U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

BUILDING TECHNOLOGIES OFFICE

Strategy Guideline: Application of a Construction Quality Process to Existing Home Retrofits

D. Mallay and M. Del Bianco
Partnership for Home Innovation (PHI)

August 2013

Building America
U.S. Department of Energy

Available electronically at http://www.osti.gov/bridge

Available for a processing fee to U.S. Department of Energy
and its contractors, in paper, from:
U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
phone: 865.576.8401
fax: 865.576.5728
email: mailto:reports@adonis.osti.gov

Available for sale to the public, in paper, from:
U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
phone: 800.553.6847
fax: 703.605.6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/ordering.htm

Printed on paper containing at least 50% wastepaper, including 20% postconsumer waste

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Strategy Guideline: Application of a Construction Quality Process to Existing Home Retrofits

Prepared for:

The National Renewable Energy Laboratory

On behalf of the U.S. Department of Energy's Building America Program

Office of Energy Efficiency and Renewable Energy

15013 Denver West Parkway

Golden, CO 80401

NREL Contract No. DE-AC36-08GO28308

Prepared by:

Home Innovation Research Labs

Partnership for Home Innovation (PHI)

400 Prince George's Blvd

Upper Marlboro, MD 20774

NREL Technical Monitor: Stacey Rothgeb

Prepared under Subcontract No. KNDJ-0-40335-00

August 2013

[This page left blank]

Contents

List of Figures iv
List of Tables v
Definitions vi
Executive Summary vii
1 Background 1
2 Introduction to the Construction Quality Process 3
3 The Construction Quality Process applied to a High Performance Home 4
3.1 Establish HPH Goals 4
3.2 Develop HPH Specifications 5
3.3 Determine Monitoring Points 6
3.4 Schedule Monitoring Points 7
3.5 Implement Monitoring Points 8
4 The Construction Quality Process with Enhanced Specifications 9
4.1 Establish Project Goals (Step 1) 9
4.2 Develop Enhanced Specifications (Step 2) 9
4.3 Determine Monitoring Points for the Enhanced Specifications (Step 3) and Schedule Monitoring Points (Step 4) 13
4.4 Implement Monitoring Points (Step 5) 15
5 Applying the Detailed Construction Quality Process to Existing Homes: Vented Crawlspace Example 16
5.1 Establish Remodeling Goals (Step 1) 16
5.2 Develop Remodeling Specifications (Step 2) 20
5.3 Determine Monitoring Points for Remodeling (Step 3), Schedule Monitoring Points (Step 4), and Implement Monitoring Points (Step 5) 22
6 Conclusion 27
References 28
Appendix A: K. Hovnanian Homes Jockey Club High Performance Home Specifications 29
Appendix B: NCTH Example Review Detail 31
Appendix C: K. Hovnanian Homes Jockey Club Performance Test Results 34

List of Figures

Figure 1. A Building America prototype home by K. Hovnanian Homes. 4
Figure 2. Monitoring points incorporated into construction schedule. 8
Figure 3. Enclosure air sealing specification detail. 13
Figure 4. GHI pre-design assessment checklist (p.1). 18
Figure 5. GHI pre-design assessment checklist (p.2). 19
Figure 6. GHI vented crawlspace pre-design assessment (p.3). 20

Unless otherwise noted, all figures were created by Partnership for Home Innovation (PHI).

List of Tables

Table 1. NCTH—Summary of Changes to Standard Builder Practice. 5
Table 2. NCTH Monitoring Points. 7
Table 3. Detailed Specifications by Trade Partner. 10
Table 4. Enclosure Monitoring Points. 14
Table 5. Detailed Specifications. 21
Table 6. Comprehensive Construction Monitoring Table for a Crawlspace Energy Retrofit. 23

Unless otherwise noted, all tables were created by Partnership for Home Innovation (PHI).

Definitions

BA	U.S. Department of Energy's Building America Program
DOE	U.S. Department of Energy
HPH	High performance home
NAHB	National Association of Home Builders
NCTH	New construction test house
OVE	Optimum value engineering
QA	Quality assurance
QC	Quality control
QMS	Quality management system
SPFcc	Closed cell spray polyurethane foam
SOW	Scope of work

Executive Summary

Historically, the focus of the U.S. Department of Energy's (DOE) Building America (BA) program has been to accelerate the development of energy innovations that reduce operating costs, increase durability, improve health, safety, and comfort, and reduce energy use by validating benefits and costs via system and whole building research studies. The program aims to give builders and remodelers a clear understanding of why certain approaches perform better than others and to provide them with building science-based specifications that meet energy and green building program criteria.

As BA expands from new home construction to encompass high performance renovations, the quality processes developed for new homes must be translated to meet the needs of the existing home sector. The uniqueness of every remodeling project complicates the task of applying a quality management system (QMS) to renovations. However, the sheer number of existing homes, compared to the relative paucity of new homes, and the tremendous potential for increasing performance in this aging portion of the nation's housing stock, lends tremendous importance to achieving success with high performance renovations.

Even for companies with well-established QMS, constructing and renovating homes to meet the demanding performance goals of the BA program requires additional steps in the project schedule—and often additional time in the construction cycle. This extra time and attention to detail is necessary to accommodate more rigorous specifications, critical installation details, and products, methods, and construction sequencing that is often new or unfamiliar to builders and trade contractors. However, a systematic approach will minimize added time in the production schedule and maximize performance of the final product.

The Partnership for Home Innovation (PHI) developed a construction quality process for new and existing high performance homes (HPH) in which high performance goals are established, specifications to meet those goals are defined, and construction monitoring points are added to the construction schedule so that critical energy efficiency details are systematically reviewed, documented, and tested in a timely manner.

This construction quality process was demonstrated to facilitate the successful implementation of numerous energy enhancements in a new construction test house. These include the effective installation of a tight building enclosure, in which numerous trade contractors were involved, and a vented crawlspace renovation.

This report follows the evolution of the construction quality process from its development for new homes to its application in the construction of a HPH with enhanced specifications, and its application in a crawlspace renovation. In this project, a construction quality process is applied to a new construction test house and in the foundation retrofit phase of an energy efficient renovation project.

Acknowledgements

The authors would like to thank builders K. Hovnanian Homes, Winchester Homes, Nexus Energy Homes, and Greenbelt Homes Inc. for their significant time and resources in support of this project.

1 Background

The U.S. Department of Energy's Building America Program (BA) strives to improve the energy performance of new and existing homes by providing examples of cost-effective solutions for all U.S. climate zones. Using a whole-house system engineering approach, the program unites segments of the industry that traditionally work independently—such as architects, engineers, builders, remodelers, trade contractors, utilities, manufacturers, material suppliers, community planners, and mortgage lenders—into cohesive teams working toward a common goal.

Historically, the focus of BA has been to accelerate the development of energy innovations that reduce operating costs, increase durability, improve health, safety, and comfort, and reduce energy use by validating benefits and costs via whole building research studies. Traditional BA research activities focus on finding successful system innovations that are ready for deployment. The program aims to give builders and remodelers a clear understanding of why certain approaches perform better than others and to provide them with building science-based specifications that meet energy and green building program criteria.

As BA expands from new home construction to encompass high performance renovations, the quality processes developed for new homes must be translated to meet the needs of the existing home sector. The uniqueness of every remodeling project complicates the task of applying a one-size-fits-all QMS to renovations. However, the sheer number of existing homes and the tremendous potential for energy usage reduction in this aging portion of the nation's housing stock lends tremendous importance to achieving success with high performance renovations.

A QMS generally involves a formal system of planning, implementing, checking, and acting toward the completion of a product or process. After overall project goals are visualized and key stakeholders are identified, the basic and essential steps of a QMS process are:

- **Plan**: develop/define a plan
- **Do**: implement the plan
- **Check**: measure, test, and analyze to ensure the desired results
- **Act**: act and continuously improve the plan.

A fully developed QMS program includes well-defined inspections, internal audits, clear performance metrics, and surveys and other tools to obtain feedback for continuous improvement. A QMS improves production and efficiency and reduces product defects, all of which translates to lower costs, higher profits, and predictable performance. The goal of a QMS is to systematically plan and check each aspect of a home's construction such that uncertainty is minimized and the product consistently meets specifications.

Recognizing that QMS programs are effective for facilitating change in any industry, BA established a quality research and outreach program to support the home building and remodeling industry's transition to higher performing homes. By systematically adopting QMS programs, builders have demonstrated the value of such programs to reduce construction defects and warranty claims. Successful QMS programs, adapted to high performance home (HPH) designs by methodically considering system interactions throughout the construction process, affect not only the energy performance, but also the durability, health, safety, comfort, and affordability of homes.

Quality activities under BA began with the development of scopes of work (SOW) for components of a HPH.[1] This seminal work weaves HPH building specifications and procedures into the active management and implementation strategies of a comprehensive QMS. In addition, it addresses trade partnering and continual monitoring, feedback, and control. A wide variety of BA quality resources applicable to new construction activities are available on the BA[2] and the Partnership for Home Innovation[3] (PHI) websites, however, the systematic application of quality management processes in the high performance remodeling industry is just beginning to be documented, as described in the example in this report.

