

***Final Report on the Expert Meeting for  
Details for Deep Energy Retrofit***

**Building Science Corporation Industry Team**

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## **EXECUTIVE SUMMARY**

1. Title: Final Report on the Expert Meeting for Details for Deep Energy Retrofit
2. Overview: The Building Science Consortium held an Expert Meeting on Details for Deep Energy Retrofit on 12 March 2010 at the Seaport World Trade Center in Boston, Massachusetts. Invited speakers gave presentations in their particular area of expertise. Speakers included Dr. Joseph Lstiburek, Dr. John Straube, Kohta Ueno and Chris Schumacher of Building Science Corporation, Paul Eldrenkamp of Byggmeister, Marc Rosenbaum of Energysmiths and James Petersen of Petersen Engineering.
3. Key Results: Key results from this meeting were identification of knowledge gaps within the industry to be addressed, research gaps, and code constraints.
4. Conclusions: The key knowledge gaps within the industry that remain to be addressed concern a) the required permeability of components and assemblies in various retrofit details, b) that less insulation to the exterior presents a greater durability risk than thick insulation such as may substantiate a deep energy retrofit, c) details to maintain bulk water management in assemblies and details, d) effective strategies to provide air flow control and transition air flow control between assemblies; e) details for phased retrofit that anticipate future treatment of components; f) appreciation for the relative risk of uninsulated basement and crawl spaces; and g) enumeration of common risk factors and failure mechanisms pertaining to retrofit assemblies.

Key research gaps include a) attachment of cladding, porches, and overhangs over thick exterior insulation; b) transition of drainage and airflow control functions at windows, roof-wall interface, and above grade wall to foundations; c) coatings that significantly reduce wetting of brick masonry without changing the aesthetics, but do not reduce vapor drying of the brick to levels that would cause damage; d) methods to address vulnerability of wood structural elements embedded in insulated masonry assemblies; e) effective and safe insulation and air separation at basement/crawl space ceiling; f) for common foundation materials, identify above-grade exposure beyond which a capillary break between the foundation and sill is no longer necessary; g) structural window attachment in high R wall assemblies; h) methods of implementing air flow control systems on board sheathing; i) appropriate retrofit mechanical systems for high performance retrofits; j) appropriate mechanical strategies for phased retrofits.

The identified building code constraints concern a) permeability requirements that address requirements for specific materials whereas the designer is ultimately responsible for the performance of the assembly; b) fire protection needs for insulations used in foundation wall assemblies; c) fire protection needs for insulation used in above grade masonry wall assemblies; and d) ambiguity in codes that allow basements and crawl spaces to be only partially excluded or partially included in conditioned space.

## INTRODUCTION

The Building Science Consortium held an Expert Meetings on Details for Deep Energy Retrofit on 12 March 2010 at the Seaport World Trade Center in Boston, Massachusetts. There were 65 individuals in attendance. Betsy Pettit, FAIA and president of Building Science Corporation, formally opened the meeting by welcoming attendees and describing the desired participation of attendees. In doing so, she also made it clear that the session would address retrofit details for a cold climate. Ms. Pettit also made it clear that the meeting is to address *deep* energy retrofit measures and not minor measures.

Invited speakers gave presentations in their particular area of expertise. The presentations were followed by discussion with the expert audience. Questions and comments were also entertained during the course of presentations.

A summary of the individual presentations and major discussion points is provided in the sections below.

The final agenda for the meeting is listed in Appendix A. A list of attendees for the meeting is given in Appendix B. The presentations are included in Appendices C through J.

## PRESENTATIONS

### **Speaker 1: Dr. Joseph Lstiburek, Building Science Corporation**

Presenter bio: Dr. Joseph Lstiburek is a principal of Building Science Corporation and an ASHRAE Fellow. He has twenty-five years of experience in design, construction, investigation, and building science research. Through the Department of Energy's Building America program, Dr. Lstiburek has forged partnerships with designers, builders, developers, materials suppliers and equipment manufacturers to build higher performance homes across the U.S.

