sheet					
170	Sand and gravel cushion					
171	Washed Aggregate					
11.2 Floor finishes						
326	Pad and carpet					
327	Direct-glued carpet					
330	Ceramic tile					
20.18 Dehumidification strategy						
460	None					
458	Stand-alone unit					
459	Whole house					
20.2 Distribution medium Strategies (water, air, radiant)						
463	Ducted air distribution					
464	Non-ducted air distribution					
461	Radiant slab water					



<b>interaction name</b>							
<b>contributing systems choice heading</b>							
<b>contributing systems choice</b>							
<b>mitigating systems choice factors</b>							
<b>triggering factor</b>							
<b>Premature Roofing Aging due to overheating</b>							
<b>lack of vent space below sheathing</b>							
2.1 Design & Engineering Credentials							
8	Builder/developer						
9	None						
3	Engineer Only						
4	Unlicensed Designer						
5	Energy rater						
6	Part of building america program						
7	Part of energy star program						
1	Architect & Engineer						
2	Architect Only						
2.7 House Design Characteristics							
37	Presence of ventilated attic						
38	Presence of attic ridge vents						
39	Presence of attic soffit vents						
2.95 Roof type							
78	Hip						
79	Gable						
80	Shed						
2.96 Roof Slope							
84	3:12 – 4:12						
85	5:12 – 7:12						
86	8:12 – 12:12						
87	>12:12						
3.2 Construction Method (min/max subs)							
104	In-house superintendent, all external subs						
107	All subcontract - self supervision						
106	All in-house personnel						
105	In-house superintendent, In-house shell crew, minimal subs						
3.3 Construction Quality System Design							
108	Quality check of personnel training						
111	Fit & Finish check at the end of the project						
109	Quality check of work as increments are completed						
110	Commissioning of performance of the completed house						
8.1 Roof							
Primary membrane							
251	Asphalt shingles						
252	Wood shingle						
253	Prefinished metal						
254	Clay or cement tile						
8.5 Insulation - Cathedral (sloped rafter/joist)							
270	EPS SIP						
271	XPS SIP						
272	Polyiso SIP						
274	Mineral fiber batts						
275	Sprayed on Icylene						
273	Glass batts						
8.6 Ventilation - Attic							
276	Eave to ridge - no chutes						
281	Power vent						
282	None						
277	Eave to ridge - preformed chutes						
278	Power vents - temperature controlled						
280	Gravity vent cold roof						
9.2 Floor/ceiling Water Vapor Management							
296	None						
294	Poly sheet						
295	Building paper						

interaction name							
contributing systems choice heading							
contributing systems choice							
mitigating systems choice factors							
triggering factor							
Radon							
Radon factor >1							
2.1 Design & Engineering Credentials							
4	Unlicensed Designer						
8	Builder/developer						
9	None						
1	Architect & Engineer						
2	Architect Only						
3	Engineer Only						
5	Energy rater						
6	Part of building america program						
7	Part of energy star program						
2.4 Thermal Energy Systems							
23	Engineered by suppliers or installers						
24	Components prescriptively described						
25	Components traditionally described						
21	Fully Engineered						
22	Designed integration						
2.5 Water, Sewer & Gas Systems							
28	Engineered by suppliers or installers						
29	Components proscriptively described						
30	Components traditionally described						
26	Fully Engineered						
27	Designed integration						
2.97 Foundation Type							
91	Crawl space - conditioned						
92	Basement - full						
93	Basement - daylight or lookout						
94	Basement - walkout						
88	Slab-on-grade						
89	Pier - open beneath						
90	Crawl space - vented						
3.3 Construction Quality System Design							
109	Quality check of work as increments are completed						
110	Commissioning of performance of the completed house						
4.1 Subgrade Systems - Footing							
123	Treated Wood						
125	Crushed rock						
127	None -- see slab on grade						
124	Site cast concrete						
4.6 Subgrade Water Management Layer (Horizontal)							
172	None						
168	4 mil poly sheet						
169	6 mil poly sheet						
170	Sand and gravel cushion						
171	Washed Aggregate						
20.17 Radon mitigation Strategies							
457	None						
453	Under slab barrier						
454	Foundation/sump sealing						
455	Passive ventilation						
456	Active sub-slab depressurization						

## Appendix Three, Test Case Configurations:

itemName	factorName	Test Case Configurations					
		test case 1	test case 2	test case 3	test case 4	test case 5	case 6
Design & Engineering Credentials	Architect & engineer	1	1	0	1	1	0
Design & Engineering Credentials	Architect only	0	0	0	0	0	0
Design & Engineering Credentials	Engineer only	0	0	1	0	0	1
Design & Engineering Credentials	Unlicensed Designer	0	0	0	0	0	0
Design & Engineering Credentials	Energy rater	0	0	0	0	1	0
Design & Engineering Credentials	Part of Building America program	0	0	0	0	1	0
Design & Engineering Credentials	Part of Energy Star program	0	0	0	0	1	0
Design & Engineering Credentials	Builder / developer	0	0	1	0	0	1
Design & Engineering Credentials	None	0	0	0	0	0	0
Design & Engineering Services	Custom design & siting	0	0	0	1	0	0
Design & Engineering Services	Production design, custom siting	0	0	1	0	1	1
Design & Engineering Services	Production design, production siting	1	1	0	0	0	0
Design & Engineering Services	Production siting, production design with prepack	0	0	0	0	0	0
Design & Engineering Services	Purchased design, no siting	0	0	0	0	0	0
Structural Systems	Structural systems	0	0	0	0	0	0
Structural Systems	Fully engineered	1	1	1	1	1	0
Structural Systems	Designed integration	1	1	0	0	1	0
Structural Systems	Engineered by suppliers or installers	0	0	0	0	0	1
Structural Systems	Components proscriptively described	0	0	0	0	0	0
Structural Systems	Components traditionally described	0	0	0	0	0	0
Thermal Energy Systems	Fully engineered	1	1	1	0	1	0
Thermal Energy Systems	Designed integration	1	1	0	0	1	0
Thermal Energy Systems	Engineered by suppliers or installers	0	0	0	1	0	1
Thermal Energy Systems	Components proscriptively described	0	0	0	0	0	0
Thermal Energy Systems	Components traditionally described	0	0	0	0	0	0
Water, Sewer & Gas Systems	Fully engineered	1	1	1	0	1	0
Water, Sewer & Gas Systems	Designed integration	1	1	0	0	1	0
Water, Sewer & Gas Systems	Engineered by suppliers or installers	0	0	0	1	0	1
Water, Sewer & Gas Systems	Components proscriptively described	0	0	0	0	0	0
Water, Sewer & Gas Systems	Components traditionally described	0	0	0	0	0	0
Electric Power and Light Systems	Fully engineered	1	1	1	0	1	0
Electric Power and Light Systems	Designed integration	1	1	0	0	1	0
Electric Power and Light Systems	Engineered by suppliers or installers	0	0	0	1	0	1
Electric Power and Light Systems	Components proscriptively described	0	0	0	0	0	0
Electric Power and Light Systems	Components traditionally described	0	0	0	0	0	0
House Design Characteristics	Presence of overhangs > 1 foot	1	1	1	1	1	1
House Design Characteristics	Presence of ventilated attic	1	1	1	1	1	1
House Design Characteristics	Presence of attic ridge vents	1	1	0	1	1	1
House Design Characteristics	Presence of attic soffit vents	1	1	1	1	1	1
House Design Characteristics	Presence of attic gable vents	0	0	1	0	1	1
House Design Characteristics	Grading designed to slope away from fdn	1	1	1	1	1	1
House Design Characteristics	Landscape design integration	0	0	0	1	0	0
House Design Characteristics	Minimal exterior corners < 8	1	1	0	0	1	1
House Design Characteristics	Minimal wall envelope penetrations < 16	1	1	0	0	1	1
House Design Characteristics	Minimal roof envelope penetrations < 6	1	1	1	0	1	1

itemName	factorName	Test Case Configurations					
		test case 1	test case 2	test case 3	test case 4	test case 5	case 6
House Design Characteristics	OVE framing	1	0	0	0	1	0
House Plan Form (With Garage)	Square	0	0	0	0	1	0
House Plan Form (With Garage)	Rectangle	0	0	0	0	0	1
House Plan Form (With Garage)	Ell "L"	0	0	0	0	0	0
House Plan Form (With Garage)	Tee "T"	1	1	0	1	0	0
House Plan Form (With Garage)	U	0	0	1	0	0	0
House Size	< 1,000 s.f	0	0	0	0	0	0
House Size	1,001 - 1,500	0	0	0	0	0	0
House Size	1,501 - 2,000	0	0	1	0	1	1
House Size	2,001 - 3,000	1	1	0	0	0	0
House Size	3,001 - 4,000	0	0	0	1	0	0
House Size	> 4,000	0	0	0	0	0	0
Garage	Attached	1	1	0	1	0	0
Garage	Detached	0	0	0	0	0	0
Garage	Below	0	0	0	0	0	0
Garage	Beside	1	1	0	1	0	0
Garage Attachment Condition	Attached w/ shared wall (garage beside)	0	1	0	1	0	0
Garage Attachment Condition	Attached w/ shared ceiling/floor (garage under)	0	0	0	0	0	0
Garage Attachment Condition	Attached w/ shared wall and ceiling/floor (garage over)	0	0	0	0	0	0
Garage Attachment Condition	Attached w/ shared floor/ceiling (garage over)	0	0	0	0	0	0
House Height	One story	0	0	0	1	1	1
House Height	One and one-half story	0	0	0	0	0	0
House Height	Two story	1	1	1	0	0	0
House Height	Three story	0	0	0	0	0	0
House Height	Four story	0	0	0	0	0	0
Roof type	Flat	0	0	0	0	0	0
Roof type	Hip	0	0	0	0	0	0
Roof type	Gable	1	1	1	1	1	1
Roof type	Shed	0	0	0	0	0	0
Roof type	Mansard	0	0	0	0	0	0
Roof type	Gambrel	0	0	0	0	0	0
Roof Slope	< 2:12	0	0	0	0	0	0
Roof Slope	3:12 - 4:12	0	0	0	0	0	0
Roof Slope	5:12 - 7:12	0	0	0	0	1	1
Roof Slope	8:12 - 12:12	1	1	1	1	0	0
Roof Slope	> 12:12	0	0	0	0	0	0
Foundation Type	Slab-on-grade	0	0	0	1	1	0
Foundation Type	Pier - open beneath	0	0	0	0	0	0
Foundation Type	Crawl space - vented	0	0	0	0	0	1
Foundation Type	Crawl space - conditioned	0	0	0	0	0	0
Foundation Type	Basement - full	1	1	0	0	0	0
Foundation Type	Basement - daylight or lookout	0	0	0	0	0	0
Foundation Type	Basement - walkout	0	0	1	0	0	0
Construction Method (Panel, Stick)	Traditional stick frame wood	0	0	0	0	1	1
Construction Method (Panel, Stick)	Traditional stick frame light gauge steel	0	0	0	0	0	0

itemName	factorName	Test Case Configurations					
		test case 1	test case 2	test case 3	test case 4	test case 5	case 6
Construction Method (Panel, Stick)	Panelized stick frame wood	0	1	0	1	0	0
Construction Method (Panel, Stick)	Panelized stick frame light gauge steel	0	0	0	0	0	0
Construction Method (Panel, Stick)	SIPS Panels	1	0	0	0	0	0
Construction Method (Panel, Stick)	Prefabricated modular (IRC Compliant)	0	0	1	0	0	0
Construction Method (Panel, Stick)	Masonry	0	0	0	0	0	0
Construction Method (Panel, Stick)	ICF	0	0	0	0	0	0
Construction Method (Panel, Stick)	Precast concrete panels	0	0	0	0	0	0
Construction Method (Min / Max Si	In-house superintendent, all external subs	0	1	0	1	1	1
Construction Method (Min / Max Si	In-house superintendent, in-house shell crew, mini	1	0	0	0	0	0
Construction Method (Min / Max Si	All in-house personnel	0	0	1	0	0	0
Construction Method (Min / Max Si	All subcontract - self supervision	0	0	0	0	0	0
Construction Quality System Desig	Quality check of personnel training	0	0	1	0	0	0
Construction Quality System Desig	Quality check of work as increments are complete	1	1	1	0	1	1
Construction Quality System Desig	Commissioning of performance of the completed i	1	0	0	0	1	0
Construction Quality System Desig	Fit & finish check at the end of the project	1	1	1	1	1	1
Construction Safety System Desig	Safety training for personnel at project start	1	0	1	0	0	0
Construction Safety System Desig	Daily safety briefings	0	0	1	0	1	1
Construction Safety System Desig	Daily safety inspections for rigging, trenching terr	0	0	1	0	0	1
Construction Safety System Desig	Tooling and materials designed for safety (label, c	0	0	1	0	0	0
Construction Safety System Desig	Safety a personal decision	1	1	0	1	1	1
Disaster Safety Strategies	Blow out panels in floodable first floor	0	0	1	0	0	0
Disaster Safety Strategies	120 mph resistant shutters at openings	0	0	1	0	0	0
Disaster Safety Strategies	Safe room, "strong room" for high wind / seismic	0	0	1	0	0	0
Disaster Safety Strategies	Braced garage doors	0	0	1	0	0	0
Disaster Safety Strategies	High impact windows / glazing	0	0	1	0	0	0
Disaster Safety Strategies	Building elevated on piles or columns above flood	0	0	1	0	0	0
Subgrade Systems - Footing	Treated wood	0	0	0	0	0	0
Subgrade Systems - Footing	Site cast concrete	1	1	1	0	1	1
Subgrade Systems - Footing	Crushed rock	0	0	0	0	0	0
Subgrade Systems - Footing	Pilings	0	0	0	0	0	0
Subgrade Systems - Footing	None - see slab on grade	0	0	0	1	0	0
Foundation	Masonry	0	0	1	0	0	1
Foundation	Site cast concrete	0	1	0	0	0	0
Foundation	Precast concrete	1	0	0	0	0	0
Foundation	Insulated concrete formwork (ICF)	0	0	0	0	0	0
Foundation	Permanent wood	0	0	0	0	0	0
Slab on Grade	Glass strand reinforcing	0	0	0	0	0	0
Slab on Grade	Wire mesh reinforcing	1	1	1	0	0	0
Slab on Grade	Rebar reinforcing	0	0	0	0	0	0
Slab on Grade	Post tension strand reinforcing	0	0	0	0	0	0
Slab on Grade	Combination of the above	0	0	0	1	1	0
Slab on Grade	None	0	0	0	0	0	1
Subgrade Insulation - Horizontal	Expanded polystyrene (EPS)	0	0	0	0	0	0
Subgrade Insulation - Horizontal	Extruded polystyrene (XPS)	0	0	0	1	1	0
Subgrade Insulation - Horizontal	Sprayed on Icylene	0	0	0	0	0	0

itemName	factorName	Test Case Configurations					
		test case 1	test case 2	test case 3	test case 4	test case 5	case 6
Subgrade Insulation - Horizontal	Fiberglass board	0	0	0	0	0	0
Subgrade Insulation - Horizontal	Fiberglass batts	0	0	0	0	0	0
Subgrade Insulation - Horizontal	Mineral fiber blockfill	0	0	0	0	0	0
Subgrade Insulation - Horizontal	None	1	1	1	0	0	0
Subgrade Insulation - Vertical	Expanded polystyrene (EPS)	0	0	0	0	0	0
Subgrade Insulation - Vertical	Extruded polystyrene (XPS)	1	1	0	0	1	0
Subgrade Insulation - Vertical	Sprayed on Icylene	0	0	0	0	0	0
Subgrade Insulation - Vertical	Fiberglass board	0	0	0	0	0	0
Subgrade Insulation - Vertical	Fiberglass batts	0	0	0	0	0	0
Subgrade Insulation - Vertical	Mineral fiber blockfill	0	0	0	0	0	0
Subgrade Insulation - Vertical	Foam beads blockfill	0	0	1	0	0	0
Subgrade Insulation - Vertical	None	0	0	0	1	0	0
Subgrade Insulation - Location	Interior	0	0	0	0	0	0
Subgrade Insulation - Location	Exterior	1	1	0	0	1	0
Subgrade Insulation - Location	Integral	0	0	1	0	0	0
Subgrade Insulation - Location	Both sides	0	0	0	0	0	0
Subgrade Insulation - Location	None	0	0	0	1	0	0
Subgrade Water Management Laye	Brush-on cementitious	0	0	0	0	1	1
Subgrade Water Management Laye	Brush-on asphaltic	0	0	0	0	0	0
Subgrade Water Management Laye	Trowel-on asphaltic	0	0	1	0	0	0
Subgrade Water Management Laye	Spray-on bitumen	1	1	0	0	0	0
Subgrade Water Management Laye	Sheet-applied bituthene	0	0	0	0	0	0
Subgrade Water Management Laye	Drain board / panel / sheet	0	0	0	0	0	0
Subgrade Water Management Laye	Washed aggregate	1	1	1	1	0	1
Subgrade Water Management Laye	None	0	0	0	0	0	0
Subgrade Water Management Laye	4 mil poly sheet	0	0	0	0	0	0
Subgrade Water Management Laye	6 mil poly sheet	1	1	1	1	1	0
Subgrade Water Management Laye	Sand and gravel cushion	1	1	0	0	0	0
Subgrade Water Management Laye	Washed aggregate	0	0	0	0	0	0
Subgrade Water Management Laye	None	0	0	0	0	0	1
Floor Framing	Dimension lumber - site framed	0	0	1	0	0	1
Floor Framing	Engineered lumber - site framed	0	0	0	0	0	0
Floor Framing	Prefabricated trusses - site assembled	0	1	0	0	0	0
Floor Framing	Prefabricated trusses & floor panels - factory asse	1	0	0	0	0	0
Floor Framing	Light gauge steel - site framed	0	0	0	0	0	0
Floor Rim / Band Insulation and Va	Fiberglass batts - faced	1	1	1	0	0	1
Floor Rim / Band Insulation and Va	Fiberglass batts - unfaced	0	0	0	0	0	0
Floor Rim / Band Insulation and Va	Fiberglass batts and polyethylene	0	0	0	0	0	0
Floor Rim / Band Insulation and Va	Spray-on Icylene	0	0	0	0	0	0
Floor Rim / Band Insulation and Va	Spray-on polyurethane	0	0	0	0	0	0
Floor Rim / Band Insulation and Va	Interior rigid foam board	0	0	0	0	0	0
Floor Rim / Band Insulation and Va	Exterior rigid foam board	0	0	0	0	0	0
Wall Framing	Dimension lumber	0	0	1	0	1	1
Wall Framing	Engineered lumber	0	0	0	0	0	0
Wall Framing	Light gauge steel	0	0	0	0	0	0