[1] See, for example, NAHB Research Center (2008), *Four Scopes of Work for High Performance Homes*, available from: http://www.toolbase.org/PDF/BestPractices/ScopesofWork.pdf.
[2] http://www1.eere.energy.gov/buildings/residential/ba_index.html
[3] www.toolbase.org and www.homeinnovation.com

2 Introduction to the Construction Quality Process

When high performance goals are introduced, for example, when a builder wishes to improve energy efficiency by 40% to meet the BA Benchmark, the plans, process, and materials that go into producing that more efficient product also require fine tuning. Builders that have an existing successful QMS program have discovered that achieving BA performance goals requires additional steps in the project schedule. These additional processes are necessary because enhancing performance requires a combination of tightly controlled specification and installation details coupled with products, methods, and sequencing that is often new to trade contractors. Further, when a house plan is being built for the first time, identifying and accommodating the additional monitoring points on the construction schedule becomes all the more critical.

PHI worked with builders to develop a comprehensive approach to successfully implement high performance changes to standard builder practice. This approach aligns with the traditional QMS approach (NAHB Research Center 2009, 2010, 2012) but adds high performance goals and monitoring points at critical points in the construction schedule. Because this comprehensive approach facilitated the smooth completion of a first build with numerous energy enhancements compared to builder standard practice, it was postulated that this process would likely be successful when applied to energy efficiency retrofits, as well.

The construction quality process consists of establishing goals, developing specifications, developing monitoring points, accommodating quality inspections in the construction schedule, and monitoring the project’s progress toward goals. This report follows the evolution of this process from its development for new homes, to a detailed application in a HPH construction, as well as, its implementation in a vented crawlspace renovation.

3 The Construction Quality Process applied to a High Performance Home

The general QMS used by many builders was adapted to incorporate new HPH construction details. The construction quality process was developed with production builders for BA new construction test house (NCTH) projects and includes the following steps:

- Establish HPH goals
- Develop HPH specifications
- Determine monitoring points for the HPH specifications
- Schedule monitoring points
- Implement monitoring points.

The application of this construction quality process to a HPH is described below for an example NCTH built by K. Hovnanian Homes (New Jersey division) in its Jockey Club neighborhood.

3.1 Establish HPH Goals

The first step of the process is to establish high performance project goals during an initial project meeting. The overall vision of the project and key stakeholders are identified. For BA projects, overarching goals often include achieving energy and green program certifications or performance targets. Specific goals could include, for example, “install entire HVAC system in conditioned space,” or “air seal to achieve 2 ACH50 in a manner that is affordable and repeatable.”

For the K. Hovnanian NCTH shown in Figure 1, goals included meeting a specific energy savings target (40% over the 2008 BA Benchmark) and finding cost-effective solutions that were practical to construct. Additional specific goals for the 2,489 ft^2, 3-bedroom, and 2-bathroom house built in 2009 in the mixed humid climate included:

- 2.5 ACH50 air sealing target
- Optimized wall panels—or a framing design to minimize redundant lumber (OVE)
- Simplified heating and cooling duct layout with negligible leakage to outdoors.

Figure 1. A Building America prototype home by K. Hovnanian Homes.

3.2 Develop HPH Specifications

The second step of the process is to determine the most appropriate specifications for cost effectively meeting performance targets. This step requires a good deal of collaborative effort—for the consultant to provide the builder with clear guidance regarding products and construction details appropriate for meeting performance goals and for the builder to determine actual costs and ease of construction for various systems.

For this task, PHI conducted energy simulations that were used as a basis for discussing high performance features and tradeoffs with the builder. The selected energy efficiency solution package represented months of collaborative development during this design phase. In addition to PHI, the design team included the builder's project manager, architect, purchasing manager, production manager, and site superintendent, wall panel and various product vendors, and trade partners: framing, insulation, HVAC, sprinkler, plumbing, and electrical. The vendors and trade partners' participation was critical to ensure that each individual component of the solution package would be practical to construct and install. These features were selected for durability, practical and repeatable installation, and cost effectiveness.

Together, the team arrived at a package of solutions for the NCTH, which is outlined in Table 1 and presented in detail in Appendix A. Changes from the builder's standard practice were designed to dramatically reduce air leakage, improve insulating value of the building's exterior walls and roof, and reduce losses from the HVAC distribution system. The finished NCTH, which has a HERS index of 41 with a 4.2-kW photovoltaic system, is predicted to use less than half the energy of an identical model built using the company's standard practices.

Table 1. NCTH—Summary of Changes to Standard Builder Practice.

Feature	Standard Builder Practice	New Construction Test House
Wall framing, foundation	2×4, 16-in. on center, slab on grade	Same, optimized to reduce unnecessary lumber
Sheathing, full coverage	Wood structural	R-5.5 structural insulating sheathing (1-in. thick)
Sheathing air sealing	None	Taped seams, top/bottom plate gaskets
Cavity insulation	R-13 batt, Grade 1 installation	same
Wall air sealing	Bottom plate caulked, penetrations and window rough openings foamed	Same, plus top plates foamed from attic
Truss	Top chord overhang	Cantilevered overhang; integral trunk duct chase
Attic insulation	R-38, blown	R-49, blown
Space conditioning equipment	Equipment and ducts in attic	Equipment and return ducts inside, supply trunk duct in truss chase and foamed from attic, and supply ducts deeply buried

In addition to selecting specific products and methods, this step of the process includes developing sets of details that can be used for reviews, scopes of work, and checklists for the builder, vendors, and trade contractors. Final short-term testing and long-term monitoring plans are also developed as needed. Much of this step in the process necessarily takes place during the early design stage before construction begins, but the need for other details may be identified and developed during the next steps in the process. For example, the NCTH foundation insulation specification had to be complete before construction began, but a final HVAC duct installation specification did not need to hold up the project and was developed after construction was underway. An example air sealing detail developed for the NCTH is included in Appendix B.

3.3 Determine Monitoring Points

Determining the monitoring points for the new specifications is a key aspect to the construction quality process. This step helps tie together the design, construction, and verification of building a HPH. The term "monitoring points" is used to identify the tasks that are considered necessary to successfully implement the new high performance specifications. The monitoring points for the construction quality process are identified as follows:

- *Review*: identifies that a meeting or call is required to finalize specification details, or to review these details before work begins. A review with the site superintendent and appropriate trades, ideally on site just before the work begins, is important to ensure that all agree on the implementation details and expectations of the particular task.

- *Document:* identifies a required inspection to verify and evaluate the implementation of a particular component. Documentation can take the form of a completed checklist (e.g., energy program checklists), inspection form (e.g., equipment start-up procedure form), photographs, observation during and after implementation, verbal feedback from trades, or a combination of these. Documentation is important, particularly in a first-time build, to evaluate high performance enhancements for future practical installation. Additionally, this step provides an opportunity to correct any implementation errors in a timely manner (e.g., before work is covered), as required.

- *Test:* indicates a physical test required to evaluate the project with respect to performance goals and expectations. Examples of testing include duct blaster testing, blower door testing, air balancing, and long-term monitoring. This monitoring point also allows for corrections as needed.

For the K. Hovnanian Jockey Club NCTH, the team identified fifteen monitoring points consisting of five review, seven documentation, and three test points (Table 2).

Table 2. NCTH Monitoring Points.

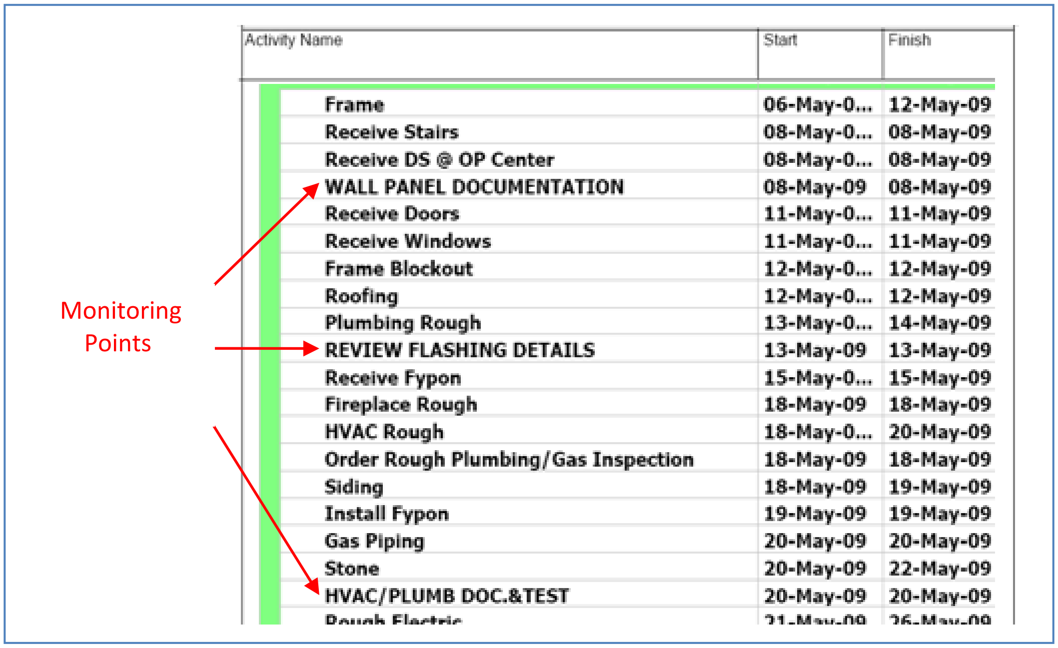
#	Monitoring Points Description (oversight by the appropriate builder representative(s) and the participants identified below)	Monitoring Points (Review, Document, or Test)
1	Review wall panel specifications (wall panel vendor and framing trade partner)	R
2	Review site air sealing goals and details (framing and insulation trade partners)	R
3	Document wall panel fabrication (at vendor site)	D
4	Document wall panel site installation	D
5	Review window and door flashing details (framing and siding trade partners)	R
6	Review plumbing and HVAC installation and startup (mechanical trade partners)	R
7	Document thermal bypass checklist (insulation and framing trade partners before insulation)	D
8	HVAC duct leakage rough-in test (HVAC trade partner)	T
9	Review insulation and air sealing (insulation/framing trade partners, coordinate air barrier sequence)	R
10	Document wall insulation	D
11	Document drywall (air barrier, register boots) and attic sealing (top plates)	D
12	Document attic insulation	D
13	Document plumbing and HVAC startup	D
14	Final short-term testing (blower door, duct blaster, air flows, hot water flow and temperature)	T
15	Long-term energy monitoring if applicable	T