Presentation Title: *Roof/ Re-cladding Options*

#### Presentation Summary:

Dr. Joseph Lstiburek led a discussion of roof retrofit strategies and presented images of retrofit details. The images that Dr. Lstiburek presented provided examples of compact (unvented) roof strategies. These images helped to spark a discussion of various high performance roof retrofit considerations. The discussion addressed water vapor diffusion control and air flow control in retrofit roof assemblies. Dr. Lstiburek also outlined the evolution of flat roof technology to compact sloped roof assemblies pointing out that much has been learned about these roof applications and that lessons from new construction are largely transferable to retrofit. A significant amount of the discussion considered the suitability of various building materials to perform critical functions within the roof assembly.

Dr. Lstiburek also used images of roof details to present challenges to- as well as strategies for transitioning air flow control function from the roof to the wall.

Dr. Lstiburek made the following key points during his presentation:

- Improving the thermal performance of a roof assembly will significantly reduce energy flows that may have previously compensated for various flaws in the system. Therefore, retrofit measures to significantly increase insulation in the roof assembly must also provide more robust water management.
- Air-transported moisture (air flow control) is more important to moisture management than vapor diffusion, hence the need for air impermeable materials and air-tight assemblies to control condensation in compact roof assemblies.
- Closed-cell spray foam insulation does not elevate the risk of damage from roof leaks relative to open-cell spray foam. The vapor permeability of open-cell spray foams does not appear to be a factor in mitigating damage from roof leaks.
- In climate zones 6 and above, a vapor control layer must be added to assemblies that employ open-cell spray foam in a configuration with all of the insulation below the roof deck. Open cell foams in compact roof assemblies may require supplemental vapor control layers in climate zones 4 and 5 depending upon the interior conditions, construction of the roof and other factors.
- Transitioning the air control layer from the roof to the wall can be very challenging with the insulation above the deck and air permeable insulation materials below the roof deck. The challenge is largely due to the framing that interrupts a simple or planar transition.
- The “chain saw” retrofit strategy (removing roof projections to allow a membrane to wrap from the wall onto the roof) is very robust in terms of air flow control because it offers a very effective means of transitioning the wall air control layer to that of the roof. However, some will object to removing character-defining details even if they are to be rebuilt or replaced.
- A cavity fill insulation permeability of 3-4 perms is a desirable characteristic.

#### Questions, comments and responses

Dr. Lstiburek led a lively and broad discussion, with participation from the assembled experts in the audience. The following summarizes relevant questions, comments, and elicited responses.

- Question: Does an unvented roof assembly necessarily employ spray foam insulation?  
Reponse: No. For example, with insulation exterior to the roof deck, virtually any insulation works underneath the deck (that is, insulation below the roof deck need not be air impermeable or offer significant vapor diffusion control in this configuration). Board foam in conjunction with sealants or tapes may also be used as the air impermeable insulation below a roof deck. It is also appropriate to use a “flash” application of spray foam below the deck (for airflow control and vapor control) and then provide the balance of the insulation with an air permeable insulation material.
- Comment: Massachusetts State Building Code addresses permeability as a matter of material/component property not an assembly property. Response: The building code takes the wrong approach. It is the assembly permeability that matters.
- Comment: Application of air-impermeable cavity insulation does not, itself, comprise an effective air control system. This was evidenced by the field experience of the participants, which included observations of significant air leakage at sistered framing members, as an example. Response: (consensus).