itemName	factorName	Test Case Configurations					
		test case 1	test case 2	test case 3	test case 4	test case 5	case 6
Wall Framing	Reinforced masonry	0	0	0	0	0	0
Wall Framing	Unreinforced masonry	0	0	0	0	0	0
Wall Framing	Prefabricated panels	0	0	0	1	0	0
Wall Framing	Structural insulated panels - SIPS	1	1	0	0	0	0
Wall Framing	Insulated concrete formwork (ICF)	0	0	0	0	0	0
Shear Framing	Shear panels at corners only	0	0	0	1	0	0
Shear Framing	Let-in "T" bracing	0	0	0	0	0	0
Shear Framing	Fully sheathed in structure panels	1	1	1	0	1	1
Shear Framing	Prefabricated shear panels (eg strongwall)	0	0	0	0	0	0
Shear Framing	Light gauge steel	0	0	0	0	0	0
Roof Framing	Dimension lumber	0	0	1	0	0	0
Roof Framing	Engineered lumber	0	0	0	0	0	0
Roof Framing	Prefabricated wood trusses	1	1	0	1	1	1
Roof Framing	Prefabricated light gauge steel trusses	0	0	0	0	0	0
Roof to Wall Connection	Toe nail	0	0	1	1	0	0
Roof to Wall Connection	Clips	1	1	0	0	1	0
Roof to Wall Connection	Single plate wrap	0	0	0	0	0	0
Roof to Wall Connection	Double plate wrap	0	0	0	0	0	0
Roof Bracing (If Gable)	Braced in vertical and sloped plane	0	0	0	0	0	0
Roof Bracing (If Gable)	Braced in vert plane only	0	0	0	1	1	0
Roof Bracing (If Gable)	Unbraced	1	1	0	0	0	1
Wall Exterior Finish	Sawn wood siding	0	0	1	0	0	0
Wall Exterior Finish	Plywood siding	0	0	0	0	0	0
Wall Exterior Finish	Composition board siding	0	0	0	0	0	0
Wall Exterior Finish	Cement board siding	0	0	0	1	1	0
Wall Exterior Finish	Masonry veneer	1	1	0	0	0	0
Wall Exterior Finish	Vinyl siding	1	1	0	0	0	1
Wall Exterior Finish	Metal siding	0	0	0	0	0	0
Wall Exterior Finish	Acrylic-stucco, exterior insulation and finish syste	0	0	0	0	0	0
Wall Exterior Finish	Traditional 3 coat stucco	0	0	0	0	0	0
Wall Exterior Finish	Economy 2 coat stucco	0	0	0	0	0	0
Bulk Moisture Management	Water managed wall with rainscreen	0	0	0	0	0	0
Bulk Moisture Management	Face-sealed wall	1	1	1	1	1	1
Bulk Moisture Management	Water managed wall without rainscreen	0	0	0	0	1	0
Air Barrier	Non-woven, non-perforated housewrap	0	0	0	0	0	1
Air Barrier	Perforated housewrap	0	0	0	0	0	0
Air Barrier	Woven housewrap	1	1	1	1	0	0
Air Barrier	Water managing housewrap	0	0	0	0	1	0
Air Barrier	Asphalt-impregnated building paper	0	0	0	0	0	0
Air Barrier	Kraft paper	0	0	0	0	0	0
Air Barrier	Sealed exterior gypsum sheathing	0	0	0	0	1	0
Wall Insulation	Glass batt in stud cavity-unfaced	0	0	0	0	0	0
Wall Insulation	Glass batt in stud cavity-foil faced	0	0	0	0	0	0
Wall Insulation	Glass batt in stud cavity-paper faced	0	0	1	1	0	1
Wall Insulation	Glass batt in stud cavity with extruded polystyren	0	0	0	0	1	0

itemName	factorName	Test Case Configurations					
		test case 1	test case 2	test case 3	test case 4	test case 5	case 6
Wall Insulation	Glass batt in stud cavity with foil faced polyiso bc	0	0	0	0	0	0
Wall Insulation	Sprayed on Icylene	0	0	0	0	1	0
Wall Insulation	Mineral fiber batt or fill	0	0	0	0	0	0
Wall Insulation	Spray-on polyurethane	0	0	0	0	0	0
Wall Insulation	Blown-in fiberglass	0	0	0	0	0	0
Wall Insulation	Dense-pack cellulose	0	0	0	0	0	0
Water Vapor Management	Poly sheet barrier	0	0	0	0	0	0
Water Vapor Management	Vapor-retarding latex paint	0	0	0	0	0	0
Water Vapor Management	Vinyl wall covering	0	0	0	0	0	0
Water Vapor Management	Kraft paper	0	0	0	0	0	0
Water Vapor Management	Smart vapor retarder	0	0	0	0	0	0
Water Vapor Management	None	1	1	1	1	1	1
Opening Flashing	Field applied bituthene sheet	0	0	0	1	1	0
Opening Flashing	Field fabricated metal	0	0	0	0	0	0
Opening Flashing	Prefabricated metal	0	0	0	0	0	0
Opening Flashing	Prefabricated plastic	1	1	0	0	0	0
Opening Flashing	Tape-sealed nailing flange	1	1	0	0	0	0
Opening Flashing	None	0	0	0	0	0	0
Opening Flashing	Building Paper	0	0	1	0	0	1
Roof Primary Membrane	Asphalt shingles	1	1	1	1	1	1
Roof Primary Membrane	Wood shingle	0	0	0	0	0	0
Roof Primary Membrane	Prefinished metal	0	0	0	0	0	0
Roof Primary Membrane	Clay or cement tile	0	0	0	0	0	0
Roof Primary Membrane	Single-ply membrane	0	0	0	0	0	0
Roof Primary Membrane	Built-up roofing	0	0	0	0	0	0
Eave / Valley Ice Dam Protection	Bituthene sheet	1	1	0	1	1	1
Eave / Valley Ice Dam Protection	Hot-mopped roofing felt	0	0	0	0	0	0
Eave / Valley Ice Dam Protection	Building paper	0	0	1	0	0	0
Eave / Valley Ice Dam Protection	None	0	0	0	0	0	0
Roof Secondary Membrane	Bituthene sheet	0	0	0	0	1	0
Roof Secondary Membrane	Hot-mopped roofing felt	0	0	0	0	0	0
Roof Secondary Membrane	Building paper	1	1	1	1	0	1
Roof Secondary Membrane	None	0	0	0	0	0	0
Insulation - Attic	Blown fiberglass	0	0	0	1	0	0
Insulation - Attic	Blown mineral fiber	0	0	0	0	0	0
Insulation - Attic	Blown cellulose	0	0	0	0	0	0
Insulation - Attic	Glass batts	1	1	1	0	1	1
Insulation - Attic	Mineral fiber batts	0	0	0	0	0	0
Insulation - Cathedral (Sloped Raft)	EPS SIP	0	0	0	0	0	0
Insulation - Cathedral (Sloped Raft)	XPS SIP	0	0	0	0	0	0
Insulation - Cathedral (Sloped Raft)	Polyiso SIP	0	0	0	0	0	0
Insulation - Cathedral (Sloped Raft)	Glass batts	0	0	0	0	0	0
Insulation - Cathedral (Sloped Raft)	Mineral fiber batts	0	0	0	0	0	0
Insulation - Cathedral (Sloped Raft)	Sprayed on Icylene	0	0	0	0	0	0
Insulation - Cathedral (Sloped Raft)	None	1	1	1	1	1	1

itemName	factorName	Test Case Configurations					
		test case 1	test case 2	test case 3	test case 4	test case 5	case 6
Ventilation - Attic	Eave to ridge - no chutes	1	1	1	0	0	1
Ventilation - Attic	Eave to ridge - preformed chutes	0	0	0	1	1	0
Ventilation - Attic	Power vents - temperature controlled	0	0	0	0	0	0
Ventilation - Attic	Gravity vent	0	0	0	0	0	0
Ventilation - Attic	Gravity vent cold roof	0	0	0	0	0	0
Ventilation - Attic	Power vent	0	0	0	0	0	0
Ventilation - Attic	None	0	0	0	0	0	0
Roof Flashing	Prefabricated metal	0	0	0	0	0	0
Roof Flashing	Site-formed membrane	1	1	0	1	1	0
Roof Flashing	Site fabricated metal	1	1	1	1	0	1
Roof Flashing	Preformed plastic	0	0	0	0	0	0
Floor Insulation	Glass batts	1	1	1	0	0	1
Floor Insulation	Mineral fiber batts	0	0	0	0	0	0
Floor Insulation	Blown fiberglass	0	0	0	0	0	0
Floor Insulation	Blown mineral fiber	0	0	0	0	0	0
Floor Insulation	Sprayed on Icynene	0	0	0	0	0	0
Floor Insulation	Spray-on polyurethane	0	0	0	0	0	0
Floor Insulation	None	0	0	0	1	1	0
Floor / Ceiling Water Vapor Manag	Poly sheet	1	1	0	1	1	1
Floor / Ceiling Water Vapor Manag	Building paper	0	0	0	0	0	0
Floor / Ceiling Water Vapor Manag	None	0	0	1	0	0	0
Partition Framing	Site framed wood	0	0	0	0	1	1
Partition Framing	Prefabricated wood	0	0	0	1	0	0
Partition Framing	Site framed light gauge steel	0	0	0	0	0	0
Partition Framing	Prefabricated light gauge steel	1	1	0	0	0	0
Partition Framing	Masonry	0	0	0	0	0	0
Wall Finish Substrate	Plaster	0	0	0	0	0	0
Wall Finish Substrate	Drywall	1	1	1	1	1	1
Wall Finish Substrate	Reduced-cellulose drywall	0	0	0	0	0	0
Wall Finish Substrate	Drywall over engineered wood (SIPS, OSB, plywoo	1	1	0	0	0	0
Wall Finish Substrate	Masonry	0	0	0	0	0	0
Wall Finish Substrate	ICF	0	0	0	0	0	1
Primary Interior Finish at Exterior V	1 latex primer + 1 finish latex	0	0	1	0	1	0
Primary Interior Finish at Exterior V	1 latex primer + 2 finish latex	1	1	0	1	0	1
Primary Interior Finish at Exterior V	Vinyl wall covering	0	0	0	0	0	0
Primary Interior Finish at Exterior V	Wood veneer paneling	0	0	0	0	0	0
Primary Interior Finish at Exterior V	Ceramic tile	0	0	0	0	0	0
Primary Interior Finish at Exterior V	None	0	0	0	0	0	0
Primary Wall Finishes (Interior Wall)	1 latex primer + 1 finish latex	0	0	1	0	1	1
Primary Wall Finishes (Interior Wall)	1 latex primer + 2 finish latex	1	1	0	1	0	0
Primary Wall Finishes (Interior Wall)	Vinyl wall covering	0	0	0	0	0	0
Primary Wall Finishes (Interior Wall)	Wood veneer paneling	0	0	0	0	0	0
Primary Wall Finishes (Interior Wall)	Ceramic tile	0	0	0	0	0	0
Primary Wall Finishes (Interior Wall)	None	0	0	0	0	0	0
Subfloor	Particle board	0	0	1	0	0	0

itemName	factorName	Test Case Configurations					
		test case 1	test case 2	test case 3	test case 4	test case 5	case 6
Subfloor	OSB	1	1	0	0	0	0
Subfloor	Plywood	0	0	0	0	0	1
Subfloor	Cement board	0	0	0	0	0	0
Subfloor	Concrete	0	0	0	1	1	0
Subfloor	Self-leveling gypsum topping	0	0	0	0	0	0
Floor Finishes	Pad and carpet	1	1	0	0	0	1
Floor Finishes	Direct-glued carpet	0	0	1	0	1	0
Floor Finishes	Vinyl sheet goods	0	0	0	0	0	0
Floor Finishes	Vinyl tile	0	0	0	0	0	0
Floor Finishes	Ceramic tile	0	0	0	0	0	0
Floor Finishes	Hardwood - solid	0	0	0	0	0	0
Floor Finishes	Hardwood - veneer	0	0	0	0	0	0
Floor Finishes	Plastic laminate	0	0	0	1	0	0
Ceiling Substrates	Plaster	0	0	0	0	0	0
Ceiling Substrates	Drywall	1	1	1	1	1	1
Ceiling Substrates	Reduced-cellulose drywall	0	0	0	0	0	0
Ceiling Substrates	Wood deck or panel	0	0	0	0	0	0
Ceiling Substrates	None	0	0	0	0	0	0
Ceiling Finishes	1 latex primer + 1 finish latex	0	0	0	0	0	0
Ceiling Finishes	1 high-build primer / finish coat	1	1	1	1	1	1
Ceiling Finishes	Lay-in tile	0	0	0	0	0	0
Ceiling Finishes	None	0	0	0	0	0	0
Countertops	Plastic laminate	0	0	1	0	1	1
Countertops	Stone	1	1	0	0	0	0
Countertops	Cultured stone	0	0	0	1	0	0
Countertops	Solid cast acrylic-plastic	0	0	0	0	0	0
Countertops	Ceramic tile	0	0	0	0	0	0
Countertops	Metal	0	0	0	0	0	0
Countertops	Concrete	0	0	0	0	0	0
Interior Trim	Milled wood	0	0	1	0	0	0
Interior Trim	Milled or formed wood composite	1	1	0	1	1	1
Interior Trim	PVC	0	0	0	0	0	0
Interior Trim	Other plastic	0	0	0	0	0	0
Cabinetry	Prefabricated - milled wood	1	1	0	0	0	0
Cabinetry	Prefabricated - engineered wood	0	0	1	1	1	1
Cabinetry	Custom fabricated - milled wood	0	0	0	0	0	0
Cabinetry	Custom fabricated - engineered wood	0	0	0	0	0	0
Gas Appliance Venting	Plumber-installed	1	1	1	1	1	1
Gas Appliance Venting	Builder-installed	0	0	0	0	0	0
Gas Appliance Venting	Owner-installed	0	0	0	0	0	0
Gas Appliance Venting	Third-party-tested	1	1	0	0	1	0
Appliance Subcontract Method	By builder	1	1	1	1	1	1
Appliance Subcontract Method	By owner	0	0	0	0	0	0
Integration Strategies	Bundled-weaved together based on schedule	0	0	1	1	1	1
Integration Strategies	Unbundled-each subsystem has designed place	1	1	0	0	0	0

itemName	factorName	Test Case Configurations					
		test case 1	test case 2	test case 3	test case 4	test case 5	case 6
Integration Strategies	Hybrid-system trunks in designed places, distributed	0	0	0	0	0	0
Production Strategies	Site fabricated trunks and feeders	0	0	1	1	1	1
Production Strategies	Prefabricated trunks and feeders	0	0	0	0	0	0
Production Strategies	Hybrid, prefabricated trunks, site fabricated distribution	1	1	0	0	0	0
Ductwork Location	All in unconditioned spaces	0	0	0	1	0	1
Ductwork Location	All in conditioned spaces	0	0	0	0	1	0
Ductwork Location	In conditioned and unconditioned spaces	1	1	1	0	0	0
Air Handling Unit Location	In unconditioned space	1	1	1	0	0	1
Air Handling Unit Location	In conditioned space	0	0	0	1	1	0
Air Handling Unit Location	In garage	0	0	0	0	0	0
Ductwork Material	Site formed metal	0	0	0	0	0	0
Ductwork Material	Site formed ductboard	0	0	1	1	1	1
Ductwork Material	Flexduct - insulated	0	0	0	0	0	0
Ductwork Material	Flexduct - uninsulated	0	0	0	0	0	0
Ductwork Material	Prefabricated metal	0	0	0	0	0	0
Ductwork Material	Prefabricated ductboard	1	1	0	0	0	0
Electrical Wiring Strategies (Conduit)	Conduit	0	0	1	0	0	0
Electrical Wiring Strategies (Conduit)	Romex	1	1	1	1	1	1
Electrical Wiring Strategies (Conduit)	Wiring harness	0	0	0	0	0	0
Communication Wiring Strategies (Category 5/6)	Category 5/6	1	1	0	1	0	0
Communication Wiring Strategies (Category 5/6)	Separate wiring for each system	0	0	1	0	1	1
Generation Types	On grid	1	1	1	1	0	1
Generation Types	Self - PV generation	0	0	0	0	0	0
Generation Types	Self - wind generation	0	0	0	0	0	0
Generation Types	Self - gas or propane generator	0	0	0	0	0	0
Generation Types	Hybrid on-grid and self-generation	0	0	0	0	1	0
Lighting Design Types	Designed by lighting engineer	1	1	0	0	0	0
Lighting Design Types	Designed by electrical engineer	0	0	1	0	0	0
Lighting Design Types	Designed by architect	0	0	0	1	0	0
Lighting Design Types	Designed by supplier	0	0	0	0	1	1
Lighting Design Types	Designed by installer	0	0	0	0	0	0
Primary Lighting Types	Incandescent	1	1	1	1	0	1
Primary Lighting Types	Compact fluorescent	0	0	0	0	1	0
Primary Lighting Types	Low voltage	0	0	0	0	0	0
Water Piping Location	All in conditioned spaces	0	0	0	1	1	0
Water Piping Location	In conditioned and unconditioned spaces	1	1	1	0	0	1
Water Piping Material	Copper	0	0	0	0	1	1
Water Piping Material	Polyisobutylene	1	1	1	1	0	0
Water Piping Material	PVC	0	0	0	0	0	0
Water Piping Material	CPVC	0	0	0	0	0	0
Water Piping Material	HDPE	0	0	0	0	0	0
Water Piping Insulation Strategy	All insulated	1	1	0	1	1	0
Water Piping Insulation Strategy	Hot water only insulated	0	0	1	0	0	1
Water Piping Insulation Strategy	No insulation	0	0	0	0	0	0
Sewer Piping Location	Within partitions	1	1	1	0	0	0