3.4 Schedule Monitoring Points

The fourth step of the construction quality process is to incorporate the monitoring points into the construction schedule. Although this may seem trivial, it is very important to schedule monitoring points in a manner that makes them effective and produces minimal disruption to the flow of construction. This step is also identified separately from the previous step because different or additional personnel may be responsible to make this change to the builder's existing QMS.

Timing of monitoring points can be critical. Timely reviews ensure that products are installed in accordance with expectations and allow for corrections before work is covered and no longer accessible. The best date to perform each monitoring checkpoint should be established by examining the builder's standard construction schedule and then adding to it.

For the NCTH, the team identified a date that would fit into the construction schedule, and then each monitoring point was added to the builder's standard construction schedule (Figure 2). This helped the site superintendent keep track of progress to ensure that the project was on time and that high performance features were incorporated correctly.



Activity Name	Start	Finish
Frame	06-May-0...	12-May-09
Receive Stairs	08-May-0...	08-May-09
Receive DS @ OP Center	08-May-0...	08-May-09
WALL PANEL DOCUMENTATION	08-May-09	08-May-09
Receive Doors	11-May-0...	11-May-09
Receive Windows	11-May-0...	11-May-09
Frame Blockout	12-May-0...	12-May-09
Roofing	12-May-0...	12-May-09
Plumbing Rough	13-May-0...	14-May-09
REVIEW FLASHING DETAILS	13-May-09	13-May-09
Receive Fypon	15-May-0...	15-May-09
Fireplace Rough	18-May-09	18-May-09
HVAC Rough	18-May-0...	20-May-09
Order Rough Plumbing/Gas Inspection	18-May-09	18-May-09
Siding	18-May-09	19-May-09
Install Fypon	19-May-09	19-May-09
Gas Piping	20-May-09	20-May-09
Stone	20-May-09	22-May-09
HVAC/PLUMB DOC.&TEST	20-May-09	20-May-09
Rough Electric	21-May-09	26-May-09

Figure 2. Monitoring points incorporated into construction schedule.

3.5 Implement Monitoring Points

The fifth step of the process is to perform the monitoring point tasks according to schedule. The review and documentation points help to ensure the proper implementation of the energy solution package components. Test points provide evidence of the building's compliance with the target specifications. Successful implementation of the monitoring points allows for a thorough evaluation of the new products and methods to determine which components should be incorporated into the standard house design.

For the NCTH, some of the monitoring points were combined and performed on the same day, and some documentation points were performed by builder personnel, to minimize travel time for team members and optimize efforts. The site superintendent was responsible for the monitoring points schedule and notifying team members of any changes to the schedule. Group flexibility was critical during this dynamic step of the process. For example, inspection during a documentation point revealed that air sealing at the ceiling plane in several locations (where HVAC register boots had been sealed at the ceiling) was below specification and an additional spray foam application was required. The schedule had to accommodate another site visit by the spray foam insulation subcontractor without compromising the pre-scheduled installation time allotted to other subcontractors. The final house leakage results were one-third that of the builder's standard practices (the NCTH tested at 2.4 ACH50, while the community model house tested at 7.25 ACH50). Other results gathered at the monitoring points demonstrated that specifications were installed and functioning as designed (Appendix C).

The level of effort invested by the builder, vendors, trade partners, and researchers during the application of this construction quality process was important to the successful design and implementation of the NCTH, and for the development of plans and specifications for future homes.

4 The Construction Quality Process with Enhanced Specifications

The same QMS process was applied to the construction of another NCTH. To reiterate the steps:

- Establish goals
- Develop enhanced specifications
- Determine monitoring points
- Schedule monitoring points
- Implement monitoring points.

Again, the project team included the appropriate builder's representatives (project, quality, purchasing, design, and site construction managers and energy consultants), vendors (such as wall panel and products), and trade partners (framing, insulation, drywall, HVAC, sprinkler, plumbing, and electrical).

PHI developed an enhanced specification step with K. Hovnanian's New Jersey division for a second NCTH in its Hunters Brook subdivision. The same construction quality process as the first NCTH was followed, but a higher level of specification provided enhanced details for products, construction methods, sequencing, and responsibilities by trade. This higher level of detail provides indoctrination to the quality and HPH process for novice builders and remodelers who are eager to adopt a QMS.

4.1 Establish Project Goals (Step 1)

As with the construction quality process for the HPH, the first step is to establish project goals during an initial project meeting. The primary goal for the NCTH was to create a cost-effective high performance enclosure. Specifically, the enclosure needed to be tight (target air leakage rate of 2.5 ACH50), contain an optimized HVAC duct design, minimize jobsite waste, and be practical to build.

4.2 Develop Enhanced Specifications (Step 2)

The process of determining more detailed specifications for this NCTH expanded and developed the HPH specifications. During this step, the team identified specific trade partner expectations, and coordinated construction activities to establish a sequence for installation of the enclosure components. All of the trades involved in the construction prior to the close-in inspection participated. Results of the compilation of the detailed specifications are contained in Table 3. This level of detail helps avoid confusion in the construction process when new responsibilities are introduced. Detailed specifications such as these will be especially useful in the energy retrofit/remodeling arena where there is a general void of scopes of work and high performance specifications.

Table 3. Detailed Specifications by Trade Partner.

ENCLOSURE SPECIFICATIONS

All Trade Partners

- Minimize size of holes through framing and air barriers
- Install appropriate Quickflash Weatherproofing Panel for all exterior penetrations
- Air sealing must always be continuous to be effective

Framing Trade Partner

- Factory built wall panels
  - Exterior walls 2×6, 24 in. on center
  - Factory installed second top plates except at panel ends for field installed second top plate
  - ½-in. OSB sheathing raised ¾ in. to attach to second top plate
  - Factory installed gasket (BG32) between OSB and first top plate of second floor panels using Conservation Technologies BG32 EPDM cellular foam drywall gasket http://www.conservationtechnology.com/building_gaskets.html
  - Siding attached at 24 in. on center to studs and additional nail at midpoint to sheathing
  - Interior walls 2×4, 24 in. on center; second top plates field installed
- Wall panel nailing schedule construction and installation specification
  - May be required by inspector
  - Panel-panel details including corners
  - Panel-floor deck details
  - Panel-panel air sealing not required with house wrap as exterior air barrier
- Engineered rim joists as first floor headers per design
- Efficient framing design to eliminate unnecessary exterior wall framing
  - Additional framing for siding J-channel, if required, use 2×4 turned on edge
- Interior walls held 1 in. from exterior walls for continuous drywall
  - Interior-exterior wall second top plate attachment using specified bracket
- Pre-fabricated fireplace box (not a cantilevered floor)
- Air sealing
  - Sill plate: attach 2×6 structural gasket (BG65) to sill plate
  - Install OSB gasket (BG32) at sill plate
  - Caulk all bottom plates to sub-floor deck (standard practice)
  - Install garage draft stops
  - Attic access panel with gasket
  - Install framed cavity air barriers
    - Fireplace wall, floor, ceiling (after insulation)
    - Attic knee wall at front porch (before insulation)
    - Attic knee wall at master bedroom cathedral ceiling (before insulation)
    - Dropped ceilings on second floor (before insulation)
    - Master bath tub and shower enclosure (after insulation)
    - Duct chase and double wall for stairs at garage (after insulation)
    - Cantilevered floor of breakfast bay (after insulation)
    - Knee wall at garage attic
    - Dropped soffit for plumbing in garage

Siding Trade Partner

- House wrap will be the exterior air barrier as well as the drainage plane
- Covalence Barricade Plus house wrap field installed
  - Use widest 9-ft width roll
  - Consider starting with one, 3-ft width layer and continuing with two 9-ft width layers