- **Comment:** A representative from a cellulose manufacturer noted that dense pack cellulose was not offered as an option for a compact roof assembly in the presented details. The representative posited that unvented, dense-packed cellulose roof assemblies have worked successfully in cold climates. **Response:** There was polite disagreement as to whether there have ever been instances of moisture problems related to using cellulose as the sole thermal control layer in a compact roof assembly in cold climates. Participants agreed to be more diligent about assembling documentation of purported problems.
- **Question:** Are open cell foams more appropriate for compact roof assemblies than closed-cell foams because the open cell foams allow some drying in the case of a leak? **Response:** (Straube:) In ~20 years of people using closed-cell foams in a compact roof assembly, there is not a body of evidence to suggest this system has inherent problems. (Lstiburek:) The few cases of which he is aware of compact roof assemblies that had problems were in Florida involved open-cell foams. (Schumacher: ) Closed-cell foams can help to contain a leak-induced moisture/rot problem to a small area. (consensus) roof leaks are to be fixed before the roof is insulated.
- **Question:** Do compact roof assemblies employing open cell foams require a vapor control layer? **Response:** Yes in Zones 6 and higher, probably 5 as well. Direct applied vapor retarder paints have not provided rated perm ratings in lab trials. Dr. Lstiburek recommends drywall in contact with foam and painted with a vapor control primer. In this configuration, the drywall must cover and be in contact with the insulation over the entire area of insulation application, including behind kneewalls and above flat ceilings.
- **Question:** What about slate roofs? **Response:** All roof claddings should be drained and preferably, back-vented and drained. Yes, slate shingles leak water. So do asphalt shingles and cedar shingles: we need a drainage layer behind the roof cladding.
- **Question:** What if you can't fix a slate roof because of historic considerations when it shows evidence of previous liquid water leakage but is not necessarily damaged? **Response:** If the roof is leaking, then one should be permitted to fix it. If, for some reason, it is not possible to fix a leaking roof, then the insulation should not be installed in plane with the roof—don't do a compact roof.
- **Question:** Is it better not to vent a roof? **Response:** I like to vent whenever I can. But when roof venting cannot be done so that it will be effective or when it is difficult (e.g. with hipped roofs or multiple dormers) it is better to have an unvented assembly.
- **Question:** Is it a concern to have board roof sheathing sandwiched between SPF and board insulation? **Response:** It is not a concern for a roof because there is no air transport mechanism (for interior air). It is possible to adequately control air transport in a roof assembly but this is not reasonable to expect to be able to achieve this in a wall assembly. In a wall assembly, it is recommended to have a hygric re-distribution layer between the sheathing and the cladding. Similarly, when closed-cell SPF is used for rim joist air sealing and insulation, it is advisable to provide for drying or, at least, redistribution outside of sheathing.

**Speaker 2: Dr. John Straube, Building Science Corporation**

Presenter bio: Dr. John Straube is a principal of Building Science Corporation and a professor of building science in the Civil Engineering Department and School of Architecture at the University of Waterloo, Canada. Dr. Straube has acted as an

educator, researcher, consultant and expert witness on energy efficiency, durability and IAQ. Current interests include the optimal system design of buildings, sustainable buildings, and moisture problem avoidance.

Presentation Title:        *Walls / Re-cladding Options*

Presentation Summary:

Dr. John Straube led a discussion of wall retrofit strategies and presented images of retrofit details. He noted that walls tend to have greater aesthetic significance than roofs. Therefore, customer desires in terms of appearance tend to carry greater weight in decision processes. Images presented by Dr. Straube also demonstrated window details and above grade wall-to-foundation wall transition details.

Dr. Straube confirmed what was laid out in the meeting introduction regarding the thermal performance levels implied in a deep energy retrofit. He indicated that the target effective insulation level for a wall assembly should be in the neighborhood of R-40, and that a guiding concept of a deep energy retrofit should be to extend the viability of the building 50 to 100 years into the future. Dr. Straube reviewed options for- and limitations of wall cavity insulation. Similarly, options and limitations of board foam and spray foam products were also reviewed. The discussion delved into the impact that adding significant levels of insulation have on the moisture dynamics of wall assemblies.

Dr. Straube opined that deep energy retrofits do not “pencil out” (from a strict cost accounting perspective) on energy savings alone. A comprehensive DER will essentially renew – both functionally and aesthetically – many of the important systems of a house. He made a comparison to building a new house and observed that one would not expect energy savings from constructing that house a particular way to pay for the new home. Regarding a particular retrofit case example, Dr. Straube suggested that the energy savings from the added exterior insulation could not pay for the new cladding, but the savings from the added insulation could support the incremental installed cost of the insulation.