itemName	factorName	Test Case Configurations					
		test case 1	test case 2	test case 3	test case 4	test case 5	case 6
Sewer Piping Location	Directly to subgrade	0	0	0	1	1	1
Sewer Piping Material	PVC	1	1	1	1	1	1
Sewer Piping Material	Iron	0	0	0	0	0	0
Source Strategies	Municipal	1	1	1	1	1	1
Source Strategies	Private well	0	0	0	0	0	0
Source Strategies	Purchased service	0	0	0	0	0	0
Treatment Strategies	None	0	0	1	0	0	0
Treatment Strategies	Filtered	0	0	0	0	0	0
Treatment Strategies	Softened	1	1	0	1	0	0
Storage Strategies	None	1	1	1	0	0	0
Storage Strategies	Cistern	0	0	0	0	0	0
Disposal Strategies	Municipal	1	1	1	1	1	1
Disposal Strategies	Septic system	0	0	0	0	0	0
Disposal Strategies	Storage tank	0	0	0	0	0	0
Disposal Strategies	Greywater recovery	0	0	0	0	0	0
Overall Strategies	Central system	1	1	1	1	1	1
Overall Strategies	Room by room conditioning	0	0	0	0	0	0
Overall Strategies	Through the wall units	0	0	0	0	0	0
Overall Strategies	Window units	0	0	0	0	0	0
Heating Strategies	Gas fired boiler or water heater	0	0	0	0	0	0
Heating Strategies	Oil fired boiler or water heater	0	0	0	0	0	0
Heating Strategies	Electric boiler or water heater	0	0	0	0	1	0
Heating Strategies	Gas hot air furnace	0	0	1	0	1	0
Heating Strategies	Oil hot air furnace	0	0	0	0	0	0
Heating Strategies	Electric hot air furnace	0	0	0	0	0	0
Heating Strategies	Ground coupled electric heat pump	0	0	0	0	0	0
Heating Strategies	Air source electric heat pump	1	1	0	1	0	1
Heating Strategies	Straight cooling w/ electric baseboard heat	0	0	0	0	0	0
Cooling Strategies	Central forced air	0	0	0	0	0	0
Cooling Strategies	Split system	1	1	1	1	1	1
Cooling Strategies	Window unit	0	0	0	0	0	0
Cooling Strategies	Through wall unit	0	0	0	0	0	0
Cooling Strategies	Whole house exhaust fan	0	0	0	0	0	0
Filtration Strategies	Fiberglass filter	0	0	0	0	0	0
Filtration Strategies	Pleated filter	0	0	0	0	0	1
Filtration Strategies	Deep pleated media	1	1	1	0	1	0
Filtration Strategies	Electronic	0	0	0	1	0	0
Filtration Strategies	None	0	0	0	0	0	0
Radon Mitigation Strategies	Under slab barrier	1	1	1	1	1	0
Radon Mitigation Strategies	Foundation / sump sealing	0	0	0	0	0	0
Radon Mitigation Strategies	Passive ventilation	1	1	0	0	1	1
Radon Mitigation Strategies	Active sub-slab depressurization	0	0	0	0	0	0
Radon Mitigation Strategies	None	0	0	0	0	0	0
Dehumidification Strategies	Stand-alone unit	0	0	0	0	0	0
Dehumidification Strategies	Whole house	1	1	1	0	0	0

itemName	factorName	Test Case Configurations					
		test case 1	test case 2	test case 3	test case 4	test case 5	case 6
Dehumidification Strategies	None	0	0	0	1	1	1
Distribution Medium Strategies (W: Radiant slab water		0	0	0	0	0	0
Distribution Medium Strategies (W: Hot water radiator		0	0	0	0	0	0
Distribution Medium Strategies (W: Ducted air distribution		1	1	1	1	1	1
Distribution Medium Strategies (W: Non-ducted air distribution		0	0	0	0	0	0
Domestic Hot Water Integration St Integrated hot water and furnace		0	0	0	0	0	0
Domestic Hot Water Integration St Stand alone hot water heat and storage		1	1	1	1	1	1
Domestic Hot Water Integration St Tankless electric hot water source heaters		0	0	0	0	0	0
Domestic Hot Water Integration St Tankless gas hot water source heaters		0	0	0	0	0	0
Domestic Hot Water Integration St Solar hot water heat and storage		0	0	0	0	0	0
Domestic Hot Water Integration St Heat pump water heater		0	0	0	0	0	0
Supply Strategies (Loc, Vel, Diff, C Perimeter diffuser locations		1	1	1	1	1	1
Supply Strategies (Loc, Vel, Diff, C Core diffuser locations		0	0	0	0	0	0
Control Strategies	Zoned	1	1	1	1	1	1
Control Strategies	Programmable thermostat	1	1	1	1	1	1
Control Strategies	Time delay relay	0	0	0	0	0	0
Air Velocity	Low velocity	1	1	1	1	1	1
Air Velocity	High velocity	0	0	0	0	0	0
Air Velocity	Ultra high velocity	0	0	0	0	0	0
Diffuser Characteristics	Pressure-reducing	0	0	0	0	0	0
Diffuser Characteristics	Point	1	1	1	1	1	1
Diffuser Characteristics	Linear	0	0	0	0	0	0
Return Strategies	Fully ducted returns from each space	0	0	0	0	0	0
Return Strategies	Central ducted return	0	0	1	1	1	1
Return Strategies	Ducted return for each floor served	1	1	0	0	0	0
Return Strategies	Panned joist return duct	0	0	0	0	0	0
Return Strategies	Wall cavity return duct	0	0	0	0	0	0
House Ventilation Strategies	Continuous supply ventilation	1	1	0	0	0	0
House Ventilation Strategies	Supply vent only when AHU runs	0	0	1	0	0	1
House Ventilation Strategies	Exhaust-driven makeup air	0	0	0	1	0	0
House Ventilation Strategies	Balanced with heat recovery	0	0	0	0	1	0
House Ventilation Strategies	Balanced with no heat recovery	1	1	0	0	0	0
House Ventilation Strategies	Balanced with energy recovery	0	0	0	0	0	0
House Ventilation Strategies	Timed supply ventilation	0	0	0	0	0	0
House Ventilation Strategies	Timed exhaust ventilation	0	0	0	0	0	0
House Ventilation Strategies	None	0	0	0	0	0	0
Fireplace Strategies	Masonry on exterior wall	0	0	0	0	0	0
Fireplace Strategies	Masonry on interior wall	0	0	0	0	0	0
Fireplace Strategies	Metal on exterior wall	0	0	0	0	0	0
Fireplace Strategies	Metal on interior wall	1	1	0	1	0	0
Fireplace Strategies	None	0	0	1	0	1	1
Fireplace Venting Strategies	Chimney above roof	1	1	0	0	0	0
Fireplace Venting Strategies	Vented through wall	0	0	0	0	0	0
Fireplace Venting Strategies	Ventless gas	0	0	0	0	0	0
Fireplace Venting Strategies	Ventless alcohol	0	0	0	1	0	0

itemName	factorName	Test Case Configurations					
		test case 1	test case 2	test case 3	test case 4	test case 5	case 6
Fireplace Venting Strategies	Ventless electric	0	0	0	0	0	0
Fireplace Venting Strategies	None	0	0	1	0	1	1
Kitchen Ventilation	Hood - recirculating	0	0	1	0	0	0
Kitchen Ventilation	Hood - exhausting	1	1	0	1	1	1
Kitchen Ventilation	Downdraft	0	0	0	0	0	0
Central Vacuum	Present	0	0	0	1	0	0
Central Vacuum	None	1	1	1	0	1	1



## Appendix Four, Regional Recommended Practices House Configurations:

Factor	NE	CE	NC	SW	SE	WE
Architect & Engineer	1	1	1	1	1	1
Architect Only						
Engineer Only						
Unlicensed Designer						
Energy rater	1	1	1	1	1	1
Part of building america program	1	1	1	1	1	1
Part of energy star program						
Builder/developer						
None						
Custom Design & Siting	1	1	1	1	1	1
Production Design, Custom Siting	1	1	1	1	1	1
Production Design, Production Siting	1	1	1	1	1	1
Production Siting, Production Design with prepacked options	1	1	1	1	1	1
Purchased Design, no siting						
Structural Systems						
Fully Engineered	1	1	1	1	1	1
Designed integration	1	1	1	1	1	1
Engineered by suppliers or installers						
Components prescriptively described						
Components traditionally described						
Fully Engineered	1	1	1	1	1	1
Designed integration	1	1	1	1	1	1
Engineered by suppliers or installers						
Components prescriptively described						
Components traditionally described						
Fully Engineered	1	1	1	1	1	1
Designed integration	1	1	1	1	1	1
Engineered by suppliers or installers						
Components prosriptively described						
Components traditionally described						
Fully Engineered	1	1	1	1	1	1
Designed integration	1	1	1	1	1	1
Engineered by suppliers or installers						
Components prosriptively described						
Components traditionally described						
Presence of overhangs>1 foot	1	1	1	1	1	1
Presence of ventilated attic			1	1		
Presence of attic ridge vents			1	1		
Presence of attic soffit vents			1	1		
Presence of attic gable vents						
Grading designed to slope away from fdn	1	1	1	1	1	1
Landscape design integration	1	1	1	1	1	1
Minimal exterior corners <8	1	1	1	1	1	1
Minimal wall envelope penetrations <16	1	1	1	1	1	1
Minimal roof envelope penetrations < 6	1	1	1	1	1	1
OVE framing	1	1	1	1	1	1
Square	1		1			1
Rectangle	1		1			1
Ell "L"						
Tee "T"						
"U"						
< 1,000 s.f.						
1,001 – 1,500						
1,501 – 2,000						
2,001 – 3,000						
3,001 – 4,000						
> 4,000						
attached						
detached	1	1	1	1	1	1
below						
beside						
attached w/ shared wall (garage beside)						
attached w/ shared ceiling/floor (garage under)						
attached w/ shared wall and ceiling/floor (garage under and beside)						
attached w/ shared floor/ceiling (garage over)						

Factor	NE	CE	NC	SW	SE	WE
one story						
one and one-half story						
two story						
three story						
four story						
Flat				1		
Hip	1	1	1	1	1	1
Gable	1	1	1	1		1
Shed	1	1	1	1		1
Mansard						
Gambrel						
< 2:12				1		
3:12 – 4:12	1	1		1	1	1
5:12 – 7:12	1	1	1	1	1	1
8:12 – 12:12	1	1	1			1
>12:12						
Slab-on-grade			1	1	1	1
Pier - open beneath						
Crawl space - vented						
Crawl space - conditioned		1		1	1	1
Basement - full	1	1	1			
Basement - daylight or lookout						
Basement - walkout						
Traditional stick frame wood	1	1	1	1		1
Traditional stick frame light gauge steel				1	1	
Panelized stick frame wood	1	1	1	1		1
Panelized stick frame light gauge steel				1	1	
SIPS Panels		1	1	1		1
Prefabricated Modular (IRC Compliant)	1	1	1	1	1	1
Masonry				1		1
ICF	1	1	1	1	1	1
Precast concrete panels						
In-house superintendent, all external subs						
In-house superintendent, In-house shell crew, minimal subs	1	1	1	1	1	1
All in-house personnel	1	1	1	1	1	1
All subcontract - self supervision						
Quality check of personnel training						
Quality check of work as increments are completed	1	1	1	1	1	1
Commissioning of performance of the completed house	1	1	1	1	1	1
Fit & Finish check at the end of the project						
Safety training for personnel at project start	1	1	1	1	1	1
Daily safety briefings	1	1	1	1	1	1
Daily safety inspections for rigging, trenching temp structures	1	1	1	1	1	1
Tooling and materials designed for safety (label, cg, edges, switches, falls)						
Safety a personal decision						
Blow out panels in floodable first floor						
120 mph resistant shutters at openings		1			1	
"Safe room", "strong room" for high wind/seismic survivability		1		1	1	1
Braced garage doors		1			1	
High impact windows/glazing		1			1	
Building elevated on piles or columns above flood levels		1			1	
Treated Wood						
Site cast concrete	1	1	1	1	1	1
Crushed rock						
Pilings					1	
None – see slab on grade				1	1	1
Masonry						
Site cast concrete	1	1	1	1	1	1
Precast concrete						
Insulated Concrete Formwork (ICF)	1	1	1	1	1	1
Permanent Wood						
Glass Strand reinforcing						
Wire mesh reinforcing	1	1	1		1	
Rebar reinforcing	1	1	1		1	
Post tension strand reinforcing						

Factor	NE	CE	NC	SW	SE	WE
Combination of the above				1		1
None						
Expanded Polystyrene (EPS)						
Extruded Polystyrene (XPS)	1	1	1			1
Sprayed on Icynene						
Fiberglass Board						
Fiberglass Batts						
Mineral fiber blockfill						
Foam Beads						
None				1	1	
Expanded Polystyrene (EPS)						
Extruded Polystyrene (XPS)			1	1		1
Sprayed on Icynene	1	1				
Fiberglass Board					1	
Fiberglass Batts	1	1				
Mineral fiber blockfill						
Foam Beads						
None						
Interior	1	1	1		1	1
Exterior				1		
Integral						
Both sides						
None						
Brush-on cementitious						
Brush-on asphaltic						
Trowel-on asphaltic	1	1	1		1	1
Spray-on bitumen						
Sheet-applied bituthene	1		1			
Drain Board/Panel/Sheet	1	1	1		1	
Washed Aggregate	1	1	1		1	
None				1		1
4 mil poly sheet						
6 mil poly sheet	1	1	1	1	1	1
Sand and gravel cushion						
Washed Aggregate	1	1	1	1	1	1
None						
Dimension lumber - site framed	1	1		1	1	1
Engineered lumber - site framed	1	1	1	1	1	1
Prefabricated trusses - site assembled	1	1	1	1	1	1
Prefabricated trusses & floor panels - factory assembled						
Light gauge steel - site framed				1	1	
Fiberglass Batts - faced						
Fiberglass Batts - unfaced	1	1	1	1	1	1
Fiberglass Batts and Polyethylene						
Spray-on Icynene	1	1	1	1	1	1
Spray-on polyurethane						
Interior rigid foam board						
Exterior rigid foam board	1	1	1		1	
Dimension lumber	1	1	1	1	1	1
Engineered lumber			1			
Light gauge steel				1	1	
Reinforced masonry				1	1	1
Unreinforced masonry						
Prefabricated panels						
Structural Insulated Panels - SIPS	1	1	1	1	1	1
Insulated Concrete Formwork - ICF	1	1	1	1	1	1
Shear panels at corners only						
Let-in "T" bracing						
Fully sheathed in structure panels	1	1	1	1	1	1
Prefabricated shear panels (eg strongwall)						
Light gauge steel						
Dimension lumber	1					1
Engineered lumber	1	1	1	1	1	1
Prefabricated wood trusses	1	1	1	1	1	1
Prefabricated light gauge steel trusses				1	1	