ENCLOSURE SPECIFICATIONS
• Seal bottom of house wrap to first floor OSB at sill plate ○ Apply primer for 4 in. minimum butyl tape to OSB ○ Apply butyl tape with 1 in. overhang below bottom edge of OSB ○ Install house wrap over butyl tape, leaving enough butyl tape exposed to apply house wrap tape ○ Apply house wrap tape over house wrap and butyl tape
• Seal top of house wrap to second floor OSB at top plate ○ Install house wrap to within 2 in. of top edge of OSB ○ Apply primer to OSB for butyl tape ○ Apply 3 in. minimum butyl tape to OSB and over house wrap ○ Above applies to gable ends of house as well; continue with house wrap or building paper above wall for gable end water barrier ○ Does this conflict with frieze board installation by others before siding installation?
• Tape all vertical and horizontal seams and penetrations
• Cut window opening in house wrap per drawing
• Install windows using self-adhered flashing per drawing
• Attach siding at 24 in. on center to studs and additional nail at midpoint to sheathing
Insulation Trade Partner
• Attic eave baffles
• R-49 attic blown fiberglass (as late as practical to avoid being walked on)
• R-21 wall cavity batt (Grade I installation; conform to cavity; slit insulation as required)
• Insulate attic access panel with gasket to R-49 and provide insulation dam
• Spray foam behind electrical boxes facing the interior and seal boxes facing the exterior
• Spray 1-in. thick SPFcc and then install fiberglass batt insulation (“flash and batt”): ○ Garage draft stops ○ Deck at conditioned floor above garage and fill floor cavity with batts ○ All rim joist areas and R-19 fiberglass batts with tight fit ○ Cantilevered bay floor and fill floor cavity with batts ○ Fireplace floor and fill with batts
• Seal framed cavity air barriers ○ Fireplace wall, floor, ceiling ○ Attic knee wall at front porch ○ Attic knee wall at master bedroom cathedral ceiling ○ Dropped ceilings on second floor ○ Master bath tub and shower enclosure ○ Duct chase and double wall for stairs at garage ○ Cantilevered floor of breakfast bay ○ Knee wall at garage attic ○ Dropped soffit for plumbing in garage
Electrical Trade Partner
• Electrical boxes facing exterior: putty around boxes
• Electrical boxes facing interior: install gaskets (spray foam behind box by insulator)
• Install gasket for all second floor ICAT recessed can fixtures at attic
• Install wire at bottom plate of exterior walls (standard practice)
• Install CFLs for all standard screw based fixtures
• “The Energy Detective” (TED) whole house energy monitor

ENCLOSURE SPECIFICATIONS
Drywall Trade Partner

• Provide interior air barrier using the Airtight Drywall Approach
  ○ Seal top and bottom plates and around rough openings of exterior walls
    – Seal for all top plates must be applied to the first (lower) top plate or between top plates
  ○ Seal top plates of interior walls at attic (second floor)
  ○ Seal all second floor ceiling penetrations

• Seal garage-side drywall at conditioned space: top and bottom plates, around door
• Airtight drywall approach air seal using DOW Great Stuff Pro Wall and Floor Adhesive http://building.dow.com/na/en/products/sealants/gspwallfloor.htm
Plumbing Trade Partner
• A O Smith Vertex GPHE 0.90 EF, 50-gallon natural gas power vent heater
• Substitute direct vent for NGBS points?
• Branch and tee piping system (not manifold)
• Minimize branch sizing (except where doing so will require a non-standard fitting)
• Hot water piping will not be insulated
• Low flow lavatory and shower heads (standard)
• Low flow or dual flush toilets?
HVAC Trade Partner
• Equipment and duct located in conditioned space
• Three zones controlled by automatic electronic zone dampers and bypass damper
• Simplified central return for each level with bedroom transfer grilles
• 95% AFUE, 2-stage, variable speed, 70,000 Btuh natural gas furnace
• 15 SEER, 3-ton cooling system
• Honeywell IAQ thermostat to control fresh air ventilation damper ducted to return
• MERV 10 minimum filtration
• Bath exhaust fan: individual spot ventilation fans; insulated duct in attic
• Seal duct system with mastic
• Seal bath exhaust fan at ceiling and hoods at exterior
• Seal kitchen range hood ducting to exterior
• Supply branch air balancing damper location

The detailed specifications brought to light overlapping areas of responsibility, such as areas where separate contractors were responsible for various components of the air sealing package. The siding contractor on this job was responsible for applying butyl tape to connect the house wrap to the OSB sheathing and the framing contractor was responsible for caulking joints in the framing. To clarify the specifications and enumerate job responsibility, PHI team developed an ancillary construction drawing detailing the air sealing strategy and related execution responsibilities (Figure 3).

Details such as these may be used by various contractors and can help to provide a common understanding of responsibility. Remodelers will benefit by using the drawing initially as a checklist for identifying air leak locations and subsequently, customized, as the detail for action and responsibility in job execution.

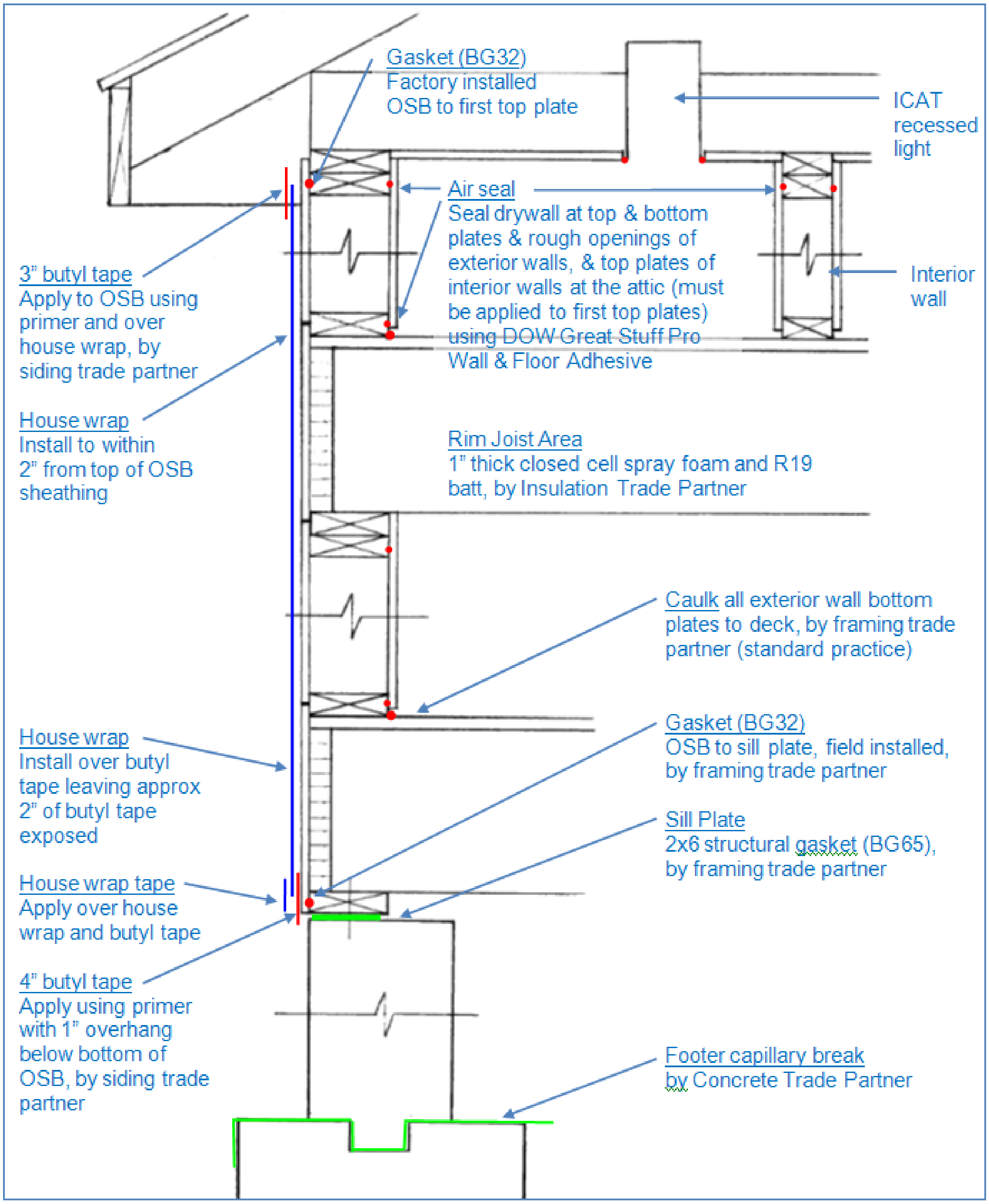


Figure 3. Enclosure air sealing specification detail.

4.3 Determine Monitoring Points for the Enhanced Specifications (Step 3) and Schedule Monitoring Points (Step 4)

Continuing with the same methodology as employed in the HPH construction quality process, monitoring points must be identified and scheduled for the more detailed specifications. For this NCTH, 17 monitoring points were identified consisting of eight reviews, six documentation points, and three testing points. This project added two additional review points: the early-on meeting where project goals were established and the lessons-learned review where the changes to the builder's standard building were evaluated for durability, practical installation, and cost effectiveness. These monitoring points that were incorporated in the construction schedule are outlined in Table 4.

Table 4. Enclosure Monitoring Points.