Dr. Straube made the following key points during his presentation:

- Cavity insulation can improve thermal performance and air flow control, but the improvements possible with cavity insulation are not enough.
- Relative to the goals of deep energy retrofit, the performance of cavity insulated 2x6 walls is approximately the same level as that of cavity insulated 2x4 walls. The maximum thermal performance of both options is inadequate.
- Improving rain control is an essential component of wall retrofit. Retrofit of cavity insulation alone is limited in that it does not afford the opportunity to improve rain control.
- Insulating walls makes things wetter—the critical question is whether it makes things too wet.
- Foam stops air and slows vapor. The challenge of using foam in a retrofit strategy is getting it everywhere when the strategy relies upon it for airtightness and vapor control.
- Adding board foam to the interior of a wall assembly is rarely recommended. This strategy is described as delivering the “lowest bang for the buck” and is compromised by

intervening partitions and floors. The board foam interior application tends to leave large air leaks unresolved and also places the framing in a more vulnerable situation, with respect to moisture.

- With exterior insulation, any reasonable level of insulation can be provided.
- A retrofit involving the application of exterior insulation typically provides the opportunity to improve water control, air control, and vapor control of the assembly.
- Face sealing of exterior insulation is not sufficient to achieve airflow control and drainage. An air flow control system and drainage plane/water control layer should be implemented behind the exterior insulation.
- An intermediate drainage gap may be incorporated outside of the existing sheathing (inboard of the exterior insulation). This should be considered.
- There are no real technical problems regarding the installation of cladding over thick exterior insulation, but there are perceptual problems. Installation over insulation layers thicker than ~1-1/2" starts to encounter the perceptual hurdles. There are concerns about compression of foam but 15 PSI is actually quite adequate for most situations – i.e. 15 PSI > 2000 PSF.

#### Questions, comments and responses

Dr. Straube entertained questions throughout his presentation and encouraged meeting participants to contribute to the discussions. The following summarizes relevant questions, comments, and elicited responses.

- Question: Should we be concerned about the service life of [housewrap] as an air barrier? Response: The major damage factors are UV radiation, elevated temperature and reactive chemicals. Having the [housewrap] behind insulation will certainly enable it to last longer. Equally important, the tapes and sealants that enable the [housewrap] to function as an air control system will also last longer behind insulation.
- Question: can a window be installed in such a way that the flashing can be integrated at a later date with a new drainage plane when cladding is removed? Response: Perhaps this could be done. Perhaps if one cannot afford to rip off the cladding, it would be better to just wait.
- Question: Can a Larsen truss exterior wall assembly filled with cellulose insulation be used to provide significant insulation to the exterior of a structure? Response: With a Larsen truss, cellulose and sheathing on the outside, the sheathing is actually colder than ambient air because of radiation transfer. Therefore there is a condensation risk for the exterior sheathing in this situation.
- Comment: Condensation risk would appear to be bad news for SIPS. Response: It would be very risky to have cedar siding directly against a vapor open layer—i.e. housewrap—which is directly against sheathing with low drying potential—i.e. OSB with foam directly against it. In such situations, the OSB will tend to rot.
- Comment: The foil-facing on insulating sheathing makes me nervous. This is a vapor barrier. Response: Yes, it is risky if the insulation board is thin, with a 4" layer of [polyisocyanurate] insulation there is very low risk, due to the elevation of the condensing surface temperature. However, there are risks associated with bulk water control, if it is not correctly addressed during the retrofit.

- Question: Is there a concern about the longevity of tape on the face of exterior insulation in light of the fact that the panels expand and contract? Response: Yes this is a concern. That is why it is important to have a good air flow control system and drainage plane behind the exterior insulation.
- Question: Why stop at a merely “deep” retrofit? Is there a threshold after which there is no need for mechanical systems? Response: There is no such threshold and it is not productive to minimize systems further because below 40kBtu/h equipment is more expensive (and less commonly available) and it is difficult to dehumidify.
- Question: Do mechanical systems that could take advantage of drastically reduced loads exist in the US? Response: Yes and no. How much insulation does one need to eliminate the hot water load? (Rosenbaum) A big difference encountered in the US is the preference for cooling. It is unlikely that point source cooling is going to be effective, and cooling on the back of ventilation provides very low capacity within a reasonable range of ventilation flow.

**Speaker 3: Chris Schumacher, Building Science Corporation**

Presenter bio: Chris Schumacher is recognized as an expert in the field of building monitoring and building systems and enclosure testing. He has lead the design, installation and analysis of monitoring systems for 15 building enclosure test facilities, 6 test building sites, 3 climate chambers and 2 sustainable building technologies demonstration projects in over a dozen states and countries as far abroad as Mongolia and New Zealand.