Factor	NE	CE	NC	SW	SE	WE
Toe nail						
Clips	1		1	1		
Single plate wrap	1	1	1	1	1	
Double plate wrap	1	1	1		1	1
Braced in vert and sloped plane	1	1	1	1	1	1
Braced in vert plane only						
Unbraced						
Sawn wood siding						
Plywood siding						
Composition board siding						
Cement board siding	1	1	1	1	1	1
Masonry veneer	1	1	1	1	1	1
Vinyl siding	1	1	1	1	1	1
Metal siding		1			1	
Acrylic-stucco, Exterior insulation and Finish System (EIFS)			1	1		1
Traditional 3 coat stucco				1	1	1
Economy 2 coat stucco						
Water managed wall with rainscreen		1			1	1
Face-sealed wall						
Water managed wall without rainscreen	1		1	1		
Non-woven, non, perforated Housewrap						
Perforated Housewrap						
Woven Housewrap						
Water managing housewrap	1	1	1	1	1	1
Asphalt-impregnated building paper						
Kraft paper						
Sealed exterior gypsum sheathing						
Glass batt in stud cavity-unfaced	1	1	1	1	1	1
Glass batt in stud cavity-foil faced						
Glass batt in stud cavity-paper faced						
Glass batt in stud cavity with extruded polystyrene board sheat	1	1	1	1	1	1
Glass batt in stud cavity with foil faced polyiso board sheathing			1			
Sprayed on Icynene	1	1	1	1	1	1
Mineral fiber batt or fill						
Spray-on polyurethane						
Blown-in Fiberglass						
Dense-pack cellulose						
Poly sheet barrier						
Vapor-retarding latex paint	1	1		1		1
Vinyl wall covering						
Kraft paper			1			
Smart vapor retarder			1		1	1
none						
Field applied bituthene sheet	1	1	1	1	1	1
Field fabricated metal						
Prefabricated metal	1	1	1	1	1	1
Prefabricated plastic						
Tape-sealed nailing flange						
None						
Asphalt shingles	1	1	1		1	1
Wood shingle						1
Prefinished metal		1		1	1	
Clay or cement tile				1		
Single-ply membrane				1		
Built-up roofing						
Bituthene sheet	1	1	1	1	1	
Hot-mopped roofing felt						
Building paper						1
None						
Bituthene sheet		1			1	
Hot-mopped roofing felt					1	
Building paper	1	1	1	1		1
None						
Blown fiberglass						
Blown mineral fiber						

Factor	NE	CE	NC	SW	SE	WE
Blown cellulose						
Glass batts	1	1	1	1	1	1
Mineral fiber batts						
EPS SIP						
XPS SIP						
Polyiso SIP						
Glass batts						
Mineral fiber batts						
Sprayed on Icylene	1	1	1	1	1	1
Eave to ridge - no chutes						
Eave to ridge - preformed chutes		1	1			
Power vents - temperature controlled						
Gravity vent						
Gravity vent cold roof			1			
Power vent						
None	1	1		1	1	1
Prefabricated metal	1	1	1	1	1	1
Site - formed - membrane				1		1
Site fabricated metal	1	1	1	1	1	
Preformed plastic						
Glass batts						
Mineral fiber batts						
Blown fiberglass						
Blown mineral fiber						
Sprayed on Icylene						
Spray-on polyurethane						
None	1	1	1	1	1	1
Poly Sheet - G3 ReAdded						
Building Paper - G3 ReAdded						
None - G3 ReAdded						
Site framed wood	1	1	1	1	1	1
Prefabricated wood	1	1	1	1	1	1
Site framed light gauge steel	1	1	1	1	1	
Prefabricated light gauge steel	1	1	1	1	1	
Masonry						
Plaster						
Drywall						
Reduced-cellulose drywall	1	1	1	1	1	1
Drywall over engineered wood (SIPS, OSB, plywood)						
Masonry						
ICF						
1 latex primer + 1 finish latex	1	1	1	1	1	1
1 latex primer + 2 finish latex						
Vinyl wall covering						
Wood veneer paneling						
Ceramic tile						
None						
1 latex primer + 1 finish latex	1	1	1	1	1	1
1 latex primer + 2 finish latex						
Vinyl wall covering						
Wood veneer paneling						
Ceramic tile						
None						
Particle board						
OSB	1	1	1	1	1	1
Plywood	1	1	1	1	1	1
Cement board						
Concrete				1	1	1
Self-leveling gypsum topping						
Pad and carpet						
Direct-glued carpet						
Vinyl sheet goods						
Vinyl tile						
Ceramic tile				1	1	1
Hardwood-solid	1	1	1	1	1	1

Factor	NE	CE	NC	SW	SE	WE
Hardwood-veneer						
Plastic laminate						
Plaster						
Drywall						
Reduced-cellulose drywall	1	1	1	1	1	1
Wood deck or panel						
None						
1 latex primer + 1 finish latex	1	1	1	1	1	1
1 high-build primer / finish coat						
Lay-in tile						
None						
Plastic laminate						
Stone	1	1	1	1	1	1
Cultured stone						
Soild cast arylic-plastic						
Ceramic tile						
Metal						
Concrete						
Milled wood	1	1	1	1	1	1
Milled or formed wood composite						
PVC						
Other plastic						
Prefabricated - milled wood	1	1	1	1	1	1
Prefabricated - engineered wood						
Custom fabricated - milled wood	1	1	1	1	1	1
Custom fabricated - engineered wood						
Plumber-installed	1	1	1	1	1	1
Builder-installed						
Owner-installed						
Third-party-tested	1	1	1	1	1	1
By builder	1	1	1	1	1	1
By owner						
Bundled-weaved together based on schedule						
Unbundled-each subsystem has designed place	1	1	1	1	1	1
Hybrid-system trunks in designed places, distribution woven	1	1	1	1	1	1
Site fabricated trunks and feeders						
Prefabricated trunks and feeders						
Hybrid, prefabricated trunks, site fabricated distribution	1	1	1	1	1	1
All in unconditioned spaces						
All in conditioned spaces	1	1	1	1	1	1
In conditioned and unconditioned spaces						
In unconditioned space						
In conditioned space	1	1	1	1	1	1
In garage						
Site formed metal						
Site formed ductboard						
Flexduct - insulated						
Flexduct - uninsulated						
Prefabricated metal	1	1	1	1	1	1
Prefabricated ductboard	1	1	1	1	1	1
Conduit						
Romex	1	1	1	1	1	1
Wiring harness						
Category 5/6	1	1	1	1	1	1
Separate wiring for each system						
On grid	1	1	1	1	1	1
Self - PV generation						
Self - wind generation						
Self - gas or propane generator						
Hybrid on-grid and self-generation						
Designed by lighting engineer	1	1	1	1	1	1
Designed by electrical engineer	1	1	1	1	1	1
Designed by architect						
Designed by supplier						
Designed by installer						

Factor	NE	CE	NC	SW	SE	WE
Incandescent						
Compact fluorescent	1	1	1	1	1	1
Low Voltage						
All in conditioned spaces	1	1	1	1	1	1
In conditioned and unconditioned spaces						
Copper	1	1	1	1	1	1
Polyisobutylene						
PVC						
CPVC						
HPBE						
All insulated	1	1	1	1	1	1
Hot water only insulated						
No insulation						
Within partitions						
Directly to subgrade	1	1	1	1	1	1
PVC	1	1	1	1	1	1
Iron						
Municipal	1	1	1	1	1	1
Private well						
Purchased service						
None						
Filtered	1	1	1	1	1	1
Softened	1	1	1	1	1	1
None						
Cistern	1	1	1	1	1	1
Municipal	1	1	1	1	1	1
Septic system						
Storage tank						
Greywater recovery						
Central System	1	1	1	1	1	1
Room by Room conditioning						
Through the wall units						
Window units						
Gas fired boiler or water heater	1	1	1		1	
Oil fired boiler or water heater						
Electric boiler or water heater	1	1	1		1	
Gas hot air furnace	1	1	1		1	1
Oil hot air furnace						
Electric hot air furnace	1	1	1		1	1
Ground coupled electric heat pump						
Air source electric heat pump	1	1	1	1	1	1
Straight cooling w/ electric baseboard heat				1		
Central forced air	1	1	1	1	1	1
Split system	1	1	1	1	1	1
Window unit						
Through wall unit						
Whole house exhaust fan						
Fiberglass filter						
Pleated filter	1	1	1	1	1	1
Deep pleated media	1	1	1	1	1	1
Electronic	1	1	1	1	1	1
None						
Under slab barrier						
Foundation/sump sealing						
Passive ventilation		1		1	1	1
Active sub-slab depressurization	1		1			
None						
Stand-alone unit					1	
Whole house	1	1	1			1
None				1		
Radiant slab water						
Hot water radiator						
Ducted air distribution	1	1	1	1	1	1
Non-ducted air distribution						
Integrated hot water and furnace						

Factor	NE	CE	NC	SW	SE	WE
Stand alone hot water heat and storage						
Tankless electric hot water source heaters	1	1	1	1	1	1
Tankless gas hot water source heaters	1	1	1	1	1	1
Solar hot water heat and storage						
Heat pump water heater						
Perimeter diffuser locations	1	1	1	1	1	1
Core diffuser locations						
Zoned						
Programmable thermostat	1	1	1	1	1	1
Time delay relay						
Low velocity	1	1	1	1	1	1
High velocity						
Ultra high velocity						
Pressure-reducing						
Point	1	1	1	1	1	1
Linear						
Fully ducted returns from each space						
Central ducted return	1	1	1	1	1	1
Ducted return for each floor served						
Panned joist return duct						
Wall cavity return duct						
Continuous supply ventilation						
Supply vent only when ahu runs	1	1	1	1	1	1
Exhaust-driven makeup air						
Balanced with heat recovery	1		1	1		1
Balanced with no heat recovery		1			1	
Balanced with energy recovery						
Timed supply ventilation						
Timed exhaust ventilation						
Masonry on exterior wall						
Masonry on interior wall						
Metal on exterior wall						
Metal on interior wall	1	1	1	1	1	1
Chimney above roof	1	1	1	1	1	1
Vented through wall						
Ventless gas						
Ventless alcohol						
Ventless electric						
Hood - recirculating						
Hood - exhausting	1	1	1	1	1	1
Downdraft						
Present						
None	1	1	1	1	1	1



## Appendix Five, Glossary of Systems Choices used in the Calculator:

The following are the requested glossary explanations that appear on the web pages when the user lets the mouse linger over the words shown in bold face below:

- **Architect & engineer** Licensed design and engineering (structural, mechanical, electrical engineers) professionals providing design, coordination and construction observations services for all the systems in the home
- **Architect only** A licensed architect providing design, coordination, and possibly construction observation services for the home
- **Engineer only** A structural, mechanical or electrical engineer retained to design their respective system for the house.
- **Unlicensed Designer** A draftsman, designer or other unlicensed person providing layout and drawings for the general construction of the home
- **Energy rater** A person who is nationally certified by the Residential Energy Services Network who participates in RESNET's Quality Assurance program and is an ENERGY STAR partner or is a certified under the Home Energy Rating System (HERS).
- **Part of Building America program** A member of the private/public partnership sponsored by the U.S. Department of Energy that conducts research to find energy-efficient solutions for new and existing housing that can be implemented on a production basis.
- **Part of Energy Star program** A person who participates in the voluntary partnership between the U.S. Department of Energy, the U.S. Environmental Protection Agency, product manufacturers, local utilities and retailers to provide products that use less energy than other products.
- **Builder / developer** A person or company that both develops raw land into buildable, saleable lots and provides construction services for varying degrees of customized pre-designed homes.
- **None** No single person or company outside of the owner takes responsibility for the design of the home or its systems.
- **Custom design & siting** Designed from the "ground-up" to meet the specific needs of a specific owner on a specific parcel of land.
- **Production design, custom siting** A pre-designed home that has been constructed in large numbers but is specifically oriented and located on a specific parcel to meet the needs of a specific owner.
- **Production design, production siting** A pre-designed home that has been constructed in large numbers and is one of several approved "footprints" sited to meet the local zoning requirements in a subdivision developed by the production builder.
- **Production siting, production design with prepacked options** A pre-designed home that has been constructed in large numbers and is one of several approved "footprints" sited to meet the local zoning requirements in a subdivision developed by the production builder but having pre-configured option packages that have been constructed in large numbers.
- **Purchased design, no siting** An "off-the-shelf" home design purchased from a planbook vendor and sited by the owner or builder.

- **Structural systems** The extent of services utilized to generate the instructions leading to the processes of material shaping, product assembly, in the field to make up the load transferring systems of the house.
- **Fully engineered** The design, analysis, reviews, approvals and instructions leading to the processes of material shaping and/or product assembly in the field to make up the load transferring systems of the house by a licensed architect or professional engineer.
- **Designed integration** The design, analysis, reviews, approvals and instructions developed by licensed architect or licensed professional engineer leading to the processes of material shaping and/or product assembly in the field to make up the load transferring systems of the house which includes coordination with other engineered systems to insure physical, chemical and performance compatibility and to reduce onsite modification of the structure by other systems installers.
- **Engineered by suppliers or installers** The design, analysis, reviews, approvals and instructions developed by a licensed professional engineer employed by the supplier or installer of material or products assembled in the field to make up the load transferring systems of the house.
- **Components proscriptively described** The description by a regulatory agency or local building official of minimum sizes and quality grades of the members, connections and materials which make up the load transferring systems of the house.
- **Components traditionally described** The description by historical or longstanding practices, of minimum sizes and quality grades of the members connections, and materials which make up the load transferring systems of the house.
- **Fully engineered** The design, analysis, reviews, approvals and instructions leading to the processes of material shaping and/or product assembly in the field to make up the heating, cooling and ventilating systems of the house by a licensed architect or professional engineer.
- **Designed integration** The design, analysis, reviews, approvals and instructions developed by licensed architect or licensed professional engineer leading to the processes of material shaping and/or product assembly in the field to make up the heating, cooling and ventilating systems of the house which includes coordination with other engineered systems to insure physical, chemical and performance compatibility and to reduce onsite modification of the system by other systems installers.
- **Engineered by suppliers or installers** The design, analysis, reviews, approvals and instructions developed by a licensed professional engineer employed by the supplier or installer of material or products assembled in the field to make up the heating, cooling and ventilating systems of the house.
- **Components proscriptively described** The description by a regulatory agency or local building official of minimum sizes and quality grades of the members connections and materials which make up the heating, cooling and ventilating systems of the house.
- **Components traditionally described** The description by historical or longstanding practices, of minimum sizes and quality grades of

the members connections and materials which make up the heating, cooling and ventilating systems of the house.

- **Fully engineered** The design, analysis, reviews, approvals and instructions leading to the processes of material shaping and/or product assembly in the field to make up the drain, waste, vent, potable water and gas systems of the house by a licensed architect or professional engineer.
- **Designed integration** The design, analysis, reviews, approvals and instructions developed by licensed architect or licensed professional engineer leading to the processes of material shaping and/or product assembly in the field to make up the drain, waste, vent, potable water and gas systems of the house which includes coordination with other engineered systems to insure physical, chemical and performance compatibility and to reduce onsite modification of the system by other systems installers.
- **Engineered by suppliers or installers** The design, analysis, reviews, approvals and instructions developed by a licensed professional engineer employed by the supplier or installer of material or products assembled in the field to make up the drain, waste, vent, potable water and gas systems of the house.
- **Components proscriptively described** The description by a regulatory agency or local building official of minimum sizes and quality grades of the members connections and materials which make up the drain, waste, vent, potable water and gas systems of the house.
- **Components traditionally described** The description by historical or longstanding practices, of minimum sizes and quality grades of the members connections and materials which make up the drain, waste, vent, potable water and gas systems of the house.
- **Fully engineered** The design, analysis, reviews, approvals and instructions leading to the processes of material shaping and/or product assembly in the field to make up the electric power, light and communications network systems of the house by a licensed architect or professional engineer.
- **Designed integration** The design, analysis, reviews, approvals and instructions developed by licensed architect or licensed professional engineer leading to the processes of material shaping and/or product assembly in the field to make up the electric power, light and communications network systems of the house which includes coordination with other engineered systems to insure physical, chemical and performance compatibility and to reduce onsite modification of the system by other systems installers.
- **Engineered by suppliers or installers** The design, analysis, reviews, approvals and instructions developed by a licensed professional engineer employed by the supplier or installer of material or products assembled in the field to make up the electric power, light and communications network systems of the house.
- **Components proscriptively described** The description by a regulatory agency or local building official of minimum sizes and quality grades of the members connections and materials which make up the electric power, light and communications network systems of the house.
- **Components traditionally described** The description by historical or longstanding practices, of minimum sizes and quality grades of the members connections and materials which make up the electric power, light and communications network systems of the house.

- **Presence of overhangs > 1 foot** Roof edge overhangs the exterior wall by more than 1 foot on all sides of the house
- **Presence of ventilated attic** An unconditioned space between the underside of the roof and the ceiling of the uppermost floor of the house that is provided with sufficient square feet of ventilation openings distributed between the eaves, ridge and gable end walls to meet the requirements of the building code.
- **Presence of attic ridge vents** Vents at the peak or ridge of a sloped roof designed to aid in the ventilation of an unconditioned attic space.
- **Presence of attic soffit vents** Vents at the underside of the eaves or lower roof edges designed to aid in the ventilation of an unconditioned attic space.
- **Presence of attic gable vents** Vents in the vertical walls of a gabled roof designed to aid in the ventilation of an unconditioned attic space.
- **Grading designed to slope away from fdn** Finished soil grading around the perimeter footprint of the house providing positive (6" in 10') drainage of surface water away from the exterior walls
- **Landscape design integration** Critical positioning of shrubs, trees, ponds, and berms to enhance the thermal or durability performance of the house through shading, passive heating and cooling or wind barrier effects of the landscape.
- **Minimal exterior corners < 8** A house design whose perimeter has less than eight total corners.
- **Minimal wall envelope penetrations < 16** A house design having less than sixteen total penetrations through the exterior wall including all windows, doors and utility penetrations.
- **Minimal roof envelope penetrations < 6** A house design whose roof surface has less than six total penetrations including all skylights, flues, plumbing and attic vents.
- **OVE framing** A set of advanced wood framing techniques intended on reducing thermal bridging through the exterior envelope, increasing the available space for insulation materials, and "right-sizing" members making up the structural load transfer system of the house. Examples include 24" o.c. stud spacing, insulated stud corners, insulated spaces behind partition/exterior wall intersections and the use of insulated headers over wall openings.
- **Square** The primary shape of the footprint of the house and garage where the whole is equal in length and width.
- **Rectangle** The primary shape of the footprint of the house and garage where the length and width of the whole are dissimilar.
- **ElI "L"** The primary shape of the footprint of the house and garage being a square or rectangle with an extension on one side such that the overall shape resembles the letter "L".
- **Tee "T"** The primary shape of the footprint of the house and garage being a square or rectangle with extensions on two opposing sides such that the overall shape resembles the letter "T".
- **U** The primary shape of the footprint of the house and garage being a square or rectangle with extensions on one side such that the overall shape resembles the letter "U".