Activity Description	Monitoring Checkpoint (Review, Document, Test)	Detail/ Results	Schedule	Actual Date
Project meeting – establish project goals	R			
Design review – review modeling results, thermal enclosure alternatives, and mechanical design	R			
Review wall panel specifications, factory energy detailing and installation details	R		ASAP	
Review site air sealing goals and details	R		ASAP	
Document wall framing	D		Frame start	
Review window and door flashing details	R		Prior to window and door installation	
Review plumbing and HVAC installation and startup	R		Prior to MEP roughs	
Document thermal bypass checklist	D		Following completion of rough MEPs	
HVAC duct leakage rough-in test	T		Third day of HVAC rough installation	
Review insulation and air sealing by insulation trade partner	R		Prior to batt insulation installation	
Document wall insulation	D		Following batt insulation and prior to drywall	
Document drywall (air barrier, register boots) and attic sealing (top plates)	D		During drywall hanging	
Document attic insulation	D		Following spray foam application	
Document plumbing and HVAC startup	D		Following final MEP start-up	
Final short-term testing (blower door, duct blaster, air flows, air balance, hot water performance, install long-term monitoring hardware)	T		Simultaneous to final ENERGY STAR inspection	
Long-term energy monitoring (add if applicable to the project)	T		1 yr post closing	
Lessons-learned review	R			

4.4 Implement Monitoring Points (Step 5)

The next step of the construction quality process is to perform the tasks as outlined by the monitoring points. For this NCTH, the monitoring points were implemented according to the established schedule and provided valuable information for the lessons-learned review. For example, the house leakage test result of 2.4 ACH50 met the target performance goal, so the air sealing effort was deemed effective, but some aspects of the air sealing strategy, observed during the documentation points, appeared to be problematic. The airtight drywall approach that relies on the drywall trade partner to install the sealant just prior to drywall required an additional crew member (in this case a foreman who understood the importance of this step). The project team decided that the airtight drywall approach could not be consistently implemented without a quality assurance representative on site during the entire installation process and therefore was not practical. Likewise, installing the house wrap as an air barrier did have some installation challenges, particularly at porch and garage attic knee walls, but this approach was considered workable with some modification to the procedure.

5 Applying the Detailed Construction Quality Process to Existing Homes: Vented Crawlspace Example

Translating the construction quality management process to existing homes adds complexity to the general process since the existing conditions of the home will affect various details in the remodeling project. Unlike new construction where a construction detail can be specified to always be implemented, the condition of the existing home will significantly influence both the construction detail and the product selection. Further, the often direct interaction of the homeowner in the remodeling project can change the specific selection of details. For example, the homeowner may limit the amount of insulation or air sealing based on costs or time constraints and therefore change the detail specification for the remodeler.

In addition to these nuances of remodeling projects, many HPH approaches to remodeling will occur piecemeal. Many remodeling projects are undertaken on a far more limited basis than a whole-house renovation. Given this much narrower focus for many projects, the general quality process will likely also be more narrowly focused, for example, on one building feature such as the attic, basement, or kitchen.

However, with modification, the general construction quality process can be applied to and work well for existing home projects. As an example, this section details the process for a vented crawlspace renovation in PHI's BA Greenbelt Homes, Inc. (GHI) existing home test house project in the mixed-humid climate of Maryland.

When applied to an existing home, the general steps in the construction quality process do not change; however, some additional steps are necessary. The additional steps for this remodeling project are identified as an element of a larger task within the first step:

1. Establish remodeling goals
   - Inspect and evaluate the existing conditions of the project
   - Identify problems that require resolution
   - Identify existing conditions that are not intended for remodel/upgrade
   - Revise the original remodeling goals.
2. Develop remodeling specifications
3. Determine monitoring points for the remodeling project
4. Schedule monitoring points
5. Implement monitoring points.

5.1 Establish Remodeling Goals (Step 1)

As with the construction quality process for new homes, the first step for existing homes is to establish project goals during the initial project meeting. The goal of this project was to improve the energy efficiency and durability of the home's crawlspace. In this step during a renovation project, a homeowner would most likely be closely involved.

Remodeling project goals will often be initiated by the remodeler rather than by the homeowner. The remodeler may need to outline the associated costs and benefits of various alternatives (i.e., insulating the crawlspace walls versus insulating the floor above the crawlspace). While this aspect of Step 1 is not an assigned item, it is appreciably supported by having the construction quality process defined and available for consideration.

The project goals may be discussed initially in a more general way, for example, to improve energy efficiency or comfort. However, once the decision to move forward is made, a more thorough review of the actual conditions of the space will be performed. This review will lead to identification of specific conditions that may lead to a revision of the original project goals. These details are a subset of Step 1 but are important to developing a final set of project goals based on the actual conditions encountered.

A Pre-Design Assessment Checklist was developed for the GHI crawlspace upgrade project (Figure 4 and Figure 5). This checklist can be used to identify the project goals (Step 1) and develop project specifications (Step 2).

PRE-DESIGN ASSESSMENT Checklist For Crawlspace Foundation

Date 10/15/10 Time 8AM

Project & Location LH4 CLIMATE ZONE 4 By: MTDB

Page 1

Reference		Notes/Specs	Design Checklist
	Inside of House		
EP-1	Condensation on windows	YES	
EP-1	Warped wood flooring	NO	
EP-1	Visible mold	YES - ATTIC ROOF RAFTERS	
EP-1	Musty odor	YES	
	Temperature and Relative Humidity at inspection 65 °F / 50 % RH		
	Homeowner Interview - Crawlspace Use/Issues: STORMS FOR SUNROOM FALL 2010		
	Outside of Crawlspace	**Notes & Specifications**	**Sign Off**
	Input foundation wall height and other dimensions on the crawlspace section. Page 3 of PDA Checklist.		MTDB
	Measure foundation and sketch onto graph paper to be used as the design's floor plan.		MTDB
	Crawlspace Ventilation (Vented Crawlspace, ONLY)		
I-1	Ventilation grills are operative and completely exposed to ambient air.	NO — COVERED WITH MULCH/DECK BAND BDS.	
	Size of ventilation grills	16" x 8" 8 EA	
	Note: Each 1,500 sf of crawlspace area requires 1 sf of vent with vapor barrier and cross ventilation. Otherwise, 150 sf of floor area to 1 sf of vent area.		
	Crawlspace Ventilation (Closed Crawlspace, ONLY)	NO	
I-1	Ventilation grills are closed and sealed inside and out, or non-existant.		
	Note: Inspect interior for mechanical exhaust or conditioned air supply and note in Crawlspace Conditioning section.		
T-1, NA-5	**Moisture Management and Exterior Drainage**		
	Exterior grade for 10' from building	FLAT & SOMETIMES NEG. FRONT	
B-2	Note: Maintain 5% grade for 10' from building.	ONLY AT RIGHT END	
B-2	Location of downspout and sump pump outfall (Put on floor plan.)		✓
	Note: Runoff water should be directed a minimum of 3' away from building.	NEED DOWNSPOUT EXTENSIONS	
B-2	Is drainage to storm drain or daylight?	Storm Drn / Daylight ✓	
B-2, NA-4	Foundation plantings and mulch 18"-24" from exterior wall?	PLANTS MULCH & STORAGE CONTAINERS TOO CLOSE	
K-1, NA-4	Exterior insulation visible?	NO 6 1/2"	
	Durable finish above grade?	N/A	
B-1	Dampproofing on foundation wall visible?	CAN'T SEE	
B-1	Flashings at building penetrations?	SEEM OK	
	Pest Control		
	Mud tunnels indicating termites, wasps, other insect infestation?	NO	
	Feces, feathers, etc. indicating nesting of small mammals?		
	Contaminants		
EP-1	Asbestos		
EP-1	Lead paint		
	General Conditions		
	Temperature and Relative Humidity at inspection ________°F / ________% RH		
	Inside of Crawlspace (Closed and Ventilated)	**Notes & Specifications**	**Sign Off**
	Moisture Management & Interior Grade		
C-1	Wet building products - i.e. insulation, sheathing, etc.?	insulation in floor assembly in bad shape	
C-1	Sump pit location.	RIGHT REAR W/ STAGNANT H2O	
	Sump pump operable? (Sump pump is required if there is standing water in the sump pit.)	NO DOESN'T ENGAGE	
	Sketch location of interior perimeter drain on floor plan. Type?		✓
	Condensate and overflow piping - sketch locations onto floor plan.		✓
C-1	Note standing water on floor plan. Investigate and note source.	IN TRENCH - FRONT - DRAINTILE ABOVE TRENCH	
I-1	Locate ventilation grills and size on floor plan.		✓
	Automatic controls on vents?		NO
	Vapor Barrier		
B-2	Minimum 6 mil poly.	EXISTING 10 MIL EXCEPT OVER TRENCH	
B-2	Minimum 12" overlap at floor seams, taped. No tears and sealed where penetrated by pipes, etc.	NO	
B-2	Minimum 6" overlap up walls or above exterior grade level whichever is greater, taped.	NO	
E-2	**Foundation Walls**	16" x 8" x 8" CMU at 32" HIGH	
B-2	Wall construction and condition	DRY — GOOD COND.	
B-2	Wall insulation type and R-value	NONE FG IN FLOOR	
	How is insulation secured?	N/A	

Figure 4. GHI pre-design assessment checklist (p.1).