Presentation Title: *Testing Brick Units Before Insulating Walls*

Presentation Summary:

Mr. Schumacher offered a presentation on techniques to assess the freeze-thaw risk in existing masonry assemblies. He noted that there is a large population of existing masonry buildings of various types. He observed that many of these buildings are in good condition and offer flexibility in how the interior space might be used. Thus they seem likely candidates for reuse and renovation provided they could be insulated for comfort and energy performance. Exterior insulation would provide excellent durability of the structure, but it typically not an option, due to aesthetic and historic concerns. Interior insulation, on the other hand, creates concerns about freeze-thaw damage particularly if the interior bricks would be subject to freezing temperatures.

Mr. Schumacher described a procedure for precisely determining material properties of masonry materials that are relevant to their freeze-thaw behavior. Mr. Schumacher then outlined a risk assessment methodology that uses the empirically determined material property data in combination with hygrothermal models to estimate the likelihood that a particular masonry assembly will sustain damage if it is insulated. This methodology is effectively a limit states design approach to the problem (as commonly used in fields such as structural engineering): it compares the load (exposure of the assembly to moisture and temperature cycles) with the material’s ability to resist these loads.

Mr. Schumacher noted that this method is not a perfect prediction of risk, but asserted that it is a significant improvement over previous methods which did not incorporate the material property testing that he described. The outlined methodology determines capacity of the sample bricks to

withstand freeze-thaw cycles—a heretofore elusive determination in risk assessment. However, knowing the rain loading upon surfaces of a building remains a conundrum. Mr. Schumacher advises that this type of brick materials testing always be combined with thorough visual assessment of the building.

Some of the key attributes of the brick testing procedure are:

- Representative samples taken from every wythe of the assembly
- Liquid water uptake with surface water contact measured (A value;  $\text{kg}/(\text{m}^2 \text{ hr}^{1/2})$ )
- Saturation moisture content is measured using a vacuum saturation apparatus. Testing found significant differences (up to 20%) in saturation moisture content between the standard boil test (as used in the cold soak/boil test, to determine the c/b ratio) and this vacuum saturation method.
- Saturated brick is sealed and temperature cycled above and below the freezing point ( $20^\circ \text{C}$  to  $-15^\circ \text{C}$ )
- Strain of brick is measured after temperature cycling the saturated brick; the critical degree of saturation (a property used in the simulation work) can be determined by graphing the strain against the degree of saturation.

Some of the key attributes of the modeling used in the risk assessment are:

- Hygrothermal modeling of wall assemblies predicts the number of freeze-thaw cycles for insulation scenarios to be evaluated.
- Modeling does not estimate the rain water loading of the assembly; a value can be assumed, though, based on the climate and location/exposure of the assembly on the building.

#### Questions, comments and responses

Mr. Schumacher entertained questions and comments throughout his presentation. The following summarizes relevant questions, comments, and elicited responses:

- Question: Are there coatings that we could use to control the wetting of brick masonry?  
Response: We do not yet have a robust coating solution. (Straube:) A cementitious slurry with synthetic polymers has worked to protect brick but this changes the appearance.
- Question: How long does it typically take for these failures to occur? Response: It depends on the moisture content. (Straube:) A crack can start with the right temperature and moisture content. Damage can occur quickly and can be evident in the first winter.
- Question: Wouldn't there be particular vulnerability for wood in contact with insulated masonry. Response: (Lstiburek, Straube) We are aware of this and believe we are closing in on methods to address this concern.
- Question: Is it possible to just insulate the interior of the masonry wall with rock wool?  
Response: We cannot do just rock wool. It is necessary to have air flow control and moisture control, to avoid moisture accumulation from the interior in the assembly.

- Question: Does an abandoned building that has been left unheated for a number of years provide ample proof that it can withstand interior insulation? Response: Yes: if this situation exists, it provides an excellent and robust test. However, abandoning a building that is occupied and operational is not a cost effective option for a building owner. (Lstiburek:) The abandoned building test does not work if we are going to significantly change the conditions inside—e.g. if the enclosure is to contain a museum or a pool.