- **< 1,000 s.f** A house having less than 1,000 square feet of conditioned (heated and cooled) space.
- **1,001 - 1,500** A house having between 1,001 and 1,500 square feet of conditioned (heated and cooled) space.
- **1,501 - 2,000** A house having between 1,501 and 2,000 square feet of conditioned (heated and cooled) space.
- **2,001 - 3,000** A house having between 2,001 and 3,000 square feet of conditioned (heated and cooled) space.
- **3,001 - 4,000** A house having between 3,001 and 4,000 square feet of conditioned (heated and cooled) space.
- **> 4,000** A house having more than 4,000 square feet of conditioned (heated and cooled) space.
- **Attached** A garage constructed directly adjacent to the house such that one could walk from the house into the garage without going outside.
- **Detached** A garage constructed apart from the house such that one would have to walk outside to pass from the house into the garage.
- **Below** A garage constructed immediately below the house.
- **Beside** A garage constructed immediately beside the house at or within 9 vertical feet of the main floor of the house.
- **Attached w/ shared wall (garage beside)** A garage having one wall shared with an occupied floor of the house.
- **Attached w/ shared ceiling/floor (garage under)** A garage whose ceiling is attached to an occupied floor of the house above.
- **Attached w/ shared wall and ceiling/floor (garage under and beside)** A garage constructed below the main floor of the house, but sharing a wall with the lower level or basement of the house
- **Attached w/ shared floor/ceiling (garage over)** A garage constructed above the occupied floors of a house.
- **One story** A house with all occupied spaces on the same horizontal plane.
- **One and one-half story** A split-foyer or split level type of house where the entry is half a level above the lower floor and half a level below the upper floor.
- **Two story** A house having occupied spaces on two floors where both are above grade level.
- **Three story** A house having occupied spaces on three floors where two or more are above grade level.
- **Four story** A house having occupied spaces on four floors where three or more are above grade level.
- **Flat** A house designed with a roof that slopes at or near 1/2 inch per foot or less.
- **Hip** A roof formed by sloping planes from all sides to a ridge or peak.
- **Gable** A roof formed by sloping planes from two sides to a ridge.
- **Shed** A roof formed by sloping planes from one side to a ridge.
- **Mansard** A roof formed by planes having two sloped surfaces where the lower surface is a steeper slope and the upper plane has a significantly lower slope.
- **Gambrel** A roof formed by planes having two sloped surfaces where the lower surface has a steeper slope than the upper surface.

- **< 2:12** Sloping less than 2 inches in 12 inches.
- **3:12 - 4:12** Sloping between 3 inches vertically in 12 inches horizontally and 4 inches vertically in 12 inches horizontally.
- **5:12 - 7:12** Sloping between 5 inches vertically in 12 inches horizontally and 7 inches vertically in 12 inches horizontally.
- **8:12 - 12:12** Sloping between 8 inches vertically in 12 inches horizontally and 12 inches vertically in 12 inches horizontally.
- **> 12:12** Sloping more than 12 inches vertically in 12 inches horizontally.
- **Slab-on-grade** A concrete slab forming the lowest occupied floor of the house which is supported by the earth.
- **Pier - open beneath** A series of columns which are not enclosed by permanent walls carrying beams and joists supporting the house above grade.
- **Crawl space - vented** An enclosed, unconditioned space 6 to 72 inches high below the first occupied floor of the house provided with vents to exchange air at a rate required by a building code.
- **Crawl space - conditioned** An insulated, vapor-controlled, enclosed, conditioned (heated and cooled) space 24 to 72 inches high below the first occupied floor of the house without vents exchanging air with the outside.
- **Basement - full** An enclosed conditioned or unconditioned space beneath the house usually high enough to allow a person to walk upright beneath the house
- **Basement - daylight or lookout** An enclosed conditioned or unconditioned space beneath the house usually high enough to allow a person to walk upright beneath the house where the surrounding exterior grade is low enough to allow the installation of windows extending to within 44 inches of the floor.
- **Basement - walkout** An enclosed conditioned or unconditioned space beneath the house usually high enough to allow a person to walk upright beneath the house where the surrounding exterior grade is low enough to allow the installation of a door or doors on one or more sides of the basement which provides access to the exterior without the use of stairways.
- **Traditional stick frame wood** A method of construction where dimension lumber 2x4, 2x6, 2x8, 2x10, 2x12 is shipped to the construction site in bundles of standard lengths and subsequently measured, cut, nailed together to form stud walls, floors and roof structures.
- **Traditional stick frame light gauge steel** A method of construction where standard dimension light gauge steel (18ga loadbearing, 20-22ga non-loadbearing) in sizes equivalent to 2x4, 2x6, 2x8, 2x10, 2x12 are shipped to the construction site in bundles of standard lengths and subsequently measured, cut, screwed, crimped or welded together to form stud walls, floors and roof structures.
- **Panelized stick frame wood** A method of construction where 2 to 25 foot long walls are prefabricated from dimension lumber 2x4, 2x6, 2x8, 2x10, 2x12, labeled and shipped to the construction site in bundles. These prefabricated panels are subsequently placed, nailed or bolted together to form exterior and/or interior walls.

- **Panelized stick frame light gauge steel** A method of construction where 2 to 25 foot long walls are prefabricated from standard dimension light gauge steel (18ga loadbearing, 20-22ga non-loadbearing) in sizes equivalent to 2x4, 2x6, 2x8, 2x10, 2x12, labeled and shipped to the construction site in bundles. These prefabricated panels are subsequently placed, screwed, crimped, welded or bolted together to form exterior and/or interior walls.
- **SIPS Panels** Structural Insulated Panels (SIPS). A panelized form of construction where the wall panel includes thermal insulation as an integral part of the panel. In wood SIPS panels, the insulation performs a structural role, bracing the oriented strand facing panels against lateral deflection.
- **Prefabricated modular (IRC Compliant)** A form of construction where a house design is broken down into twelve to sixteen foot wide modules which are assembled off-site in an manufacturing facility, inspected to certify compliance with the same building codes (International Residential Code) used in on-site constructed homes, and shipped to the jobsite complete with interior finishes, electrical, and plumbing systems installed. At the site, modular houses are often lifted into position with cranes to assemble them into one to three story homes of any size and configuration.
- **Masonry** A method of construction using brick or concrete masonry units to form the primary structural walls of the house.
- **ICF** Insulated Concrete Formwork (ICF). A method of construction using concrete formed in expanded or extruded polystyrene forms which remain in place after concrete curing to make the integrate insulation into the concrete walls of the house.
- **Precast concrete panels** Prefabricated concrete panels cast off-site, labeled, shipped to the construction site, placed with a crane on a bed of crushed rock, bolted together and sealed onsite.
- **In-house superintendent, all external subs** A form of project delivery where the builder selling the house to the buyer provides one of it's own employees to supervise the work of subcontractors providing labor and materials to install the systems making up the house.
- **In-house superintendent, in-house shell crew, minimal subs** A form of project delivery where the builder selling the house to the buyer provides it's own employees to construct the exterior shell of the house (dry-in) and one employee to supervise the work of subcontractors providing labor and materials to install the remaining interior systems making up the house.
- **All in-house personnel** A form of project delivery where the builder selling the house to the buyer provides it's own employees to construct all aspects of the house.
- **All subcontract - self supervision** A form of project delivery where the seller of the house operates as a broker and subcontracts all aspects of the construction of the systems comprising the house to independent subcontractors and depends on those subcontractors to coordinate with each other in performing their work.
- **Quality check of personnel training** A quality assurance method which makes one person responsible for verifying that the qualifications of all personnel involved in the construction meet a standard for knowledge and skill agreed upon in the contracts/subcontracts.

- **Quality check of work as increments are completed** A quality assurance method which places an inspection step between the installation and payments steps of subcontract performance.
- **Commissioning of performance of the completed house** A performance assurance method which actively tests the subsystems of a house (typically envelope, thermal, ventilation and electrical systems) and various aspects of the interior environment (interior air quality) to assure an owner that in the "as-built" state, the house meets or exceeds the performance parameters established by the design.
- **Fit & finish check at the end of the project** A quality control approach which depends upon visual observation of the fit and finish of the surfaces and fixtures to rectify any visual defects prior to turning over the house to the owner.
- **Safety training for personnel at project start** An accident-avoidance approach that describes risk factors and best safety practices for each subcontract and for cross-subcontract work environments at the beginning of the project.
- **Daily safety briefings** An accident-avoidance approach that describes risk factors and best safety practices for each subcontract and for cross-subcontract work environments on each workday of the project.
- **Daily safety inspections for rigging, trenching temp structures** An accident-avoidance approach that inspects temporary facilities, tools, and jobsite conditions to detect and correct unsafe situations prior to commencing that day's work.
- **Tooling and materials designed for safety (label, cg, edges, switches, falls)** An accident-avoidance approach that designs/redesign materials, tools, and equipment to prevent accident or injury.
- **Safety a personal decision** An approach to accident avoidance that leaves decisions about safe practices, tools, and equipment up to each individual worker on the jobsite.
- **Blow out panels in floodable first floor** Wall panels designed to pop out of a floodable first floor in order to prevent excessive structural loading of the building by the floodwaters.
- **120 mph resistant shutters at openings** Shutters, either hinged, sliding or coiling that have been tested and certified to prevent doors and windows from being damaged or destroyed by wind velocity up to 120 mph.
- **Safe room, "strong room" for high wind / seismic survivability** A particular room of the house specially constructed from wood, concrete, masonry or steel to remain it's spatial integrity under seismic or wind conditions that may collapse the rest of the house.
- **Braced garage doors** Garage doors that have either been retrofitted with bracing to the door segments and track or designed with door segments and track capable of resisting 120 mph wind loads.
- **High impact windows / glazing** Windows and glazing designed to meet or exceed the Florida Building Code standard for resisting a "large missile" (a 2x4 propelled by the wind at a velocity of 50 feet per second)



- **Building elevated on piles or columns above flood levels** A house constructed on piers or piles to position the lowest inhabited floor above the elevation for the 100 year flood or storm surge.
- **Treated wood** A footing component of the "All Weather Wood" AWW foundation system constructed from wood treated to resist decay from bacteria, fungi, insects and other organisms. Common forms of treatment have included Chromated Copper Arsenate (CCA) Copper Azole, Ammonical Copper Quaternary (ACQ)
- **Site cast concrete** A footing system using concrete cast into formwork (wood, steel, polystyrene or earth) constructed on the specific site and location where the concrete element will be located. Typically reinforced with steel bars to resist tension from bending.
- **Crushed rock** A footing system using crushed rock, usually screeded and tamped level as a drainable footing.
- **Pilings** A footing system made by driving or vibrating linear wood, steel, or precast concrete elements into the soil. An alternative but similar method would be drilled concrete piles. All pile foundations could be considered a "point" support system.
- **None** – see slab on grade No footing as an discrete element, footing function fulfilled by thickening and turning down the edge of a slab-on-grade to act as the footing.
- **Masonry** The wall between the footing and above-grade framing, constructed from brick, concrete block, or stone
- **Site cast concrete** The wall between the footing and above-grade framing, constructed from reinforced concrete, formed and poured in it's final location.
- **Precast concrete** The wall between the footing and above-grade framing, constructed with concrete panels, precast in a manufacturing plant and placed on the concrete or crushed rock footing.
- **Insulated concrete formwork (ICF)** The wall between the footing and above-grade framing, constructed with Insulated Concrete Formwork (ICF). A method of construction using concrete formed in expanded or extruded polystyrene forms which remain in place after concrete curing to make the integrate insulation into the concrete walls of the house.
- **Permanent wood** The wall between the footing and above-grade framing, constructed as a plywood sheathed stud wall, using pressure-treated (ACQ, CCA) plywood and framing materials to prevent deterioration.
- **Glass strand reinforcing** Concrete slab on grade mix design including short strands of polyethylene, polypropylene, nylon or fibrillated polypropylene fibers to augment or replace traditional welded wire mesh in reducing cracking in the slab.
- **Wire mesh reinforcing** A grid of welded wire mesh intended to reduce slab cracking which is a component of many concrete slabs-on-grade constructions.
- **Rebar reinforcing** A designed grid of deformed steel reinforcing bars embedded in the slab on grade to enhance the structural performance of the slab and reduce cracking.

- **Post tension strand reinforcing** An array of steel cables sheathed with plastic tubing and embedded in the slab on grade. When the concrete reaches its designed strength, the strands are stretched with a hydraulic tool and clamped to the slab in their stretched position to induce additional compressive forces in the slab thus reducing cracking and enhancing the structural performance of the slab.
- **Combination of the above** An engineered solution for the slab on grade utilizing one or more of the above methods of reinforcing to provide enhanced structural performance and reduce slab cracking.
- **None** No reinforcing in the slab on grade
- **Expanded polystyrene (EPS)** Below-slab insulation made of expanded polystyrene. Usually found at the perimeter of the slab, but occasionally found below the whole slab where radiant heating systems are placed in the slab.
- **Extruded polystyrene (XPS)** Below-slab insulation made of extruded polystyrene. Usually found at the perimeter of the slab, but occasionally found below the whole slab where radiant heating systems are placed in the slab.
- **Sprayed on Icynene** Below-slab insulation made of sprayed on Icynene, an improbable application.
- **Fiberglass board** Below-slab insulation made of compressed fiberglass boards, Usually found at the perimeter of the slab, but occasionally found below the whole slab where radiant heating systems are placed in the slab.
- **Fiberglass batts** Below-slab insulation made of fiberglass batts, an improbable application.
- **Mineral fiber blockfill** Below-slab insulation made of mineral fiber insulation, an improbable application.
- **None** No horizontal insulation below the slab on grade.
- **Expanded polystyrene (EPS)** Foundation wall insulation made up of one or more vertical boards of expanded polystyrene placed on the inside or outside of the foundation wall.
- **Extruded polystyrene (XPS)** Foundation wall insulation made up of one or more vertical boards of extruded polystyrene placed on the inside or outside of the foundation wall.
- **Sprayed on Icynene** Foundation wall insulation made up a sprayed on layer of Icynene insulation, more often found on the inside of the wall.
- **Fiberglass board** Foundation wall insulation made up of one or more vertical boards of compressed fiberglass boards usually placed on the outside of the foundation wall.
- **Fiberglass batts** Foundation wall insulation made up of batts of fiberglass placed between the studs of a permanent wood foundation wall.
- **Mineral fiber blockfill** Foundation wall insulation made of perlite, vermiculite or other mineral fiber poured into the open cores of a concrete masonry foundation wall.
- **Foam beads blockfill** Foundation wall insulation made of expanded polystyrene beads poured into the open cores of a concrete masonry foundation wall.
- **None** No insulation associated with the foundation wall.
- **Interior** Foundation insulation located on the interior face of the foundation wall.

- **Exterior** Foundation insulation located on the exterior face of the foundation wall.
- **Integral** **Foundation insulation** located within the foundation wall as in blockfill for concrete masonry walls, or fiberglass batts with permanent wood foundation walls.
- **Both sides** Foundation insulation located on both the interior and exterior of the foundation wall.
- **None** No foundation wall insulation.
- **Brush-on cementitious** An acrylic-modified cement dampproofing product brushed on the exterior face of the foundation wall to reduce capillary transfer of water.
- **Brush-on asphaltic** A solvent-based asphalt coating brushed on concrete or concrete masonry foundation walls to reduce the capillary transfer of water from the outside to the inside.
- **Trowel-on asphaltic** A solvent-based fiber-reinforced asphalt coating troweled on concrete or concrete masonry foundation walls to reduce the capillary transfer of water from the outside to the inside and being capable of bridging small cracks in the foundation wall.
- **Spray-on bitumen** A cold-applied spray-on bitumen capable of functioning as a dampproofing or as a waterproofing depending on the number and thickness of the coatings.
- **Sheet-applied bituthene** A self-adhesive cold-applied composite sheet consisting of rubberized asphalt laminated to a polyethylene film to provide a waterproof barrier on the outside of the foundation wall.
- **Drain board / panel / sheet** A prefabricated panel, roll, or sheet product made of a sheet of hollow studded or gridded polystyrene, covered on one side with a non-woven polypropylene geotextile filter fabric.
- **Washed aggregate** Crushed or river run rock which has been washed free of silt/sand/clay/fines, etc. to provide free-drainage when used as backfill against the foundation wall.
- **None** No vertical water management
- **4 mil poly sheet** A sheet of polyethylene, 4 mils in thickness laid on top of the sand and gravel sub-slab cushion and below the slab-on-grade.
- **6 mil poly sheet** A sheet of polyethylene, 6 mils in thickness laid on top of the sand and gravel sub-slab cushion and below the slab-on-grade. The additional mil thickness reduces damage to the poly sheet during the concrete reinforcing and pouring operations.
- **Sand and gravel cushion** A compacted layer of sand and gravel intended to provide a uniform substrate for the slab-on-grade
- **Washed aggregate** A tamped and leveled bed of crushed rock intended to provide a free draining substrate for the slab-on-grade
- **None** No moisture or vapor control below the slab-on-grade.
- **Dimension lumber - site framed** Lumber cut/finished/graded and stamped to certify it's allowable loading that is cut to length from standard dimension (2x4, 2x6, 2x8, 2x10, 2x12) lumber.
- **Engineered lumber - site framed** Engineered wood products (I-joist, micro-lam, paralam, parastrand etc.) that are cut to length and assembled into the structural floor on-site.
- **Prefabricated trusses - site assembled** Prefabricated, pre-engineered floor spanning members assembled into trusses designed specifically for each house to insure that minimal/no cutting or modification occurs onsite.