Reference	PRE-DESIGN ASSESSMENT Checklist — CRAWLSPACE FOUNDATION	LH4 10/15/10	Page 2
	Inside of Crawlspace (Closed and Ventilated)	**Notes & Specifications**	**Sign Off**
	Crawlspace Access		
I-1	Locate crawlspace entry on floor plan. Size:	24 x 32	✓
	Weathertight?	ADJACENT DOWNSPOUT LEAKING INTO CRAWL	
E-2	**Floor Assembly** (vented crawlspace)		
C-1	Inspect floor system for wood rot or mold. (Replace rotted wood. Remove mold.)	NONE	
B-3	Existing insulation type and R-value.	R11 FG BATTS — KRAFT FACE TO CRAWL	
	How is insulation secured?	BARELY — INSET STAPLED	
	Is there an air barrier at bottom of floor joists?	NO	
B-3	Air seal at floor deck? Type and condition.	NO	
B-3	Air seal at bandboard? Type and condition.	NO	
B-3	Existing insulation and type and means of fastening at rim boards	NONE	
	Foundation Hardware		
C-2	Sill plate attachment to foundation with bolts/straps at 24" o.c.	3/8" BOLTS OK	
C-2	Joists connected to sill plate with toenailed connection ___ straps ______.	N/A	
B-1	Termite shield at foundation/sill plate?	NO	
	Air & Thermal Barriers		
	Sill seal at sill plate and foundation junction? (closed crawlspace, only)	NO	
	Insulated access door (closed crawlspace, only)	NO - NOT REQ'D	
	Appliances/Mechanicals in Crawlspace -Identify all mechanical equipment located in crawlspace.		
B-1	Furnace/Air Handler/Boiler -type, location, venting. Sealed?	NOT IN CRAWL	
B-2, E-3	Are HVAC ducts sealed? Insulated?	NO	
	Water heater type. Note location on floor plan.		
	Water heater venting (if gas fueled). Insulated?		
	Dehumidifier location and drain outfall.		
	Crawlspace Conditioning		
I-1	Conditioned air source	NO	
I-1	Air exchange	VIA AMBIENT VENTS	
	Note: Conditioned air supply equal to 1 CFM per 50 square feet of crawlspace area. Or,A continuously operated exhaust fan operating at 1 CFM per 50 square feet of crawlspace area.	N/A	
	Dehumidification source	NONE	
	General Conditions	**Notes & Specifications**	**Sign Off**
	Pest Control		
	Evidence of termite trails or other insect infestation?	NO	
	Evidence of mice, squirrels, or other rodents? (Animal scat and nests)		
	Investigate method of entry.	N/A	
EP-1	**Contaminants**		
EP-1	Asbestos	NO	
EP-1	Lead paint		
EP-1	Radon		
EP-1	Carbon monoxide		
	Building product emissions (VOCs, formaldehyde)		
	Poisons for termite or rodent control.		
	Working Conditions/Work Protection Requirements		
	Adequate light?	WILL REQUIRE ADD'L	
	Adequate area to perform work? Explain height and obstacles.	TIGHT — CONTRACTOR TO INSPECT	
NA-3	Insulation or debris on floor of the crawlspace?	YES - FG BATTS	
	Are there electric meters, communications wiring, etc. Where? Do they require protection during upgrades?	COMM. WIRES	
	Temperature and Relative Humidity at inspection ________°F / _______% RH		

Figure 5. GHI pre-design assessment checklist (p.2).

Based on a thorough review of the existing conditions, the project goals may be modified to resolve unanticipated problems or to better improve the performance of the space.

5.2 Develop Remodeling Specifications (Step 2)

For remodeling conditions, Step 1 necessarily includes determining existing conditions so that a detailed specification can be developed that correctly reflects the improvements to be made in Step 2. This may be very specific to almost every new project; however, where generic drawings can be used to establish overall goals, these can aid in outlining the potential extent of the specifications. Figure 6 shows an example of a simple drawing that was used to help specify the extent of the work to be performed for the GHI project so that all trade contractors could understand their role and make accurate estimates of time and cost.

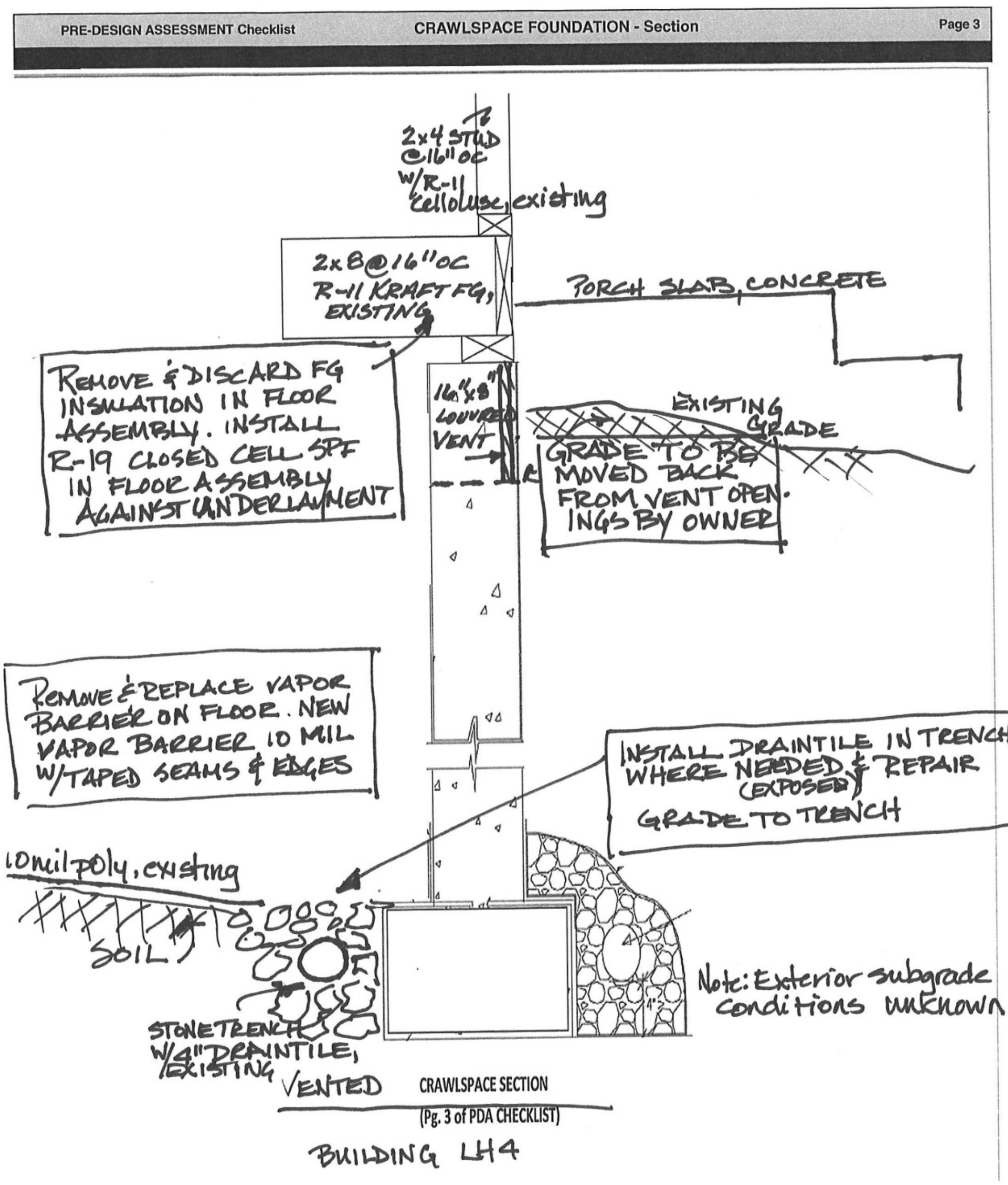


Figure 6. GHI vented crawlspace pre-design assessment (p.3).

Once the existing conditions are known and documented, an outline of work scope can be established in conjunction with the building's owner. From this, detailed specifications can be developed to meet the project's goals. The specifications that were developed for the GHI existing home vented crawlspace are outlined in Table 5 (NAHB Research Center May 2012).

Table 5. Detailed Specifications.

VENTED CRAWLSPACE SPECIFICATIONS		
Outside of Crawlspace	**Existing**	**Responsible Party & Repair**
Moisture Management & Exterior Drainage		
Exterior grade	Several front vent grilles blocked with mulch build up	Owner will remove mulch and repair grade for positive flow away from front foundation
Rear left downspout extension	6 in. elbow to 2 ft. splashblock	Owner will extend downspout 3 ft–5 ft away from building and crawlspace access
Grade at crawlspace access	Grade and downspout channeling water into crawlspace door hatch at left side rear	Owner will repair grade for positive flow away from crawlspace access
Inside of Crawlspace	**Existing**	**Responsible Party & Repair**
Moisture Management and Interior Grade		
Sump pump and pipes	Standing water in pit; unable to engage pump	Owner will repair sump pump
Perimeter drain tile/trench	Some of the drain tile pipe is above the stone in the drainage trench	Contractor will place drain tile into stone trench and repair grade in and around trench to promote drainage to sump pit
Ventilation grilles	Rear vent grille has fallen out of opening in concrete masonry unit	Contractor will install left rear vent grille with existing or similar replacement
Vapor barrier	Discontinuous at stone trench. Seams are not taped and overlaps at walls/columns are not taped	Contractor will add 10 mil material from existing vapor barrier, across stone trench and 6 in. up wall. Tape all seams and edges.
Insulation in floor joists	R-11 fiberglass batts; falling out and incorrectly installed	Contractor will remove and discard all existing insulation from joists and crawlspace
		Contractor will install R-19 SPF and thermal/ignition barrier as required by manufacturer

5.3 Determine Monitoring Points for Remodeling (Step 3), Schedule Monitoring Points (Step 4), and Implement Monitoring Points (Step 5)

PHI developed a comprehensive construction monitoring table that combines specifications, monitoring points, scheduling, and implementation. This comprehensive table (Table 6) provides a simple method for tracking the construction or remodel quality process.