**Speaker 4: Kohta Ueno, Building Science Corporation**

Presenter bio: Kohta Ueno is a Senior Associate with Building Science Corporation. His responsibilities at BSC include project management, liaison work with builders and industry clients, HVAC design, energy analysis of house designs, computer modeling, field testing and verification, and forensic field investigations. He holds a bachelor's degree in material science and engineering from the Massachusetts Institute of Technology and a master's degree in applied science from the Department of Civil Engineering/Building Engineering Group at the University of Waterloo.

Presentation Title: *Foundation Insulation Retrofits*

Presentation Summary:

Kohta Ueno presented research and details relating to retrofit of foundation assemblies. The images of foundation retrofit insulation details that Mr. Ueno shared showed predominantly interior insulation strategies. Mr. Ueno indicated that exterior insulation is not excluded from consideration in deep energy retrofit but that, for practical reasons, it is unlikely to be a frequently encountered approach.

Mr. Ueno reviewed the common moisture challenges associated with insulated foundation assemblies including condensation on the foundation, moisture in concrete, relative humidity of soil at 100%, and liquid water leaks. Mr. Ueno indicated that liquid water leaks represent the most serious risk factor.

Mr. Ueno framed the discussion by first comparing the pertinent moisture transport mechanisms and their relative magnitudes: liquid water, capillary water, air transported, and vapor diffusion. Among the strategies discussed, was a measure to address capillary transport that involves lifting the building slightly off the foundation in order to install a capillary break between the foundation and the wood framing.

Particularly salient points from Mr. Ueno's presentation include:

- Cold concrete can be thought of as a “third rail” in the assembly: interior air must be kept from contacting it during various wintertime and summertime scenarios, or condensation is likely to result. Insulation systems should prevent indoor air from reaching cold surfaces.
- Air must not be permitted to circulate from the cold side of foundation insulation to conditioned space.
- Boundary conditions: soil is 100% RH all the time; in addition, the concrete wall stores a significant amount of moisture that can take exceptionally long times to dry. As a

consequence, when a very low permeance layer (such as polyethylene sheet or a foil facer) is in contact with the foundation wall, the conditions on the concrete/soil side of that vapor retarder will also be at 100% RH.

- Insulation material applied to a foundation assembly must not be vulnerable to being in a 100% RH environment or, even, to being in prolonged contact with liquid water.
- Sealing between a basement slab and foundation wall has been demonstrated to have noticeable effect on overall building air leakage. Below grade air barriers are important.
- Sheet goods used for capillary break and vapor diffusion control below concrete slabs must be in contact with the slab. When the sheet good is not in contact with the concrete, there is a risk of bulk water pooling on top of the vapor control layer and of air transported moisture through holes in the vapor control layer.
- If the foundation wall is known to have bulk water leakage, then a drainage membrane should be used against the foundation wall to direct water to a drainage system.
- If the foundation material does not have significant capillary potential (generally corresponding to porosity) and/or if there is a significant amount of foundation wall exposed above grade, then it may be safe to omit the capillary break between the framing and foundation.
- A wood sill may look o.k. from outside yet have significant hidden damage.

#### Questions, comments and responses

Mr. Ueno entertained questions and comments during and after his presentation. The following represent highlights from the questions, comments, and elicited responses:

- Question: With the ground roof (underground overhang) would a layer of insulation be beneficial? Response: Yes, the insulation does have a benefit but the membrane is needed to deal with water.
- Question: What is your feeling about foil-faced insulation against a concrete wall? Response: It is important to keep in mind that it will be 100% RH behind there all the time; therefore, it is critical that this environment be separated from interior conditions.
- Question: When using spray foam insulation against the foundation wall, is it preferable to use closed or open cell foam? Response: Open cell gives some drying to the interior but entails a risk of condensation/frost layer in cold climates. Closed cell is less vulnerable to moisture.
- Comment: When using SPF directly applied to the ground below a slab it must be ballasted to prevent cure-lift.
- Question: What are the concerns with applying a drainage membrane to the inside of the foundation wall but not lifting the structure to place a capillary break at the top of the foundation? Response: Provided the conditions are such that a capillary break is not needed, this would be acceptable as long as the top of the drainage layer is encapsulated. But, in any case, it is very important to assess the condition of the sill.
- Comment: It is not that crazy or hard to lift house and put in the capillary break.
- Question: How high must the drainage membrane extend against a rubble wall [or other foundation walls]?. Response: This relies upon judgment as to how wet the basement is, but a reasonable level is at least to grade, and perhaps 6" to 12" above grade.

