building science.com
© 2006 Building Science Press All rights of reproduction in any form reserved.

Community-Scale Evaluation Results

Research Report - 0405
2004
Building Science Corporation

Abstract:

Using four Building Science Consortium Building America community-scale projects, this paper investigates the nature, strength, and durability of connections between high performance dwellings and developments. There are few inherent or natural links between the two (particularly in the production home setting); the connections must be either imposed (by government entities) or created in the marketplace. Because communities often involve two very distinct players—the developer and the builders—and the project often spans up to 10 years, it is challenging to develop and sustain either an imposed or marketed system with strong and meaningful links between high performance homes and neighborhoods.

COMMUNITY-SCALE EVALUATION RESULTS

ABSTRACT

Using four Building Science Consortium Building America community-scale projects, this paper investigates the nature, strength, and durability of connections between high performance dwellings and developments. There are few inherent or natural links between the two (particularly in the production home setting); the connections must be either imposed (by government entities) or created in the marketplace. Because communities often involve two very distinct players—the developer and the builders—and the project often spans up to 10 years, it is challenging to develop and sustain either an imposed or marketed system with strong and meaningful links between high performance homes and neighborhoods.

An important element in keeping high performance homes and neighborhoods linked is bringing Building America performance criteria into ongoing efforts to develop national green building criteria, at both the building and the development level. Overall, perhaps the most promising approach is to combine certain imposed elements (from the Prairie Crossing and Civano projects) with new quality/value strategies that capture the developer's, the builder's, and the homebuyer's interest. If the developer and the builder have the tools they need to link quality and high performance, the buyer will have no trouble recognizing the value of living in both a home and a community that is lighter on their budget and their environment.

KEY WORDS

Boise, Idaho
Building Science Consortium
Chuck Miller Construction
Civano
Grayslake, Illinois
Green building
Green development
Hidden Springs
High performance
Ladera Ranch, California
Prairie Crossing
Pulte Homes
Quality
Solar energy
Terramor
Tucson, Arizona

INTRODUCTION

It's not hard to find great examples of green developments — the ones with low impact on the local environment and landscape. It's also not that hard to find really great examples of resource- and energy-efficient homes — the ones designed and built for high performance. But what about projects that have accomplished **both**? And just how inherent are the links between resource-efficient development and structures?

As part of the Department of Energy's Building America program,[1] the Building Science Consortium (BSC) works with production builders nationwide on the design, construction, and commissioning of high performance homes (see side bar). This paper is about BSC evaluation of four of its community-scale projects, searching for the nature, strength, and durability of the connections between high performance development and high performance homes. The four projects are:

- Hidden Springs – Boise, Idaho
- Prairie Crossing – Grayslake, Illinois
- Civano – Tucson, Arizona
- Terramor – Ladera Ranch, California.

The following fundamental questions about these projects yield many interesting answers and more questions:

- What criteria shape the homes and community; how binding are these criteria?
- What were/are the drivers of the project criteria; are they market-based, municipally-required, or both?
- Which communities have sustained their level of energy and resource performance over time, and why?

[1] For more information on the Building America program, see: http://www.eere.energy.gov/buildings/building_america.

THE PROJECTS

Hidden Springs[4] Hidden Springs is a community of 1135 homes located on 1844 acres with over 800 acres of protected wetlands, farmland, and natural wildlife areas. This project features a community center within walking distance of all homes, a charter school, its own post office, and miles of hiking and biking trails. Hidden Springs won the BALA Best Smart Growth Community in 2000.[5] Homes range in price from approximately $185,000 to $750,000. Construction of homes began in June 1998 with build-out slated for December 2004. BSC began work with Hidden Springs under the Building America program in February 1998 with assistance tailing off in 2001. Approximately 32 homes were certified under the Building America program.

What exactly is a high performance home?

The **Building America** systems approach to high performance is based on the premise that links among energy efficiency, indoor environmental quality, and building durability are inherent and immutable. The BSC approach to ensuring high performance involves plan and specification review, energy modeling, performance testing, and building commissioning. The following requirements constitute the lion's share of our definition of high performance[2]:

- Superior energy performance — HERS rating of 88 or better.
- Mechanical ventilation per ASHRAE 62.2.
- All combustion appliances in the conditioned space sealed-combustion (furnaces and boilers) or power-vented (water heaters).
- All ducts and air handling equipment in the conditioned space.
- Performance testing for whole house and duct air tightness (per Energy Star testing regime); blower door of 2.5 $in^2/100\ ft^2$ surface area leakage ratio or less; duct leakage of 5.0 percent or less of the total air handling system rated air flow at high speed.
- Interzonal air pressure differences, when doors are closed, of 3 Pascals or less.