- **Prefabricated trusses & floor panels - factory assembled**  
Prefabricated, pre-engineered floor spanning members assembled into trusses and attached to floor decking in modules designed specifically for each house to insure that minimal/no cutting or modification occurs onsite.
- **Light gauge steel - site framed** A method of construction where standard dimension light gauge steel (18ga loadbearing, 20-22ga non-loadbearing) in sizes equivalent to 2x4, 2x6, 2x8, 2x10, 2x12 are shipped to the construction site in bundles of standard lengths and subsequently measured, cut, screwed, crimped or welded together to form spanning floors and roof structures.
- **Fiberglass batts - faced** Placing paper, foil, or poly-faced fiberglass batts behind the rim joist to reduce heat loss/gain and control moisture infiltration/exfiltration.
- **Fiberglass batts - unfaced** Placing unfaced fiberglass batts behind the rim joist to reduce heat loss/gain without control over moisture infiltration/exfiltration.
- **Fiberglass batts and polyethylene** Placing polyethylene sheet material and unfaced fiberglass batts behind the rim joist to reduce heat loss/gain and control moisture infiltration/exfiltration.
- **Spray-on Icynene** Spraying Icynene foam on the back (inside) of rim joists to reduce heat loss/gain and control moisture infiltration/exfiltration.
- **Spray-on polyurethane** Spraying Polyurethane foam on the back (inside) of rim joists to reduce heat loss/gain and control moisture infiltration/exfiltration.
- **Interior rigid foam board** Placing a rigid board of foam plastic insulation (EPS, XPS, or PolyIso) on the inside face of the rim joist between the floor joists in order to reduce heat loss/gain and control moisture infiltration/exfiltration.
- **Exterior rigid foam board** Placing a rigid board of foam plastic insulation (EPS, XPS, or PolyIso) on the outside face of the rim joist (usually over sheathing as well) in order to reduce heat loss/gain and control moisture infiltration/exfiltration.
- **Dimension lumber** Lumber cut/finished/graded and stamped to certify it's allowable loading that is cut to length from standard dimension (2x4, 2x6, 2x8, 2x10, 2x12) lumber onsite to form bearing and non-bearing walls.
- **Engineered lumber** Engineered wood products (I-joist, micro-lam, paralam, parastrand etc.) that are cut to length and assembled into bearing and non-bearing walls on-site.
- **Light gauge steel** A method of construction where standard dimension light gauge steel (18ga loadbearing, 20-22ga non-loadbearing) in sizes equivalent to 2x4, 2x6, 2x8, 2x10, 2x12 are shipped to the construction site in bundles of standard lengths and subsequently measured, cut, screwed, crimped or welded together to form bearing and non-bearing walls.
- **Reinforced masonry** A method of construction using steel-reinforcing with brick or concrete masonry units to form the primary structural walls of the house.
- **Unreinforced masonry** A method of construction using brick or concrete masonry units to form the primary structural walls of the house.

- **Prefabricated panels** A method of construction using metal or wood stud walls prefabricated offsite in lengths and heights specifically required for each house. Panels are delivered, placed anchored and fastened to surrounding structural elements and each other to form both bearing and non-loadbearing structures.
- **Structural insulated panels - SIPS** A method of construction using metal or wood wall panels prefabricated offsite with integral insulation which often plays a structural role. Panels are delivered, placed anchored and fastened to surrounding structural elements and each other to form both bearing and non-loadbearing structures.
- **Insulated concrete formwork (ICF)** A method of construction using Insulated Concrete Formwork (ICF). ICF concrete walls are formed in expanded or extruded polystyrene forms which remain in place after concrete curing to make the integrate insulation into the concrete walls of the house.
- **Shear panels at corners only** A method of providing bracing against lateral (wind, seismic or flood) loads which depends upon forming structural diaphragms (rigid corners) where the wall edges meet at the building's corners.
- **Let-in "T" bracing** A method of providing bracing against lateral (wind, seismic or flood) loads which depends upon cold-formed steel "T" or "L" shaped strips where one leg of the "T" or "L" is recessed into a slot sawn into the face of the stud and the flange is nailed to the face of the stud.
- **Fully sheathed in structure panels** A method of providing bracing against lateral (wind, seismic or flood) loads which depends upon the entire surface of the house being covered in structural panels, OSB or Plywood which are rated and stamped for use as wall sheathing and nailed or screwed to the substructure on a spacing schedule specified by code or engineered solution.
- **Prefabricated shear panels (eg strongwall)** A method of providing bracing against lateral (wind, seismic or flood) loads which depends upon specially designed, tested, and certified prefabricated shear panels secured to the foundation and adjacent structural assemblies to provide lateral load resistance.
- **Light gauge steel** A method of providing bracing against lateral (wind, seismic or flood) loads which depends upon cold-formed steel straps deployed in "X" or "V" configurations across the height of the cold-formed steel stud wall and screwed to the face of the studs to provide lateral load resistance while preventing local buckling between the studs.
- **Dimension lumber** A method of roof framing using Lumber milled/finished/graded and stamped to certify it's allowable loading that is cut to length from standard dimension (2x4, 2x6, 2x8, 2x10, 2x12) lumber and used onsite to make joists spanning from top of wall plate to the roof ridge.
- **Engineered lumber** Engineered wood products (I-joist, micro-lam, paralam, parastrand etc.) that are cut to length and assembled into joists spanning from top of wall to roof ridge on-site.
- **Prefabricated wood trusses** Prefabricated, pre-engineered wood roof spanning members assembled into trusses and attached to the top plates of the walls and are designed specifically for each house to insure that minimal/no cutting or modification occurs onsite.

- **Prefabricated light gauge steel trusses** Prefabricated, pre-engineered light gauge steel components assembled into roof spanning trusses and attached to the top plates of the walls and are designed specifically for each house to insure that minimal/no cutting or modification occurs onsite.
- **Toe nail** A method of attaching roof joists or trusses to the top plates of the wall that requires the carpenter drive nails on an angle through the vertical face of the joist or truss into the horizontal surface of the wall plates.
- **Clips** A method of attaching roof joists or trusses to the top plates of the wall that utilizes cold-formed steel angled clips nailed into the horizontal surface of the wall plates and into the vertical side surface of the roof joist or truss.
- **Single plate wrap** A method of attaching roof joists or trusses to the top plates of the wall that utilizes cold-formed steel straps nailed into the vertical side surface of the stud, then wrapping and being nailed to the vertical side surface of the wall plates and finally to the vertical side surface of the roof joist or truss.
- **Double plate wrap** A method of attaching roof joists or trusses to the top plates of the wall that utilizes cold-formed steel straps nailed into the vertical side surface of the stud, then wrapping and being nailed to the vertical side surface of the wall plates and to the vertical side surface of the roof joist or truss then back down the other side of the roof joist or truss, down the face of the wall plate and is again nailed to the vertical surface of the stud on the side opposing the first nailing.
- **Braced in vertical and sloped plane** A method of bracing a gable end wall to the ceiling joists or bottom chords of the roof trusses and bracing the sloping sides of the roof by attaching additional framing in a "V" or "X" arrangement to the underside of the slope to stiffen the roof against wind loads being applied to the gable end.
- **Braced in vert plane only** A method of bracing a gable end wall to the ceiling joists or bottom chords of the roof trusses.
- **Unbraced** No additional bracing for wind or lateral loading is installed on the gable end wall or underside of the sloping surfaces of the roof.
- **Sawn wood siding** Exterior finish treatment made up of boards (either vertical or horizontal), or horizontal clapboards made from solid sawn wood.
- **Plywood siding** Exterior finish treatment made up of panels (either structural or non-structural) made of multiple plies or layers of wood having the direction of the grain alternating between layers. Typically, the side of the plywood that faces the weather will have a weather and rot resisting wood species as its face ply.
- **Composition board siding** Exterior finish treatment made up of non-structural boards or panels composed of wood particles bonded together with adhesive under heat and pressure usually with a higher-density composition as its face layer to receive paint.
- **Cement board siding** Exterior finish treatment made up of non-structural boards or panels composed of wood or glass fibers in a cement matrix.
- **Masonry veneer** Exterior finish treatment made up of brick or concrete masonry units which carry no gravity load but their own weight and transfer wind loads to the structural backup layer through cold-formed steel ties.

- **Vinyl siding** Exterior finish treatment made up of sheets of vinyl formed to match the appearance of solid-sawn beveled, shiplap, or clapboard siding.
- **Metal siding** Exterior finish treatment made up of sheets of vinyl formed to match the appearance of solid-sawn beveled, shiplap, or clapboard siding or as a uniform or specially designed corrugation.
- **Acrylic-stucco, exterior insulation and finish system (EIFS)** Exterior finish treatment made up of a layer of rigid foam plastic insulation (typically EPS) which is fastened to the wall sheathing and covered with a thin layer of acrylic-modified stucco. A fiberglass mesh is applied to the acrylic-modified stucco and covered with additional layers of acrylic modified stucco colored and textured to appear similar to traditional cement-stucco finishes.
- **Traditional 3 coat stucco** Exterior finish treatment made up of three stucco-cement layers (scratch coat, brown coat, finish coat) and a layer of metal lath which is fastened through a layer of building paper, housewrap or stuccowrap to the wall sheathing.
- **Economy 2 coat stucco** Exterior finish treatment made up of two stucco-cement layers (brown coat, finish coat) and a layer of metal lath which is fastened through a layer of building paper, housewrap or stuccowrap to the wall sheathing.
- **Water managed wall with rainscreen** An exterior wall design that employs a pressure-equalizing void behind the siding in combination with an air-pressure barrier (usually tape-sealed exterior sheathing) covered with building paper or housewrap and having flashings at wall openings and vapor management layers designed to dry the wall to the outside, inside or either side depending on the climate in the specific location of the house.
- **Face-sealed wall** An exterior wall design that employs a network of chemical sealants (urethane, acrylics, acrylized silicones, or silicones) at every material change, at the perimeter of every opening in the wall, and at every change in the plane of the wall in an effort to completely seal the wall from penetration by rain or thawing snow.
- **Water managed wall without rainscreen** An exterior wall design that employs siding fastened through building paper or housewrap to the sheathing below. These walls have flashings at wall openings and vapor management layers designed to dry the wall to the outside, inside or either side depending on the climate in the specific location of the house.
- **Non-woven, non-perforated housewrap** A polymeric sheet without perforations intended to prevent air and bulk moisture infiltration through the exterior wall.
- **Perforated housewrap** A polymeric sheet with perforations intended to prevent air and bulk moisture infiltration through the exterior wall while allowing moisture within the wall to dry to the outside.
- **Woven housewrap** A polymer fiber (olefin) into a sheet attached to the exterior face of the sheathing to reduce air and bulk moisture infiltration while allowing the wall to dry to the exterior.
- **Water managing housewrap** Housewrap sheets, either woven or nonwoven wrinkled, deformed, or including filaments intended to conduct water from behind the siding to flashings below to drain the water out of the wall.

- **Asphalt-impregnated building paper** Paper or felt rolls impregnated with asphalt to increase water resistance. The measure of resistance is typically associated with the amount of asphalt retained in the paper/felt substrate measured in weight per 100 square feet of material. 15 pound felt and 30 pound felt is commonly used in residential construction.
- **Kraft paper** High strength paper made from unbleached kraft pulp and recycled content.
- **Sealed exterior gypsum sheathing** Gypsum sheathing with tape sealed joints on the outside face of the sheathing.
- **Glass batt in stud cavity-unfaced** An insulation strategy using spun-glass fibers assembled into low, medium or high-density slabs or batts (batting) without any facing layer, friction fit between wall studs.
- **Glass batt in stud cavity-foil faced** An insulation strategy using spun-glass fibers assembled into low, medium or high-density slabs or batts (batting) with a thin foil facing layer held between the wall studs by both friction and a flange stapled to the face of the stud.
- **Glass batt in stud cavity-paper faced** An insulation strategy using spun-glass fibers assembled into low, medium or high-density slabs or batts (batting) with a thin asphalt impregnated kraft paper facing layer held between the wall studs by both friction and a flange stapled to the face of the stud.
- **Glass batt in stud cavity with extruded polystyrene board sheathing** An insulation strategy using An insulation strategy using spun-glass fibers assembled into low, medium or high-density slabs or batts (batting) without any facing layer, friction fit between wall studs and a layer of extruded polystyrene (XPS) on the outside of the wall to reduce conductive losses through the studs and keep the batt insulation warm enough to prevent condensation within the batt insulation.
- **Glass batt in stud cavity with foil faced polyiso board sheathing** An insulation strategy using An insulation strategy using spun-glass fibers assembled into low, medium or high-density slabs or batts (batting) without any facing layer, friction fit between wall studs and a layer of polyisocyanurate (Polyiso) on the outside of the wall to reduce conductive losses through the studs and keep the batt insulation warm enough to prevent condensation within the batt insulation.
- **Sprayed on Icynene** An insulation strategy using a foamed-in-place insulation and air barrier (PolyIcynene) which expands and overfills the stud cavity and is trimmed flush with the stud faces.
- **Mineral fiber batt or fill** An insulation strategy using loose-filled or batts of mineral fibers made from rock, slag, or glass.
- **Spray-on polyurethane** An insulation strategy using a foamed-in-place insulation and air barrier (Polyurethane) which expands and overfills the stud cavity and is trimmed flush with the stud faces.
- **Blown-in fiberglass** An insulation strategy using spun-glass fibers blown into cavities between wall studs.
- **Dense-pack cellulose** An insulation strategy using up to 80% post-consumer recycled newsprint treated for fire and insect resistance sprayed or blown under pressure into stud cavities to pack the cellulose and achieve higher thermal resistance values.



- **Poly sheet barrier** An air and vapor barrier formed by applying 4 or 6 mil thick polyethylene sheet to the inside face of the wall studs.
- **Vapor-retarding latex paint** A vapor control strategy using specially formulated latex paint applied in specified mil thicknesses to form a vapor barrier at the inside surfaces of the walls and ceilings.
- **Vinyl wall covering** A vapor control strategy depending upon vinyl wall covering applied to the exterior walls to prevent the migration of water vapor into the exterior wall.
- **Kraft paper** A vapor control strategy depending upon a layer of kraft paper applied to the interior face of the studs to act as a wick/reservoir and allow the wall to dry to either the interior or exterior.
- **Smart vapor retarder** A vapor control strategy using polyimide film with pores capable of opening to allow the wall cavity to dry when exposed to high humidity levels and closing to reduce air infiltration when humidity drops.
- **None** No method of controlling vapor transmission into the wall is used.
- **Field applied bituthene sheet** A self-adhesive cold-applied composite sheet consisting of rubberized asphalt laminated to a polyethylene film to provide a waterproof flashing at door and window openings
- **Field fabricated metal** A set of head, jamb and sill flashing formed on-site from light gauge aluminum or steel.
- **Prefabricated metal** A set of head, jamb and sill flashing preformed off-site from light gauge aluminum or steel.
- **Prefabricated plastic** A set of head, jamb and sill flashing preformed off-site from polyethylene, pvc or acrylic plastic.
- **Tape-sealed nailing flange** A flashing technique depending upon a taped joint between the housewrap and nailing flange to prevent water intrusion
- **None** No mechanical or tape flashing is employed to prevent water intrusion at doors and windows.
- **Building Paper** A flashing technique using overlapping layers of asphalt impregnated building felt or paper to prevent water intrusion at door and window openings.
- **Asphalt shingles** A roofing material made of strips of fiberglass reinforced asphalt covered in small aggregate and laid in overlapping patterns to prevent water intrusion through the roof.
- **Wood shingle** A roofing material made up of strips of cedar, cypress or redwood laid in overlapping layers to prevent water intrusion through the roof.
- **Prefinished metal** A roofing material made from coil-stock of aluminum or steel either site or preformed into "pans" extending from ridge to eave and being joined side to side with overlapping interlocking joints
- **Clay or cement tile** A roofing material wherein fired clay or concrete tiles 13 to 18 inches in length and 9 to 12 inches in width are laid in overlapping patterns to prevent water intrusion through the roof

- **Single-ply membrane** A roofing system made up of a single layer .045, .060 or .090 mil thick Ethylene Propylene Diene Monomer rubber-like sheet held to the roof with rounded stones (ballast) glue (fully adhered) or mechanically fastened with screws.
- **Built-up roofing** A roofing system made up of overlapping layers of fiberglass reinforced felts mopped in molten asphalt to provide a multilayer membrane that is heat bonded to the roof and covered with small aggregate.
- **Bituthene sheet** A self-adhesive cold-applied composite sheet consisting of rubberized asphalt laminated to a polyethylene film to provide a waterproof flashing below roof valleys and at the building eaves.
- **Hot-mopped roofing felt** A layer of fiberglass reinforced felt hot mopped in asphalt below the valleys and along the eaves.
- **Building paper** An additional layer of asphalt impregnated building felt or paper stapled to the roof sheathing below roof valleys and along the eave edge.
- **None** No additional protection at roof valleys or eaves against ice damming leaks.
- **Bituthene sheet** A self-adhesive cold-applied composite sheet consisting of rubberized asphalt laminated to a polyethylene film to provide a waterproof secondary membrane below the roof shingles or prefinished metal roof.
- **Hot-mopped roofing felt** A layer of fiberglass reinforced felt hot mopped in asphalt to provide a waterproof secondary membrane below the roof shingles or prefinished metal roof.
- **Building paper** Paper or felt rolls impregnated with asphalt to increase water resistance. The measure of resistance is typically associated with the amount of asphalt retained in the paper/felt substrate measured in weight per 100 square feet of material. 15 pound felt and 30 pound felt is commonly used in residential construction. This layer is stapled or nailed to the roof sheathing to provide a waterproof secondary membrane below the roof shingles or prefinished metal roof.
- **None** No secondary membrane below the roof shingles or prefinished metal roof.
- **Blown fiberglass** An attic insulation strategy using spun-glass fibers blown into the attic and compacted with a 6 inch thick fiberglass batt to prevent windwashing through the insulation.
- **Blown mineral fiber** An attic insulation strategy using loose mineral fibers made from rock, slag, or glass blown into the attic to reduce heat loss.
- **Blown cellulose** An attic insulation strategy using up to 80% post-consumer recycled newsprint treated for fire and insect resistance sprayed or blown under pressure into the attic to reduce heat transmission through the attic.
- **Glass batts** An attic insulation strategy using spun-glass fibers assembled into low, medium or high-density slabs or batts (batting) without any facing layer, friction fit between and above ceiling joists in the attic.
- **Mineral fiber batts** An attic insulation strategy using mineral fibers formed into slabs or batts made from rock, slag, or glass placed between and over attic ceiling joists to reduce heat loss.