- Question: Is frost heave a concern with insulated foundations? Response: Even an insulated basement still has outwards heat flux, even though the magnitude is reduced; the direction of heat flow is basement to soil. Direction of heat flux has a critical effect on the frost-based mechanisms that cause durability problems in structures coupled to soils. In areas with extreme frost penetration, concerns could be mitigated with an insulated ground roof.
- Comment: In a New Hampshire climate (~8,000 HDD), a well sealed but uninsulated basement does not get below freezing.
- Suggestion: If sub-optimal details are included in the catalog, color coding or other device should be used to indicate relative risk.
- Question: Is radon a concern to be addressed by foundation retrofit strategies? Response: Step zero is dealing with radon.

**Speaker 5: Paul Eldrenkamp, Byggmeister**

Presenter bio: After a wide range of carpentry jobs and a bachelor's degree in History and Literature of Medieval Europe, Paul Eldrenkamp founded Byggmeister (Scandinavian for "master builder") in 1983. "I've always put a high priority on two things: fostering easy, friendly relations with our clients and building a team of people who are as interesting and diverse as they are talented and dedicated."

Presentation Title: *Selling DER In the Real World*

Presentation Summary:

Paul Eldrenkamp offered a presentation on the methods and metrics that he uses to communicate performance objectives to clients. Much of the material was drawn from his recent article in the *Journal of Light Construction* ("A Simple Approach to Home Energy Rating," February 2010). The fundamental premise of his presentation is that deep energy retrofits must be valued by private clients without third party incentives.

Mr. Eldrenkamp presented Btu/sf-year as a simple metric for representing energy performance. He shared a graphic representation of this metric for the population of his company's projects. However, he did discuss the weaknesses inherent in the use of this metric. He demonstrated how larger climate and green house gas reduction goals can inform specific energy budgets for each project. He proposed a framing question through which to evaluate work in the building field: "Is what we are doing today part of the problem or part of the solution?"

Some of the key points of Mr. Eldrenkamp's presentation include:

- Almost all remodeling decisions are emotional decisions
- The \$100K kitchen is going to look 20 years old in 20 years, while the DER is going to look better and better over time.
- Establishing an energy target for the home moves from payback discussion to what is the most cost effective way to reach the goal
- Asset rating and operational rating are useful but not necessarily overlapping assessment tools

## Questions, comments and responses

The following represent highlights from the comments elicited by the presentation:

- Comment: Discussion is needed about whether it is correct to conflate reduced consumption with suffering. Reducing consumption does not necessarily imply a compromise or sacrifice in terms of well being.
- Comment: If a retrofit results in consumers using buildings for greater commodity (e.g. cooling where there may not have been mechanical cooling, higher heating set points) this change in operation should have minimal impact in a high performance building. In other words, the difference between 72° F and 65° F heating set point has a much smaller effect in high performance buildings, compared to unrenovated building stock.

### **Speaker 6: John Straube, Building Science Corporation**

Presenter bio: Dr. John Straube is a principal of Building Science Corporation and a professor of building science in the Civil Engineering Department and School of Architecture at the University of Waterloo, Canada. Dr. Straube has acted as an educator, researcher, consultant and expert witness on energy efficiency, durability and IAQ. Current interests include the optimal system design of buildings, sustainable buildings, and moisture problem avoidance.

Presentation Title: *Window Replacement/Repair/Storms*

#### Presentation Summary:

Dr. John Straube led a discussion of window replacement and improvement options in the context of deep energy retrofit. He noted that when the walls are improved to the extent expected in a deep energy retrofit, the windows become a very significant component of the overall space conditioning load. Dr. Straube outlined the different economics applying to windows in comparison to walls, observing that incremental performance steps are relatively expensive in windows.

Dr. Straube reviewed implications of interior and exterior storm window options. He also offered observations on shutters, interior shades and window quilts. In addition to the energy implications, the water management aspects of window improvement options were discussed.