These performance requirements — along with the system of plan and specification reviews — ensure that the high performance home is energy efficient; safe, comfortable, healthy; and durable, particularly in terms of resistance to the major damage vectors — heat, air, and moisture.[3]

© buildingscience.com

---

[2] The complete list of performance targets, including recommendations not listed here, can be found on the web at: http://www.buildingscience.com/buildingamerica/targets.htm

[3] Building scientists often characterize the major damage functions as HARM—heat, air, radiation (UV exposure) and moisture. Pests, particularly insects, are generally added to these for homes.

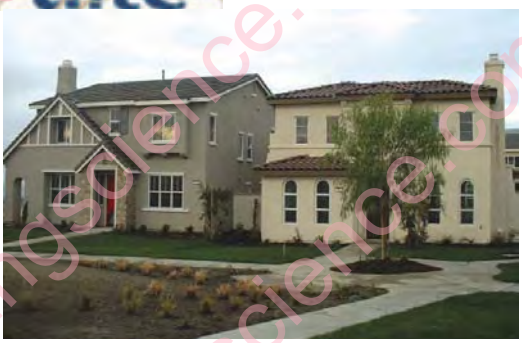
[4] For more information on Hidden Springs, see the website: http://www.hiddensprings.com. For more information on the lead builder at Hidden Springs, see http://www.chuckmillerconstruction.com.

[5] BALA is the Best in American Living Award, a program of the National Association of Home Builders and *Professional Builder* magazine.

Prairie Crossing Four Square

Prairie Crossing[6] Prairie Crossing is a community of 362 homes on approximately 677 acres with approximately 60% of the total land area designated as protected open land. Homes range in price from $279,000 to $420,000. Construction began in June 1995; home construction is nearly 90% complete with the last of four neighborhoods well underway. This conservation community features an environmental education institute, organic farm, charter school, a storm water management lake (Lake Aldo Leopold) and a 20kW wind turbine.[7] A critically acclaimed conservation community, Prairie Crossing has appeared extensively in national media — print, television, and radio. BSC work with Prairie Crossing began in June 1996 and ended in December 2002. Approximately 200 homes were built under the Building America program with BSC.

Terramor (Pulte Homes, Southern California)[8] Terramor is a community of approximately 1,260 homes in 12 neighborhoods on 290 acres. Pulte Homes is building 75 homes in a neighborhood called Clairborne, with homes in the low $500,000s. A concept entitled "**360° Living**" is being employed at Terramor, a concept that includes green land planning and home building in the form of the Terramor Green Development program. Pulte has three models for this community, with 16 homes completed and another 11 currently under construction. Only the Pulte Homes at Terramor are being built to the BSC performance targets.



Ladera Ranch neighborhood in Terramor

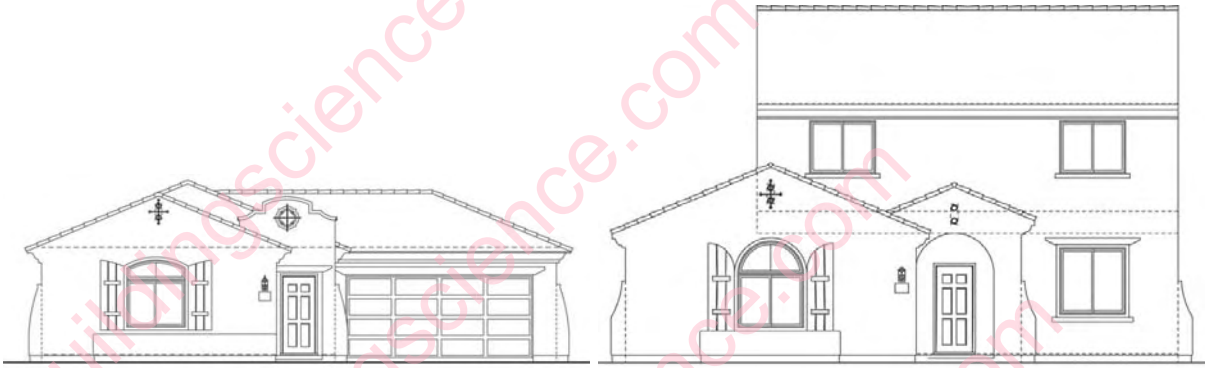
Civano (Pulte Homes, Tucson, Arizona)[9] Civano is a master-planned community of approximately 2,500 homes on 820 acres. In the second Civano neighborhood, Pulte Homes of Arizona plans to build between 1,200 and 1,300 homes on about 480 acres over a five-year period, with homes ranging in price