For the GHI vented crawlspace, 20 monitoring points were identified consisting of four reviews, 14 documentation points, and two tests. This checklist was helpful to review and document progress and verify that specifications were followed. The checklist has areas for the installer and inspector to initial and date during the post-retrofit inspection. Finally, the performance test results will be used to evaluate whether project goals were met.

Table 6. Comprehensive Construction Monitoring Table for a Crawlspace Energy Retrofit.

CONSTRUCTION MONITORING **Existing Vented Crawlspace Foundation** *Date 08/20/12*			**Project & Location:**	**Building LH** **Greenbelt, MD (CZ4)**				
Specification			**Monitoring Checkpoint (Review, Document, or Test)**	**Details/ Results**	**Schedule**	**Date**	**Installer Initial/Date**	**Inspector Initial/Date**
Plans have been reviewed and will be on the job at all times			**R**					
SOW has been reviewed and will be on the job at all times			**R**					
Insurance requirements see RFP and contract documents			**R**					
Access to crawlspace provided by owner			**R**	*24 hr notice* *8 am - 5 pm*				
Power provided by one 110 Volt receptacle in crawlspace			**D**	*Additional by contractor*				
Contractor to provide adequate lighting to perform and inspect the work			**D**					
Contractor to specify and supply all safety equipment necessary for performing the work and assures OSHA, state and local safety standards are met			**D**					
Contractor warrants that labor is trained in installation practices specified by the product manufacturer(s) and jobsite safety standards			**D**					
Subcontract trades: *None*								
Outside of Crawlspace	**Existing**	**Repair/Upgrade**						
Crawlspace Ventilation	3 ft^2 required; calculated vent area of 3.6 ft^2 clear	None Required						
	1 rear vent grille fell out of opening	See below under VENTILATION GRILLES						
Overhangs	1 in. and 5 in. gutters	None Required						
Moisture Management and Exterior Drainage								
Exterior grade	Several front vent grilles blocked with mulch build up	Remove mulch and repair grade for positive flow away from foundation (front)	**D**	*Owner to repair*				
Overhangs		No action						
Gutters, sump outflow	Gutters 5 in.	No action						

Outside of Crawlspace	Existing	Repair/Upgrade						
Rear left downspout extension	6 in. elbow to 2 ft splashblock	Extend downspout 3 ft–5 ft away from building and crawlspace access	**D**	*Owner to repair*				
Grade at crawlspace access	Grade and downspout channeling water into crawlspace door hatch at left side rear	Repair grade for positive flow away from crawlspace access	**D**	*Owner to repair*				
Foundation plantings, mulch	Shrubs and mulch within 0 in. of foundation	No action		*Owners and occupants to address*				
Foundation insulation and finish	None	No action						
Foundation dampproofing		No action						
Flashings at building penetrations	Generally in good repair	No action		*Review again at siding phase*				
Pest control		No action						
Contaminants		No action						
Inside of Crawlspace	**Existing**	**Repair/Upgrade**						
Moisture Management and Interior Grade								
Sump pit or floor drain	Yes	No action						
Sump pump and pipes	Standing water in pit; unable to engage pump	Repair sump pump	**D**	*Owner to repair*				
Inside of Crawlspace	**Existing**	**Repair/Upgrade**						
Perimeter draintile/trench	Some of the drain tile pipe is above the stone in the drainage trench	Replace drain tile into stone trench and repair grade in and around trench to promote drainage to sump pit	**D**					
Ventilation grilles	Rear vent grille has fallen out of opening in CMU	Install left rear vent grille with existing or similar replacement	**D**					

Vapor Barrier	Discontinuous at stone trench. Seams are not taped and overlaps at walls/columns are not taped	Add 10 mil material from existing vapor barrier, across stone trench and 6 in. up wall. Tape all seams and edges.	**D**					
Foundation Walls	16×8×8×32-in. CMU; dry cond. and good repair.	No action						
Air barrier	Not required - vented foundation	No action						
Thermal barrier	Not required - vented foundation	No action						
Ignition barrier	Not required - vented foundation	No action						
Floor Assembly	2×8 at16 in. on center	No action						
Insulation in floor joists	R-11 FG batts; falling out and incorrectly installed	Remove and discard all existing insulation from joists and crawlspace	**D**					
		Install R-19 SPFcc and ignition barrier as required by manufacturer	**D**	**Name manufacturer and thickness**				
Air barrier		Provided by 3 in.+ of SPF_{cc}	**T**					
Thermal barrier		Supply and install as required by manufacturer						
Ignition barrier		Supply and install as required by manufacturer						
Load Path Tie Down Hardware		No action						
Crawlspace Conditioning	None - ventilated	No action						

General Conditions	Existing	Repair/Upgrade						
Remove debris			D					
Building permit by owner				*No permit required*				
Building inspections scheduled and attended by subcontractor				*No permit required*				
Long-term monitoring	Ongoing	No action	T	*Continue*				

6 Conclusion

A comprehensive construction QMS process that establishes performance goals and outlines inspection points for verifying progress toward those goals has been successfully demonstrated on the two HPH projects by K. Hovnanian that are subjects of this report. Subsequent to its application in new home construction, the same QMS process was adapted for use in a foundation retrofit project to incorporate high performance details in existing homes. To encompass all of the details unique to existing houses, a thorough inspection and detailing of existing conditions was added to the first step of project goal establishment. The following steps and components recap the QMS process for high performance existing homes that was presented herein:

1. Establish remodeling goals
    - Inspect and evaluate the existing conditions of the project
    - Identify problems that require resolution
    - Identify existing conditions that are not intended for remodel/upgrade
    - Revise the original remodeling goals.
2. Develop remodeling specifications
3. Determine monitoring points for the remodeling project
4. Schedule monitoring points
5. Implement monitoring points.

The project goals are identified by stakeholders during the first step of the QMS process. In an existing building, the first step necessarily includes a thorough inspection and identification of existing conditions. The existing conditions become the blueprint for further action or inaction, and observed conditions requiring remediation are added to project specifications. For both remodeling and new construction projects, the second step requires a collaborative effort among owner or builder, designer, and teams that will be participating in the construction—either as component or trade labor suppliers.

The monitoring points that are established, scheduled, and acted on in steps 3 through 5 will define the tasks and trades required to implement the specifications and eventually measure progress toward the project goals while there is time and access for remediation. Monitoring reviews can be used to hone details and ensure team members agree on scope and responsibilities prior to commencement of a phase of the project. Documentation points are used to inspect and verify the work, and allow the opportunity to make timely corrections if necessary. Test points identify physical tests required to evaluate the project's performance.

The comprehensive construction monitoring table (Table 6) that was developed for the retrofit of an existing home's foundation provides a template for application of this QMS process of monitoring checkpoints to an existing home energy retrofit. The table can be adapted to cover many other high performance existing building components and facilitate a quality-oriented, well-defined, approach to creating design specifications, assigning responsibilities among construction teams, and measuring progress toward project goals consistently in remodeling projects.

References

NAHB Research Center (2009). NAHBRC 4.3.1.1 – Gate 2 - Prototype House Evaluations: ZEH2 (JWM Companies), Green Home 1 (LCCTC), & Monmouth HPH (K. Hovnanian NJ Division).

NAHB Research Center (2010). NAHBRC 4.5.2 – Quality Assurance Activities for New Homes (Interim Project Report) (Economics of Quality, Veridian Homes Case Study, Crawlspace SOW, Hotspot Implementation Guide & Tools).

NAHB Research Center (2012). Quality Management Primer for High Performing Homes (Quality Assurance Strategy for Existing Homes). April 2012. Accessed at: http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/qual_assur_strategy_exstg_hms.pdf.