- **EPS SIP** Structural Insulated Panels (SIPS). A panelized form of construction where the roof panel includes expanded polystyrene (EPS) thermal insulation as an integral part of the panel structure. In wood SIPS panels, the insulation performs a structural role, bracing the oriented strand facing panels against lateral deflection.
- **XPS SIP** Structural Insulated Panels (SIPS). A panelized form of construction where the roof panel includes extruded polystyrene (XPS) thermal insulation as an integral part of the panel structure. In wood SIPS panels, the insulation performs a structural role, bracing the oriented strand facing panels against lateral deflection.
- **Polyiso SIP** Structural Insulated Panels (SIPS). A panelized form of construction where the roof panel includes polyisocyanurate (polyiso) thermal insulation as an integral part of the panel structure. In wood SIPS panels, the insulation performs a structural role, bracing the oriented strand facing panels against lateral deflection.
- **Glass batts** An insulation strategy using spun-glass fibers assembled into low, medium or high-density slabs or batts (batting) with or without a facing layer, friction fit between cathedral ceiling framing.
- **Mineral fiber batts** An insulation strategy using mineral fibers made from rock, slag, or glass fibers assembled into low, medium or high-density slabs or batts (batting) with or without a facing layer, friction fit between cathedral ceiling framing.
- **Sprayed on Icynene** An insulation strategy using a foamed-in-place insulation and air barrier (PolyIcynene) which expands and overfills the cathedral roof joist cavity and is trimmed flush with the joist faces.
- **None** No insulation placed in the cathedral ceiling
- **Eave to ridge - no chutes** An attic ventilation strategy where air moves from vents in the eave overhang soffit up past the edge of the ceiling/attic insulation and out through a vent at the roof ridge.
- **Eave to ridge - preformed chutes** An attic ventilation strategy where air moves from vents in the eave overhang soffit through preformed plastic or cardboard chutes fastened to the roof sheathing at the roof wall intersection to insure that ceiling attic insulation will not obstruct airflow from the eave soffit vents up past the edge of the ceiling/attic insulation and out through a vent at the roof ridge.
- **Power vents - temperature controlled** An attic ventilation strategy where air movement is controlled by a powered fan and louver inlets activated by a preset thermostat to vent the attic at and above certain attic air temperatures.
- **Gravity vent** An attic ventilation strategy dependent on the natural convection of air moving in through eave vents and out through ridge vents to ventilate the attic.
- **Gravity vent cold roof** An attic ventilation strategy dependent on the natural convection of air moving in through eave vents and out through ridge vents in an additional attic/joist space layered above the enclosed attic to keep the underside of the roof surface at or near the outdoor air temperature.
- **Power vent** An attic ventilation strategy where air movement is controlled by a powered fan and louver inlets to vent the attic when activated.
- **None** No attic ventilation strategy

- **Prefabricated metal** Edge, Valley, Ridge flashing formed offsite from aluminum, steel or copper
- **Site-formed membrane** Edge, Valley, Ridge flashing formed onsite from elastomeric membrane
- **Site fabricated metal** Edge, Valley, Ridge flashing formed onsite from aluminum, steel or copper
- **Preformed plastic** Edge, Valley, Ridge flashing formed offsite from plastic materials
- **Glass batts** A floor insulation strategy using spun-glass fibers assembled into low, medium or high-density slabs or batts (batting) without any facing layer, friction fit or supported by netting or wire between floor joists.
- **Mineral fiber batts** A floor insulation strategy using mineral, slag or glass fibers assembled into low, medium or high-density slabs or batts (batting) without any facing layer, friction fit or supported by netting or wire between floor joists.
- **Blown fiberglass** An floor insulation strategy using glass fibers blown into the floor joist cavity.
- **Blown mineral fiber** An floor insulation strategy using fibers made from minerals, slag or glass blown into the floor joist cavity.
- **Sprayed on Icynene** An floor insulation strategy using a foamed-in-place insulation and air barrier (Polyicynene) which expands and overfills the floor joist cavity and is trimmed flush with the joist faces.
- **Spray-on polyurethane** An floor insulation strategy using a foamed-in-place insulation and air barrier (Polyurethane) which expands and overfills the floor joist cavity and is trimmed flush with the joist faces.
- **None** No floor insulation strategy
- **Poly sheet** A vapor management strategy placing a polyethylene sheet on either the interior or exterior face of the insulation to prevent moisture from passing into or condensing within the insulation.
- **Building paper** A vapor management strategy placing a asphalt impregnated felt sheet on either the interior or exterior face of the insulation to retard the movement of moisture vapor into the insulation.
- **None** No vapor management strategy
- **Site framed wood** Interior non-loadbearing partitions constructed from wood studs onsite.
- **Prefabricated wood** Interior non-loadbearing partitions constructed from wood studs offsite.
- **Site framed light gauge steel** Interior non-loadbearing partitions constructed from cold rolled steel studs onsite.
- **Prefabricated light gauge steel** Interior non-loadbearing partitions constructed from cold rolled steel studs onsite.
- **Masonry** Interior non-loadbearing partitions constructed from brick or concrete masonry onsite.
- **Plaster** Gypsum or Portland cement applied to lath or masonry in a two or three step process to form both wall substrate and finish.
- **Drywall** A panel of compressed gypsum with paper surface on each side nailed, screwed or glued to masonry, wood or metal studs.
- **Reduced-cellulose drywall** A panel of compressed gypsum with treated paper or non-cellulose (glass-fiber) surface meeting or exceeding ASTM D3273 on each side nailed, screwed or glued to masonry, wood or metal studs.

- **Drywall over engineered wood (SIPS, OSB, plywood)** A panel of compressed gypsum with paper surface on each side nailed, screwed or glued to directly to the surface of the Structural Insulated Panel (SIP)
- **Masonry** Exterior or interior walls constructed from brick or concrete masonry onsite onto which a finish material is installed.
- **ICF** A wall substrate constructed with Insulated Concrete Formwork (ICF). A method of construction using concrete formed in expanded or extruded polystyrene forms which remain in place after concrete curing to make the integrate insulation into the concrete walls of the house.
- **1 latex primer + 1 finish latex** Interior surface of exterior walls having been sprayed, rolled or brushed with one coat of latex paint primer (3.5-3.9 mil thickness wet) and one finish coat of latex paint (4 mils wet).
- **1 latex primer + 2 finish latex** Interior surface of exterior walls having been sprayed, rolled or brushed with one coat of latex paint primer (3.5-3.9 mil thickness wet) and two finish coats of latex paint (ea 4 mils wet).
- **Vinyl wall covering** Interior surface of exterior walls covered with with adhesive-attached colored and/or patterned vinyl sheet sheets having a permeability rating of 1 or less.
- **Wood veneer paneling** Interior surface of exterior walls covered with wood veneered paneling having an mdf, wheatstraw, or other wood composite substrate.
- **Ceramic tile** Interior surface of exterior walls with asphalt impregnated building felt covered with a one or two coat mortar base to bond a glazed, fired clay tile to the wall surface.
- **None** No interior surface finish at the exterior walls
- **1 latex primer + 1 finish latex** Surface of interior walls having been sprayed, rolled or brushed with one coat of latex paint primer (3.5-3.9 mil thickness wet) and one finish coat of latex paint (4 mils wet).
- **1 latex primer + 2 finish latex** Surface of interior walls having been sprayed, rolled or brushed with one coat of latex paint primer (3.5-3.9 mil thickness wet) and two finish coats of latex paint (ea 4 mils wet).
- **Vinyl wall covering** Surface of interior walls covered with with adhesive-attached colored and/or patterned vinyl sheet sheets having a permeability rating of 1 or less.
- **Wood veneer paneling** Surface of interior walls covered with wood veneered paneling having an mdf, wheatstraw, or other wood composite substrate.
- **Ceramic tile** Surface of interior walls with asphalt impregnated building felt covered with a one or two coat mortar base to bond a glazed, fired clay tile to the wall surface.
- **None** No interior surface finish at the interior walls
- **Particle board** Nonstructural subfloor underlayment made of coarse sawdust mixed with resins and pressed into sheet form.
- **OSB** Structural subfloor made of wood chips compressed into mats in an adhesive matrix. A sheet of OSB will often have three or more mats with strand orientation alternated between mats for additional panel stability and structural capacity.

- **Plywood** Structural subfloor made of layers of wood veneer glued together in 5 to 7 ply sandwiches where the wood grain direction is alternated between plys to enhance panel stability and structural capacity.
- **Cement board** Nonstructural subfloor made of a thin sheet of fiber or mesh-reinforced cement typically used where stone or ceramic tile finished floors are desired.
- **Concrete** Structural or nonstructural slab of cement-sand-aggregate mix reinforced with steel bars, welded wire mesh, or glass/plastic fibers, cast on site.
- **Self-leveling gypsum topping** Nonstructural subfloor made of a thin slab of gypsum, poured as a self-leveling slurry to enhance the flatness, acoustic separation, and fire resistance of a wood, steel, or concrete floor assembly.
- **Pad and carpet** A foam pad laid over the subfloor between perimeter tackless strips over which the carpet is stretched over to anchor it.
- **Direct-glued carpet** Carpet directly adhered to the subfloor or slab with an adhesive
- **Vinyl sheet goods** A thin sheet of colored, patterned and/or embossed vinyl, delivered as a roll, loose-laid with perimeter anchorage.
- **Vinyl tile** Tiles of vinyl or vinyl composite materials with either self-adhesive backing or are laid in a bed of trowled-on adhesive.
- **Ceramic tile** Glazed or unglazed fired-ceramic tiles either thinset in an adhesive-mortar bed or thickset in a cement mortar bed with grouted joints.
- **Hardwood - solid** Strips of solid-sawn hardwoods, usually with tongue and grooved edges to conceal nailed fasteners.
- **Hardwood - veneer** Strips of hardwood veneer adhered to a composite wood substrate either glued or mechanically locked along the perimeter edge of the strip.
- **Plastic laminate** Strips of plastic laminate imprinted with a color/pattern adhered to a composite wood substrate either glued or mechanically locked along the perimeter edge of the strip.
- **Plaster** Gypsum or Portland cement applied to lath or masonry in a two or three step process to form both ceiling substrate and finish.
- **Drywall** A panel of compressed gypsum with paper surface on each side nailed, screwed or glued to wood or metal joists.
- **Reduced-cellulose drywall** A panel of compressed gypsum with treated paper or non-cellulose (glass-fiber) surface meeting or exceeding ASTM D3273 on each side nailed, screwed or glued to wood or metal joists.
- **Wood deck or panel** Solid sawn or laminated wood decking nailed to the upper surface of the ceiling or roof joists or trusses so as to expose the roof structure to the room's interior.
- **None** No ceiling substrate
- **1 latex primer + 1 finish latex** Surface of the ceiling having been sprayed, rolled or brushed with one coat of latex paint primer (3.5-3.9 mil thickness wet) and one finish coat of latex paint (4 mils wet).
- **1 high-build primer / finish coat** Integrated primer/finish paint process typically sprayed or rolled on in a single layer 4 to 20 mils thick (wet)

- **Lay-in tile** Wood or mineral fiber panels laid into a metal tee-bar or z-spline grid.
- **None** No ceiling finish
- **Plastic laminate** Countertops made of plastic laminate bonded to a substrate supported by the cabinets.
- **Stone** Countertops made of granite, marble or other stone bonded to a substrate supported by the cabinets.
- **Cultured stone** Countertops with integral sinks made of granite, marble or other stone particles in a resin binder bonded to a substrate supported by the cabinets.
- **Soild cast acrylic-plastic** Countertops with integral sinks made of a single casting or molding of plastic supported by the cabinets.
- **Ceramic tile** Countertops made of glazed or unglazed fired ceramic tile in a mortar bed bonded to a substrate supported by the cabinets.
- **Metal** Countertops made of stainless steel supported by the cabinets.
- **Concrete** Countertops made of polished sitecast or precast concrete supported by the cabinets.
- **Milled wood** Interior trim planed or shaped from solid sawn or finger-jointed solid-sawn wood.
- **Milled or formed wood composite** Interior trim made of coarse wood sawdust in an adhesive binder formed or milled into trim profiles.
- **PVC** Interior trim made of polyvinyl chloride plastic
- **Other plastic** Interior trim made from plastics other than pvc.
- **Prefabricated - milled wood** Pre-manufactured cabinets made from planed or shaped from solid sawn or finger-jointed solid-sawn wood.
- **Prefabricated - engineered wood** Pre-manufactured cabinets made from coarse wood sawdust in an adhesive binder formed or milled into trim profiles.
- **Custom fabricated - milled wood** Cabinets made from planed or shaped from solid sawn or finger-jointed solid-sawn wood specifically for this house.
- **Custom fabricated - engineered wood** Cabinets made from coarse wood sawdust in an adhesive binder formed or milled into trim profiles specifically for this house.
- **Plumber-installed** Gas appliance, supply, and vent line installed by a licensed plumber.
- **Builder-installed** Gas appliance, supply or vent line installed by the builder who is not specifically licensed for this work.
- **Owner-installed** Gas appliance, supply or vent line installed by the homeowner who is not licensed for this work.
- **Third-party-tested** Gas appliance, supply or vent line tested by a third-party who specializes in inspection and detection of improperly installed gas lines, gas appliances and vents.
- **By builder** Home appliances supplied and installed as part of the builder's contract.
- **By owner** Home appliances supplied and installed by the owner outside of the builder's contract.

- **Bundled-weaved together based on schedule A** "first-come-first-served" approach to planning and installing ductwork, piping and wiring where each subcontractor installs their work by adapting to the work-in-place.
- **Unbundled-each subsystem has designed place** A planned approach to the location of ducts, pipes and wiring that separates each system vertically and/or horizontally to minimize initial installation conflicts and simplify maintenance or change.
- **Hybrid-system trunks in designed places, distribution woven A** planned approach to the location of ducts, pipes and wiring that separates the main trunk ducts and feeder piping, but leaves the location and routing of the smaller distribution piping up to the onsite installers.
- **Site fabricated trunks and feeders** A production approach utilizing field fabricated trunk ducts and main water/sewer piping.
- **Prefabricated trunks and feeders** A production approach utilizing prefabricated trunk ducts and main water/sewer piping.
- **Hybrid, prefabricated trunks, site fabricated distribution** A production approach utilizing offsite prefabrication of trunk ducts and main water/sewer piping with onsite fabrication of distribution ducts and piping.
- **All in unconditioned spaces** Ductwork located in unconditioned attics, crawlspaces, or basements.
- **All in conditioned spaces** Ductwork is located in within the thermal envelope of the house (not unconditioned attics, crawlspaces or basements).
- **In conditioned and unconditioned spaces** Ductwork is located in both heated/cooled spaces and unheated/uncooled spaces of the house.
- **In unconditioned space** Air handling unit is located in an unheated and uncooled space.
- **In conditioned space** Air handling unit is located in a heated and cooled space.
- **In garage** Air handling unit is located in the garage.
- **Site formed metal** Ductwork is fabricated onsite from light gauge metal.
- **Site formed ductboard** Ductwork is fabricated onsite from insulated ductboard.
- **Flexduct - insulated** Ductwork is fabricated from insulated flexible ductwork.
- **Flexduct - uninsulated** Ductwork is fabricated from uninsulated flexible ductwork.
- **Prefabricated metal** Ductwork of fabricated offsite from light gauge metal.
- **Prefabricated ductboard** Ductwork is fabricated offsite from insulated ductboard.
- **Conduit** Electrical lighting and power circuits are routed through a site fabricated system of plastic or metal piping.
- **Romex** Electrical lighting and power circuits are made using a proprietary assembly of two or more insulated wires wrapped in a plastic sheath.
- **Wiring harness** Electrical lighting and power circuits are prefabricated wiring assemblies designed and fabricated for this specific house.