---

[6] For more information on Prairie Crossing, see their website: http://www.prairiecrossing.com.
[7] The 20 kW wind turbine is used to power irrigation at the Prairie Crossing Organic Farm.
[8] For more information on Terramor, see their website: http://www.laderaranch.com/360degree/green.php. For more information on Pulte Homes in the Clairborne neighborhood, see: http://www.pulte.com/homefinder/community.asp?commorg_acctcode=1745.
[9] For more information on Civano, see their website: http://www.civano.com.

© buildingscience.com

from $120,000 to the upper $200,000s.[10] Pulte will construct the Civano model homes in the latter part of 2004. Civano began as a partnership of local advocates and government officials called the "Solar Village." The concept matured over time such that all homes must be designed and constructed in accordance with the Civano IMPACT[11] System and Sustainable Energy Standard. The sustainability goals of the Civano system are impressive, and detailed in the next section of this paper.



A single story design (left) and a two story design (right) for Civano

© buildingscience.com

[10] Pulte Homes is in the final stages of negotiations with Civano for Neighborhood 2, but is actively field testing an innovative new rooftop solar water unit with BSC in Tucson in preparation for their homebuilding plans at Civano.

[11] IMPACT is an acronym for Integrated Method of Performance and Cost Tracking. A summary of this system can be found at: http://www.civanoneighbors.com/docs/guiding/revised/Civano_MOU_Dec_8_2003.pdf.

THE NATURE, STRENGTH, AND DURABILITY OF CRITERIA AND CONNECTIONS

Hidden Springs This community is based on a set of Founding Principles[12] with clear emphases on traditional neighborhood design and land preservation. The community developer is not legally bound in any way to the Founding Principles (in terms of government entities setting conditions for any permitting), but the developer does see the Founding Principles as an essential element of their marketing strategy.

Principle #4 of the Founding Principles is the most closely linked to the high performance criteria of Building America:

> "We will encourage the design and construction of homes that are comfortable and long-lasting; homes that will use energy and resources efficiently and responsibly."

This criterion is neither specifically performance-based nor quantitative, and the use of the verb "encourage" sets this principle apart from most of the others as a "softer" and less binding one. The Building America standards were incorporated into the Residential Design Guidelines only as "Suggested Building Practices" and "Suggested Design Measures."

Only one builder at Hidden Springs, Chuck Miller Construction, continues to build to the original Building America criteria for energy efficiency, indoor environmental quality, and durability. Chuck Miller Construction has built approximately 12 homes a year at Hidden Springs.[13]

Prairie Crossing This community is based on a set of Guiding Principles.[14] As with Hidden Springs, most of the community criteria are related to traditional neighborhood design and land preservation. The Guiding Principles are not legally binding to the developer, since they were not a pre-condition of a local or state governmental authority for the community's development. The Principles are, however, essential to the marketing strategy of the developer.

Criterion #7 relates specifically to energy conservation:

[12] For the complete set of Hidden Springs Founding Principles, see http://www.hiddensprings.com/community/newurbanism.asp.

[13] Chuck Miller is an award-winning builder. His web site demonstrates a comprehensive embrace of high performance design, construction, commissioning, and marketing: http://www.chuckmillerconstruction.com.

[14] For the complete set of Prairie Crossing Guiding Principles, see http://www.prairiecrossing.com/pc/site/guiding-principles.html.

© buildingscience.com

> "Buildings at Prairie Crossing are being constructed with techniques that reduce energy consumption by approximately 50 percent, compared to new homes elsewhere in the area."

This criterion is both performance-based and quantitative, one that any interested party can easily pursue with the developer and the builder. This criterion is linked to an unique aspect of Prairie Crossing — an alternative high performance building code, developed specifically by BSC for this community under the Building America program.