NAHB Research Center (2012). Energy Efficient Crawlspace Foundation Retrofit – Mixed Humid Climate. May 2012. Accessed at: http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/crawlspace_found_retrofit.pdf

Appendix A: K. Hovnanian Homes Jockey Club High Performance Home Specifications[4]

Shell Specifications

- Factory built wall panels: 2×4 studs, 16 in. on center, double top plates
  - Cavity insulation: R-13 fiberglass batts (same as standard practice)
  - Interior walls held 1 in. from exterior walls for continuous drywall
- Structural Insulated Sheathing (SIS) 1-in. thick R-5.5 panels (standard practice: OSB and felt paper) to provide an exterior air barrier, drainage plane, and thermal break
- Slab on grade: R-10 slab edge, R-5 slab 24 in. perimeter insulation
- Roof truss
  - Raised heel
  - Simplified: tray and coffered ceilings framed on site
  - HVAC duct chase
- Attic insulation: R-49 blown fiberglass (standard practice: R-38)
  - Additional draft stopping at attic insulation edges
- Windows: 0.34 U-factor and 0.26 SHGC (standard practice: 0.37 U-factor)
- Air sealing
  - SIS panels: factory installed gaskets at top and bottom plates and taped seams provide exterior air barrier
  - Seal garage-side drywall of walls common to conditioned space
  - Spray foam top plates and HVAC supply trunk and register boots from the attic
  - Air barriers at framed cavities (fireplace, dropped ceilings, behind tub)
  - Thermal bypass checklist
  - Recessed ICAT lights sealed to sheetrock using gasket-tape

HVAC Specifications

- Heating
  - Gas furnace and coil installed in conditioned space (standard practice: installed in attic)
  - 95% AFUE 2-stage, variable speed 46,000 Btuh gas furnace (standard practice: 92% AFUE, 92,000 Btuh)
- Cooling
  - 15 SEER, 2.5-ton cooling system (standard practice: 13 SEER, 4-ton)
- Ventilation
  - Honeywell VisionPRO IAQ programmable thermostat and equipment interface module
  - Honeywell fresh air damper (standard practice: bath exhaust fan for mechanical exhaust ventilation)
  - Honeywell MERV 13 media air cleaner (standard practice: 1 in. throwaway filter)
  - Fantech multi-point bath exhaust fan system (standard practice: individual bath exhaust fans)

[4] Project details can be found in NAHB Research Center (2011). NAHBRC-IP Deliverable 11.2.2 – Final "Best in Class" Report, Energy Efficient Exterior Wall Design. November 2011.

- Ducts
  - Simplified HVAC central return in conditioned space with bedroom transfer grilles (standard practice: ducted returns in each bedroom, ducts in attic)
  - Simplified HVAC metal supply trunk and flexible branches in attic; R-8 insulation; deeply buried; 1 in. closed cell spray polyurethane foam (SPFcc) foam over trunk and register boots; truss chase (standard practice: attic duct system using all flexible duct hanging from roof trusses)
  - Hart and Cooley 92HVO supply diffusers with 9200V opposed blade dampers (standard practice: Hart and Cooley 661)

Plumbing and Water Heating Specifications

- Water heating
  - Navien 0.98 EF direct vent water heater (standard practice: AO Smith Vertex GPHE-50, 0.74 EF)
  - Centrally located water heater
- Fixtures
  - Low flow lavatory faucets, shower heads, and water closets

Lighting Specifications

- Fixtures
  - ENERGY STAR light fixtures (minimum of three required)
- Bulbs
  - CFL bulbs in all standard screw base fixtures
  - Dimmable CFL bulbs and ICAT fixtures

Whole House Energy Monitoring Specifications

- The Energy Detective (TED)

Photovoltaic System Specifications

- 4.2 kW

Appendix B: NCTH Example Review Detail

K. Hovnanian Jockey Club HPH
Construction Change Monitoring
Activity 9: Review Insulation Installation
May 22, 2009

Air Sealing Details by Insulation Trade Partner

Before drywall:

- ☐ Caulk sill sealer at interior bottom plate of exterior wall panels (see figure 1)
- ☐ Foam or caulk vertical joints between exterior wall panels as required
- ☐ Foam electrical and plumbing penetrations (recommend behind electrical boxes)
- ☐ Foam window and door jambs (low expanding foam)
- ☐ Seal framed cavity air barriers:
  - ☐ All coffered / dropped ceilings at trusses and exterior walls (see figure 2)
  - ☐ Framed fireplace enclosure at trusses
  - ☐ Behind tubs on exterior walls (see figure 3)
  - ☐ Garage wall air barrier (see figures 4, 5, and 6)
  - ☐ Front porch / attic plane (see figure 7)

Thermal Bypass Checklist Inspection

After drywall:

- ☐ Spray foam insulation, 1 in. thick closed cell, all top plates from attic
- ☐ Spray foam insulation over HVAC attic supply trunk and ceiling register boots
- ☐ Spray foam insulation at furnace closet ceiling penetrations
- ☐ Caulk or foam plumbing penetrations on exterior walls, before cabinets
- ☐ Caulk drywall at recessed lights (in addition to gasket)
- ☐ Caulk drywall at HVAC register boots and bath exhaust housings (HVAC contractor)
- ☐ Garage-side drywall air sealing (drywall trade partner)

Insulation Details

- ☐ Install per K. Hovnanian specifications
- ☐ Install per Thermal Bypass Checklist
- ☐ Install per RESNET Grade I Installation (attachment)
- ☐ Walls: R13 fiberglass batts
- ☐ Ceiling: R49 blown fiberglass
- ☐ Deeply buried duct:
  - ☐ Recommendation: install stake flags to indicate location of buried duct
  - ☐ Blown insulation must cover the top of all ducts by a minimum of 3.5 in.


Figure 1


Figure 2


Figure 3

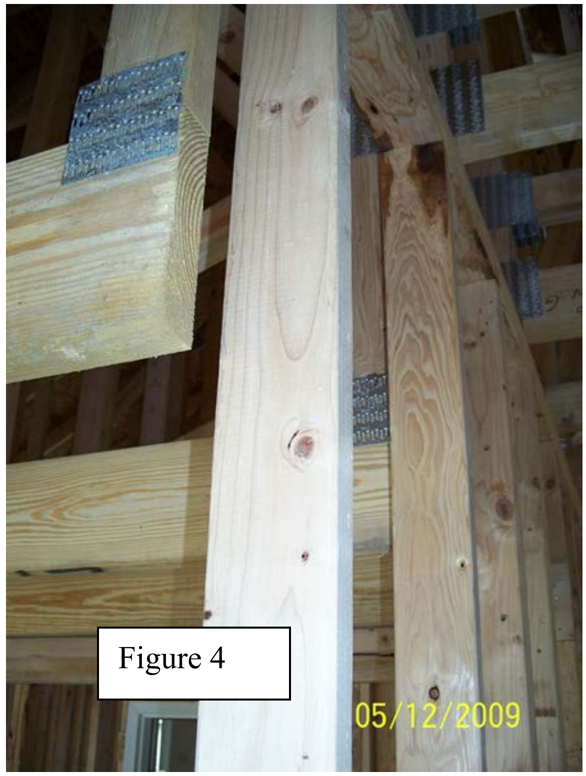


Figure 4


Figure 5

Figure 6

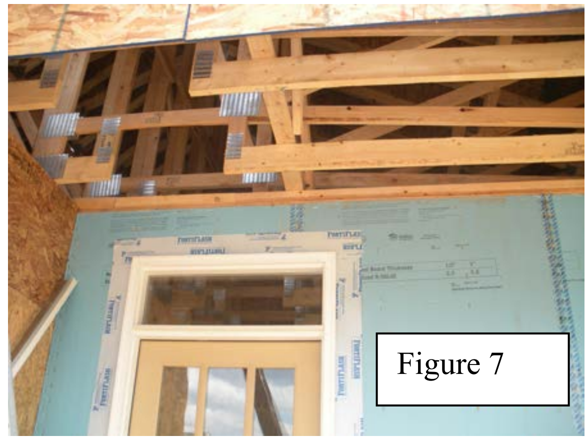


Figure 7

Appendix C: K. Hovnanian Homes Jockey Club Performance Test Results

K. Hovnanian Jockey Club HPH Testing Results

Air Leakage Performance

- Thermal envelope air leakage test (blower door)
  - HPH: 900 cfm50 (0.36 cfm/100 ft^2; 2.4 ACH50)
  - Community Model House: 2,717 cfm50 (1.09 cfm/100 ft^2; 7.25 ACH50)
  - Rough-in before foam at HPH (top plates and supply trunk duct): 3,124 cfm50
  - Rough-in after foam at HPH: 1,309 cfm50 (Note: register boots were not foamed and bath exhaust fans and recessed lights were not sealed at this point)

Duct Performance

- Duct leakage test (duct blaster)
  - HPH: 22.5 cfm25 total
  - Model: 165 cfm25 total and 74 cfm25 to outdoors
  - Rough-in supply duct (no equipment or return duct): 25 cfm25 total
  - (Note: rough-in test was before foaming of trunk and supply register boots)

- Approximately 40% less measured duct material area in the HPH than the model home
  - Approximately 70% less return duct material
  - Approximately 28% less supply duct material
- Air balance testing
  - Total air flow and air flow balance measured within ACCA HVAC Quality Installation Specifications
  - Example result: Master bedroom actual air flow in the Model home is 57% of design; the master bedroom in the HPH slightly exceeds design needs

Long-term Monitoring

- Energy and performance monitoring (ongoing):
  - Indoor, outdoor, attic, plenum, and buried duct temperature and relative humidity
  - Air handler, compressor, and whole house energy consumption

Certifications and Ratings

- HERS index: 41 with PV; 60 without PV
- Building America 40% energy savings home
- National Green Building Standard Bronze Performance Level Home
- Builders Challenge Award

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

DOE/GO-102013-3859 ▪ August 2013

Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 10% post-consumer waste.