- **Category 5/6** An integrated approach to fabricating the communication network using a cable comprised of 4 twisted pairs of copper wire meeting the ANSI/TIA/EIA 568A-5 standard.
- **Separate wiring for each system** A communication network comprised of individual wiring for individual communications systems.
- **On grid** The house receives all of the electricity from the local utility system.
- **Self - PV generation** The house generates all of its electrical energy from photovoltaic cells and often stores a surplus amount for use periods when sunlight is not available.
- **Self - wind generation** The house generates all of its electrical energy from a wind turbine or turbines and often stores a surplus amount for use periods when wind power is not available.
- **Self - gas or propane generator** The house generates all of its electrical energy from a gasoline or propane powered generator.
- **Hybrid on-grid and self-generation** The house utilizes self generation when possible and operates with local electrical utility power when self generation is not possible.
- **Designed by lighting engineer** The house lighting systems is designed by an engineer specializing in selection, sizing, and placement of the lighting system components.
- **Designed by electrical engineer** The house lighting systems is designed by an electrical engineer.
- **Designed by architect** The house lighting systems is designed by an architect.
- **Designed by supplier** The house lighting systems is designed by an electrical fixture supplier.
- **Designed by installer** The house lighting systems is designed by the electrician for the house.
- **Incandescent** A lighting source using a filament within a vacuum that emits light as a result of being heated. This lighting source casts a yellowish "warm" light.
- **Compact fluorescent** A lighting source producing light by illumination of a phosphor coating on the inside of a glass tube by gas-produced ultraviolet radiation. The tube is twisted to fit in most light fixtures designed for incandescent bulbs and can be specified to produce "cool" light in the blue part of the lighting spectrum or "warm" light in the yellow-orange part of the lighting spectrum.
- **Low voltage** A lighting source using quartz lamps powered by 12-24 volts requiring a transformer to reduce the voltage from the typical 110-120v power within the home.
- **All in conditioned spaces** All water supply and waste piping is located in unheated and uncooled spaces.
- **In conditioned and unconditioned spaces** Water supply and waste piping is located in both heated and cooled as well as unheated and uncooled spaces.
- **Copper** Hot and cold water is supplied through copper piping.
- **Polyisobutylene** Hot and cold water is supplied through a piping made of polyisobutylene solvent welded or crimp-connected to fittings and valves made of acetol.

- **PVC** Cold water and waste piping fabricated with chemically welded segments of polyvinyl chloride pipe.
- **CPVC** Cold water and waste piping fabricated with chemically welded segments of chlorinated polyvinyl chloride pipe capable of withstanding higher temperatures.
- **PEX** Potable water and waste pipling fabricated with extruded cross-linked high density polyethylene
- **All insulated** Both hot and cold water supply piping is thermally insulated.
- **Hot water only insulated** Only hot water supply piping is thermally insulated.
- **No insulation** No potable water supply piping is insulated.
- **Within partitions** Drain lines are located within partitions.
- **Directly to subgrade** Drain lines are routed directly to subgrade.
- **PVC** Drain lines are fabricated from Polyvinyl chloride.
- **Iron** Drain lines are fabricated from cast or ductile iron.
- **Municipal** The local municipal water service supplies potable water to the house.
- **Private well** Potable water for the house is provided by the homeowner's well.
- **Purchased service** Potable water for the house is purchased from a private provider.
- **None** Potable water is not treated by the house system before use.
- **Filtered** Potable water is filtered by the house system before use.
- **Softened** Calcium and Magnesium ions are removed or their numbers reduced by substituting sodium ions.
- **None** No potable or nonpotable water is stored.
- **Cistern** Rainwater is collected and stored for nonpotable uses.
- **Municipal** Wastewater produced by the house is piped to a municipal utility that treats and disposes the wastewater.
- **Septic system** Wastewater produced by the house is stored, treated through bacterial action and released in a diffused drainfield back into the environment.
- **Storage tank** Wastewater produced by the house is stored in a tank and periodically pumped out and transported to an offsite facility for treatment and release into the environment.
- **Greywater recovery** Wastewater recovered and stored from bathroom sinks, showers and laundry for use in toilet flushing and gardening. Greywater is distinguished from blackwater which contains sewage from toilets.
- **Central system** An approach to thermal conditioning of the house which has a central furnace and or airconditioner which conditions and distributes the air to various rooms through ductwork. An alternative is a central boiler or water heater that distributes hot water to radiant panels or radiators through piping.
- **Room by room conditioning** An approach to thermal conditioning of the house which involves the use of discrete heating and or cooling units within each room.
- **Through the wall units** An approach to thermal conditioning which uses a combination heating and cooling unit placed through the wall which allows heat rejection to the outside in cooling mode and ventilation to the inside during heating or cooling mode.

- **Window units** An approach to thermal conditioning, primarily used for cooling, where a small cooling (air conditioning) unit is placed in a window opening to provide local cooling. Often these window air conditioners are only in place during the cooling season and are removed during the heating season.
- **Gas fired boiler or water heater** A central water heating source that uses a burner consuming natural or propane gas to raise the temperature of water to distribute either steam, in the case of a boiler, or hot water.
- **Oil fired boiler or water heater** A central water heating source that uses a burner consuming #2 fuel oil to raise the temperature of water to distribute either steam, in the case of a boiler, or hot water.
- **Electric boiler or water heater** A central water heating source that uses an electrical heating element or elements to raise the temperature of water to distribute either steam, in the case of a boiler, or hot water.
- **Gas hot air furnace** A central heating system using a burner fired by natural gas or propane to heat air which is then circulated through ductwork to provide space heating.
- **Oil hot air furnace** A central heating system using a burner fired by #2 heating oil to heat air which is then circulated through ductwork to provide space heating.
- **Electric hot air furnace** A central heating system using an electrical heating element to heat air which is then circulated through ductwork to provide space heating.
- **Ground coupled electric heat pump** A central heating system using a heatpump to extract heat from air which has been drawn from a network of pipes buried below ground deep enough to reach soil which maintains a constant temperature near 50 degrees fahrenheit. When the heat pump can deliver air at the thermostat demanded temperature, heated air is then circulated through ductwork to provide space heating.
- **Air source electric heat pump** A central heating system using a heatpump to extract heat from outdoor air. When the heat pump can deliver air at the thermostat demanded temperature, heated air is then circulated through ductwork to provide space heating. When sufficient heat cannot be extracted from outdoor air, the heat pump switches on an electrical heating element to raise the delivered air temperature to match the demanded air temperature.
- **Straight cooling w/ electric baseboard heat** A central cooling system utilizing either a traditional compressor/condensor system or an evaporative cooling system which distributes cooled air through ductwork providing local cooling. Heating is provided through distributed baseboard electric heaters controlled on a room-by-room basis.
- **Central forced air** A central cooling system utilizing either a traditional compressor/condensor system or an evaporative cooling system which distributes cooled air through ductwork providing local cooling.

- **Split system** A central cooling system utilizing an interior cooling coil integrated into the central furnace/air handler and an exterior compressor/condensor unit where refrigerant is converted from fluid to gas within a closed network of pipes releasing heat to the exterior. Another form of the split system is the mini-split which uses an indoor integrated fan/coil/thermostat connected by copper pipe to an exterior compressor/condensor unit which rejects heat to the outside air.
- **Window unit** A combined compressor/condensor/fan cooling device seasonally placed in window openings to provide local cooling.
- **Through wall unit** A combined compressor/condensor/fan cooling device permanently placed in a sleeve through the wall to provide local cooling.
- **Whole house exhaust fan** A centrally located exhaust fan and damper that can be controlled by timer or thermostat to draw cool air in through lower-floor windows and exhaust the air into or through the attic to the outdoors.
- **Fiberglass filter** A coated fiberglass matt designed to remove large particles from the return airstream.
- **Pleated filter** A filter element, polyester or other fabric, folded in a series of "V" shaped pleats, often 3/4" to 1" deep, to increase the surface area of the filter while the change from coated glass fibers to fabric results in filtering out smaller sized particles from the return air stream.
- **Deep pleated media** A filter element, polyester or other fabric, folded in a series of "V" shaped pleats, often 1" to 2" deep, to increase the surface area of the filter while the change from coated glass fibers to fabric results in filtering out smaller sized particles from the return air stream.
- **Electronic** An air filtration strategy which uses replaceable filters to trap large particles out of the airstream, then passes the airstream over a negatively charged set of wires to negatively charge remaining particles and trap them in a positively charged cleanable/replaceable filter grid. Effective at trapping particles less than 2 microns (smaller than what can pass through the lungs into the bloodstream).
- **None** No air filtration strategy.
- **Under slab barrier** An approach to mitigating the presence of radon in the surrounding soils by placing a 6 mil polyethylene sheet (6 inch sealed overlaps between sheets) below the slab to act as a barrier to radon entry. The poly sheet is often extended up past the edge of the slab to simplify sealing the joint between slab membrane and sidewall.
- **Foundation / sump sealing** An approach to mitigating the presence of radon in the surrounding soils by sealing any penetration of the slab and membrane with a pourable urethane sealant to make an airtight seal between the sump and building interior.
- **Passive ventilation** An approach to mitigating the presence of radon in the surrounding soils by placing footing drain piping material below the slab in close intervals and connecting this piping to a vertical pipe extending through the roof of the house, venting the radon gases to the outside air.

- **Active sub-slab depressurization** An approach to mitigating the presence of radon in the surrounding soils by placing footing drain piping material below the slab membrane in the subslab sand/gravel/rock cushion and connecting this piping to a vertical pipe with a powered exhaust fan extending through the roof of the house, to form a low pressure zone between the soil and the slab which can collect and vent the radon gases to the outside air while minimizing radon passage into the building's higher air-pressure interior spaces.
- **None** No radon mitigation strategy
- **Stand-alone unit** An approach to dehumidification that employs a separate (fixed or portable) dehumidification unit to provide dehumidification of a space.
- **Whole house** An approach to dehumidification that employs a dehumidifier (often a cooling coil) as a function of the central hvac unit. This provides dehumidification of the return air stream providing generalized dehumidification of the house.
- **None** No dehumidification strategy for the house.
- **Radiant slab water** An approach to the distribution of heat through a fluid medium (water/glycol) distributed through a network of closely-spaced small-diameter piping, often plastic piping that is cast into a concrete slab, attached below wood subflooring or cast into a topping slab to make a diffuse heat source.
- **Hot water radiator** An approach to the distribution of heat through a fluid medium (water/glycol) distributed through a network of large 3/4" to 1 1/2" diameter pipe to a radiator. Often the radiator consists of a section of hot water pipe with thin metal fins attached to increase the heated surface area and enhance the transfer of heat from water to air. A thin metal cover is usually installed over the fin tube section to prevent accidental contact with the hot water pipe.
- **Ducted air distribution** An approach to the distribution of heated or cooled air where the air is pumped by a fan into a trunk or main duct, then through a series of smaller diameter ducts (8"-6") to diffusers which release the heated or cooled air into the room in a prescribed pattern.
- **Non-ducted air distribution** An approach to the distribution of heated or cooled air dependent upon gravity and convection to move the heat or cooled air within a home.
- **Integrated hot water and furnace** A gas, oil, or electric furnace with an integral hot water heating tank.
- **Stand alone hot water heat and storage** A water tank heated by an oil or gas burner or electric heating element to provide a reservoir of domestic hot water.
- **Tankless electric hot water source heaters** An electric water heater that provides hot water on-demand by heating cold water to the desired temperature as it passes through the unit.
- **Tankless gas hot water source heaters** An natural gas or propane water heater that provides hot water on-demand by heating cold water to the desired temperature as it passes through the unit.
- **Solar hot water heat and storage** A water-heating system that circulates a water/glycol mixture through solar hot water collectors to collect heat, then transfers the heat through a heat exchanger immersed in a tank of potable cold water.

- **Heat pump water heater** An electric heat pump that uses indoor air as a source to heat potable water for domestic use. Most have the capability to exhaust the cool air (after the heat pump extracts the heat and transfers it to the water the air is cooled and dried) to the exterior. Should be located in rooms with good air circulation, tends to dehumidify air as it runs.
- **Perimeter diffuser locations** Air diffusers located at the outside edges of the space adjacent to the exterior wall.
- **Core diffuser locations** Air diffusers located at the interior walls of spaces.
- **Zoned** A control strategy that divides a building into zones based on thermal needs or occupancy patterns so a space on the east side of a building could be calling for cooling in the morning, while simultaneously, the space on the west side receives cooling.
- **Programmable thermostat** A thermostat that can be programmed to reduce the temperature on certain days at certain times and raise the temperature at certain times on certain days.
- **Time delay relay** An electrical device that remains on for a set period of time once it has been activated.
- **Low velocity** An air distribution system designed to supply air in branch distribution ducts at 600 feet per minute or less.
- **High velocity** An air distribution system designed to supply air in branch distribution ducts at 800 feet per minute.
- **Ultra high velocity** An air distribution system designed to supply air in branch distribution ducts at 1,000 feet per minute.
- **Pressure-reducing** An air diffuser that reduces high velocity air entering the diffuser from 1,000 fpm to 600 fpm or less.
- **Point** An air diffuser that supplies air equally from a central point in the circular or square diffuser.
- **Linear** An air diffuser that supplies air equally along a linear outlet.
- **Fully ducted returns from each space** A return air strategy which has separate ducts leading from each space supplied with air back to the air handling unit.
- **Central ducted return** A return air strategy which uses a single return air grille, usually in a centrally located space in the house.
- **Ducted return for each floor served** A return air strategy which uses a single return air grille on each floor of the house. Each floor's return air grille is usually in a centrally located space.
- **Panned joist return duct** A method for forming return air paths that involves panning or applying a flat metal plate to the lower edge of the joists to form a duct.
- **Wall cavity return duct** A method of return air ducting which uses the stud cavities in interior walls as return air ducting by cutting openings through the top and bottom plates to provide a clear path for return air.
- **Continuous supply ventilation** An approach to ventilation uses fans to continuously introduce air from a fresh air inlet.
- **Supply vent only when AHU runs** An approach to ventilation that exhausts a proportion of returned air and replaces it with air drawn from a fresh air inlet each time the air handling unit runs.
- **Exhaust-driven makeup air** An approach to ventilation that replace air exhausted from the house with air drawn from a fresh air inlet each time the air handling unit runs.

- **Balanced with heat recovery** A separately ducted ventilation system using a fan-powered exhaust airflow that is equally matched to a fan-powered supply airflow through a heat exchanger to preheat incoming air in the winter and precool incoming air in the summer.
- **Balanced with no heat recovery** A separately ducted ventilation system using a fan-powered exhaust airflow that is equally matched to a fan-powered supply airflow.
- **Balanced with energy recovery** A separately ducted ventilation system using a fan-powered exhaust airflow that is equally matched to a fan-powered supply airflow through a heat and moisture exchanger. In the heating system, heat and moisture are transferred to the incoming air, during the cooling season heat and water vapor from the incoming air stream are transferred to the exhaust air stream.
- **Timed supply ventilation** An approach to ventilation where a timer controls the amount of fresh air drawn into the system for conditioning.
- **Timed exhaust ventilation** An approach to ventilation where a timer controls the amount of conditioned air that is exhausted.
- **None** No formal strategy for ventilating the house.
- **Masonry on exterior wall** Traditional brick and firebrick fireplace constructed on an outside wall of the house.
- **Masonry on interior wall** Traditional brick and firebrick fireplace constructed on an interior wall of the house.
- **Metal on exterior wall** Prefabricated metal fireplace assembled on an outside wall of the house.
- **Metal on interior wall** Prefabricated metal fireplace assembled on an interior wall of the house.
- **None** No fireplace
- **Chimney above roof** Fireplace combustion gases are exhausted through a brick, clay tile, or metal flue extending through the roof to a height 2 feet above any point within 12 feet of the chimney.
- **Vented through wall** Fireplace combustion gases are exhausted through an exterior sidewall.
- **Ventless gas** Fireplace has no flue or duct to the exterior.
- **Ventless alcohol** Fireplace has no flue or duct to the exterior.
- **Ventless electric** Fireplace has no flue or duct to the exterior.
- **None** No fireplace venting strategy
- **Hood - recirculating** Overhead range hood includes a replaceable filter and recycles air through the filter, no exhaust to the exterior.
- **Hood - exhausting** Overhead range hood exhausts cooking smoke, vapor and smells directly to the exterior.
- **Downdraft** Range hood pulls a powerful draft down from the cooking surface and exhausts the smoke, vapor or smells directly to the exterior.
- **Present** A centrally located vacuum, ducted to outlets distributed around the house so that one only needs to carry the hose and attachments and plug in to vacuum dust and debris into the central vacuum cannister.
- **None** No central vacuum.