The compliance mechanism for the Lake County alternative code is the certificate of occupancy (CO) — the building inspector may not release the CO on a completed home until Section 326 compliance has been confirmed by the inspector, including performance testing results. Although this system was clearly designed to be "leakproof," the actual chain of custody on building permits and approvals at Prairie Crossing challenges the system. The original approval for the Section 326 building permit comes from the Lake County

When several features of Building America high performance homes — advanced framing, air tight electrical boxes, for example — ran awry of the local building code, enlightened code officials came up with an elegant solution — they suggested that Building Science Corporation write a Building America alternative code. Section 326, the "**Advanced Energy Efficient and Resource Efficient Single Family Residence Code**," permits the high performance criteria, but only if **all** of the features are employed.[15] This alternative code is a sort of de facto, imposed link between the high performance land development and home construction of Prairie Crossing, because achieving the 50% energy consumption reduction in Criterion #7 without employment of this alternative code is impractical if not nearly impossible.

Above: Single top-plate, 24-inch o.c. in-line framing and metal cross bracing

Below: Note polyisocyanurate rigid insulating sheathing

Left: Air tight electrical box and cross bracing

[15] For more information on this alternative code, contact the Lake County Building Department, 8 N. County St., Waukegan, IL, 60085-4355.

© buildingscience.com

building inspection department, but the final approval and CO comes from the local inspector, one that may have considerably less familiarity with the exact nature of Section 326 than Lake County officials.

Terramor Terramor development and construction is managed by the "**360° Living at Ladera Ranch Green Development Program**." This program[16] has the following goals:

- Reduce water consumption by 20%
- Reduce energy consumption by 20%, with respect to California Title 24 code requirements (includes HVAC systems, hot water systems, building envelope, lighting and other regulated systems)
- At least 10% reduction in use of non-renewable resources[17]

Outside air duct connected to return duct; note outside air damper on right

The Terramor program is designed to achieve these goals by way of a detailed builder checklist, a checklist that is in part performance- and prescriptive-based.[18] The Terramor program is enforced by the Developer — there are no binding requirements at Terramor except as stated by the Developer. Compliance to the program is managed by a 4-step design review process, 3rd-party inspection of all model homes, and 3rd-party inspection of 25% of stock.[19]

A review of the Terramor program building criteria makes it difficult to characterize the program as home high performance. The program lacks the following criteria:

- Superior envelope and mechanical equipment energy efficiency
- Combustion safety
- Mechanical ventilation
- Comprehensive HVAC Performance testing

Photovoltaic rooftop system

And without a systems approach to high performance, tragic combinations of building characteristics can result — there is more than one home at Terramor

[16] The Terramor program criteria were developed by the Ensar Group for EDAW and the Master Developer.
[17] The program has non-quantitative, non-performance based goals for landscaping and indoor environmental quality.
[18] The actual requirements of the Terramor program are not electronically available to the general public.
[19] This inspection process is for all building elements except those necessary for the Energy Star rating—this process is handled by a local HERS rater and inspection company.

© buildingscience.com

with a top-of-the-line photo-voltaic rooftop system along with a minimum performance 10 SEER air conditioning unit.

Civano Civano development and construction are managed by the IMPACT system and the Sustainable Energy Standard. The stated goals of Civano are:

- Reduction of potable water consumption by 65%
- Reduction of home energy consumption by 50% over the 1995 Tucson Model Energy Code
- Reduction of internal vehicle miles by 40%
- Creation of one job onsite for every two residences
- Reduction of landfill-destined solid waste.

As Pulte Homes took on the role of Master Developer at Civano, a new Revised Civano Memorandum of Understanding and revised IMPACT system has been instituted.[20] Section 5, "Specific Procedures for Implementation," lays out both the Master Developer requirements prior to issuance of building permits, and building plan requirements and review. The latter requires the builder to:

- certify energy efficiency — 50% reduction over the 1995 Model Energy Code).
- design for passive solar — orientation for passive heating and cooling.
- incorporate solar energy device — this includes any dedicated solar energy system for heating, cooling or hot water; active or passive (such as a trombe wall).
- landscape and hardscape for low average albedo — .5 or greater average reflectivity.
- submit construction waste management plan that includes recycling.
- make all homes "solar-ready" in terms of structural and plumbing.
- install solar systems on all model homes.

Section 7, "Certification of Compliance," establishes the following compliance mechanisms:

- Annual Monitoring report by Developer
- Developer-selected professional certification
- City audit option requiring developer documentation of compliance
- Non-compliance process hinging on building permit approvals
- Process for moving compliance from Developer to City determination

Finally, Section 10, "Non-Waiver of Compliance," ends the MOU with a twist:

> "Except as may be expressly agreed upon in writing, any decision by the City approving further development without complete compliance with all requirements and targets shall not constitute a waiver of any future application of requirements or Performance Targets…"

In a sort of backhanded way, this section appears to give the City of Tucson the option of **not** fully applying the Civano IMPACT system.

[20] "Civano IMPACT System Revised Memorandum of Understanding on Implementation and Monitoring Process" is dated December 8, 2003 (http://www.civanoneighbors.com/docs/guiding/revised/Civano_MOU_Dec_8_2003.pdf).

Summary of the Nature, Strength and Durability

So where do these four exemplary community-scale high performance projects leave us?

- In all four projects, links between high performance land development and high performance homes were imposed, not inherent. While there are some natural links that are possible — such as district heating, community greywater systems, street and lot layout for solar orientation — these links are almost always at the infrastructure-level and are better suited for multi-family and cohousing developments than the American mainstay: the single-family detached home.
- Many if not most land development-level features of high performance communities are high visibility — conservation areas, bike paths, community centers, mass transit connections. Many if not most building-level features of the same communities are, at least initially[21], low visibility or even invisible — energy performance, indoor environmental quality, durability.
- Municipally-based requirements and compliance mechanisms are necessary but not always sufficient elements of imposed connections between high performance buildings and community development. Only the two projects with municipally-imposed linkages — Prairie Crossing and Civano — demonstrated any strength and durability in terms of their criteria, and even these projects' linkage systems have been stressed over the course of the projects.
- Both developer and institutional memory are needed to sustain original project objectives and performance goals. Since most community projects last up to a decade or more, the staying power of even legally binding systems can be eroded by the inevitable "changing of the guard."
- If the buying public (as market-guided by the Developer) and the general public (as public conscience-guided by local government) do not "get" the connection between high performance land development and high performance homes, then the economic pressures on both the developer and the jurisdiction can erode the rigor of imposed connections.
- The businesses of land or community development and home building seldom have inherent connections — the business entities that have the technical and the marketing skills for both land development and home building are remarkably small in number.

WHERE DO WE GO FROM HERE?

There are really three issues at stake for high performance community-scale projects:

- bringing real high performance building criteria into mainstream green building;

[21] By initially, the author means prior to home purchase.

- making the links between green development and green building bombproof;
- creating truly effective marketing that makes a value connection between high performance land development and high performance homes.

Moving High Performance into Green Building While there is movement within the residential green building industry towards a building science base, only one program in the country has embraced the Building America high performance approach in entirety — the Central New Mexico Building America Partner Program.[22] And even the most successful high performance builders struggle with the lengths to which they must go to informationally market the consumer benefits of high performance — lower energy costs, greater comfort, superior indoor air quality, reduced maintenance, increased service life. A national program, with the technical approach of the Energy and Environmental Building Association (EEBA)[23] and the market vision of the United States Green Building Council (USGBC),[24] is needed for significant penetration among homebuilders and homebuyers.

It makes little sense to pack photo-voltaics on the roof when a minimum performance 10 SEER AC unit chugs along just beneath them. It makes little sense to give green building credit for "40-year" asphalt shingles when lack of systems-thinking is leading to moisture accumulation and rot in the roof sheathing just beneath them. It makes little sense to give credit for low-formaldehyde cavity insulation and provide no outside air dilution (through mechanical ventilation) for the same pollutants. These are neither fictions nor anomalies — the green building marketplace abounds with just such examples. For its own sustainability, green building must embrace the principles of systems thinking and high performance.

Bomb-proof Links Civano and Prairie Crossing have elements, that when put together, may constitute the best approach for imposing links between high performance land development and buildings. The Civano IMPACT system is thorough and rigorous, establishing a good balance between developer and government responsibility for sustained performance. The all-or-nothing building science-based performance building code from Lake County, if coupled with training for both the builders and the building officials, delivers high performance homes. It would not hurt if communities seeking to link high performance land development and buildings had a national model program to which they could refer. The United States Green Building Council is currently developing a LEED for Neighborhood Development (LEED-ND) that could be coupled to a high performance residential green building program.[25]

---

[22] For more information on this program, see: http://www.bapartner.org. Another program, Built Green Colorado, is moving their program toward a building-science basis; see .
[23] For more information on EEBA, see: http://www.eeba.org.
[24] For more information on the USGBC, see: http://www.usgbc.org.
[25] LEED stands for Leadership in Energy and Environmental Design.

But ultimately, if the general and home buying public does not understand and demand high performance development and buildings, imposing a supply is never as successful as developing a demand.

Creating Market Demand for High Performance The current economic pressures imposed by low energy costs — for both home operating and product manufacturing costs — are simply not great enough to market high performance on the back of energy alone. But what if the value of energy efficiency, indoor environmental quality, comfort, and durability could be made strikingly visible?

A relatively new economic approach currently being employed by the military may provide guidance — Public/Private Venture (PPV) housing. PPV is a partnership between a private company and a branch of the US military in which the private company agrees to own, construct, maintain, renovate, and manage housing for an extended period of time, often as long as 50 years. Imagine — the builder now looks at every element of his product (the home) for its overall performance — its contribution to initial **and** 50-year operating costs. All of a sudden, high performance becomes not only attractive to the builder, it becomes imperative. But PPV is for the military — a special type of housing situation. How can this same approach be used to capture both the builder and the homebuyer in the open market?

Sometime in the future, developers and builders may expand the view of their businesses to embrace communities and homes as a stream of services, rather than a one-time product. To do this, they will need to gain control, much as military housing contractors within the PPV need to gain control, over both the initial and operating costs of homes. The economic engine that can drive this is the guarantee—it is currently being used by home builders for energy operating costs and comfort,[26] and could be extended to cover all manner of operating and resource costs—water, maintenance, even some aspects of transportation costs for the homeowner (moving the realm from the structure out to the community development level). The beauty of the guarantee is two-fold:

- It instills total quality — quality of design, quality of materials/components, quality of workmanship/installation. The guarantee forces participation and coordination along the entire construction process and among all of the players.
- It delivers simple and clear value. It moves resource-efficiency and high performance from complex and altruistic to straightforward and marketable.

IN SUMMARY

There are few if any inherent links between high performance dwellings and development — the links must be imposed or created. These four Building America projects have revealed both a history of, and a need for, approaches

[26] An example of a guarantee program is the MASCO Environments for Living (EFL) program; see: http://www.eflhome.com.

that link high performance dwellings and developments. It is likely that a combination of imposed public sector (the Civano IMPACT system and Lake County alternative building code) and marketed private sector (guarantee programs) tools are needed to make the resource efficiency of buildings as tangible and as visible as the resource efficiency of land development, creating the link between the two for the homebuyer.

The structure of the residential building industry reflects the difficulty in linking high performance dwellings and development — the developer and the builder are almost always different business entities, with different skill sets, obstacles, and opportunities. The one thing that unites them is the buyer — ultimately, they both need to attract homebuyers.

Quality is the one issue that can unify the developer, the builder and the buyer. All three entities understand and value quality. Extending the general issue of quality to include environmental quality is perhaps the simplest and most direct way to link high performance dwellings and development. In other words, a green home must be a quality home, a green development must be a quality development. Any entity—government agency, non-governmental organization, builder, developer — interested in accomplishing comprehensive and real environmental gain should look to performance measures and metrics that capture resource efficiency in the context of quality. It is a fit that builders and developers can sell, and consumers will buy.

About this Report

This report was prepared for the US Department of Energy's Building America Program. The report is freely available to the public at www.buildingamerica.gov.

About the Author

Joseph Lstiburek, Ph.D., P.Eng., is a principal of Building Science Corporation in Westford, Massachusetts. He has twenty-five years of experience in design, construction, investigation, and building science research. Joe is an ASHRAE Fellow and an internationally recognized authority on indoor air quality, moisture, and condensation in buildings. More information about Joseph Lstiburek can be found at www.buildingscience.com

Direct all correspondence to: Joseph Lstiburek, Building Science Corporation, 70 Main Street, Westford, MA 01886

Limits of Liability and Disclaimer of Warranty:

Building Science documents are intended for professionals. The author and the publisher of this article have used their best efforts to provide accurate and authoritative information in regard to the subject matter covered. The author and publisher make no warranty of any kind, expressed or implied, with regard to the information contained in this article.

The information presented in this article must be used with care by professionals who understand the implications of what they are doing. If professional advice or other expert assistance is required, the services of a competent professional shall be sought. The author and publisher shall not be liable in the event of incidental or consequential damages in connection with, or arising from, the use of the information contained within this Building Science document.