Dr. Straube presented examples of strategies to integrate the window with a drainage plane at various locations in the wall assembly.

Dr. Straube made the following key points during his presentation:

- Low e storm windows greatly improve the performance of the window by reducing the impact of the “frame” by making that section much deeper.
- Low e interior storm panels are typically easiest to implement but present an elevated risk of condensation.

- Exterior storm window panels reduce the rain loading on the primary window and mitigate wind pressure but may require onerous window removal in summer for ventilation.
- Low-e storms typically use a hard coat low-e coating, which tends to have a higher SHGC.
- Good quality, high performance rolling shutters may be more expensive than replacing the window.
- A fully flashed extension box allows one to put the window anywhere in depth of window opening and may allow for simpler replacement of window.
- Large rough openings allow for verification of foam in the gap between the window and framing.
- Fiberglass windows can give same glass area with less frame area, and therefore may accommodate more room in rough opening for foam when a vinyl or wood window is replaced.
- High performance windows will come down in price faster than high performance walls

#### Questions, comments and responses

The following represent highlights from the questions, comments, and elicited responses:

- Question: What measures might be taken to facilitate future replacement of the window? Response: (Coldham:) Screw the window into the opening or support brackets in such a way that screws are exposed.
- Question: How might the window installation facilitate a staged retrofit wherein wall exterior insulation is added at a later date? Response: Leave a flap of unadhered membrane at the sill which can later be lapped over the drainage plane. (Baker:) Providing an extra buck in the window opening gives room for insulation to be returned to the window opening.
- Comment: Window manufacturers deliver the same size installation brackets with windows regardless of the window size, which inspires little confidence in the structural design matching the brackets with loads.

#### **Speaker 7: Marc Rosenbaum, Energysmiths**

Presenter bio: Marc Rosenbaum, P.E. has been published in ASHRAE Journal, Fine Homebuilding, Northeast Sun, Solar Today, Journal of Light Construction, and Northwest Builder, and is a member of the Advisory Board of Environmental Building News.

He is a frequent speaker on sustainable design and has been a featured presenter at many conferences, with audiences that include architects, engineers, construction professionals, facilities managers, planners, educators, utility professionals, and those working in the public sector.

An experienced and enthusiastic teacher, he has trained thousands of professionals and especially enjoys working with students. He holds BS and MS degrees from MIT, where he studied mechanical engineering. He is a licensed

engineer in New Hampshire, Vermont, Massachusetts, and Maine, and is a LEED Accredited Professional.

Presentation Title:      *HVAC Issues for Deep Energy Retrofits*

Presentation Summary:

Marc Rosenbaum, PE, framed a discussion of mechanical systems in deep energy retrofit by presenting a series of questions pertinent to decisions about retrofit directions. The questions tended to juxtapose high performance building needs with the service delivered by standard practice. He invited discussion of the listed questions and solicited additional questions from meeting participants.

Mr. Rosenbaum observed that mechanical needs of single family homes and high performance multifamily buildings may not be fundamentally different. He touched on multifamily mechanical system choices suggesting that mini split heat pumps and a small heat recovery ventilator (HRV) per apartment unit is operationally less expensive (both in terms of energy and maintenance) and, furthermore, probably would cost less to install than typical central systems.

Mr. Rosenbaum outlined how the often encountered criterion of not changing the interior presents challenges and limitations to mechanical system choices.

Examples of questions that Mr. Rosenbaum used to frame the discussion include:

- When is mechanical ventilation needed in retrofit?
- Should heat/energy recovery always be a part of the ventilation system?
- How is the decision to keep or replace the heating system made?
- How hard do we work to put new duct work in a house that hasn't had it? What about high velocity systems?
- When is a cocooning strategy sensible? (isolating and superinsulating part of a house, providing it with its own heat)
- At what point is the gas meter disconnected to save the monthly meter charges?
- Should oil fuel use and indoor oil tanks be preserved?
- When do indoor-located heat pump water heaters make sense in cold climates?
- What is the threshold of enclosure performance where systems start to get significantly less expensive? Beyond what point of enclosure performance are there few cost savings opportunities for mechanical systems?
- Do we need more or less cooling with super insulation?

Questions, comments and responses

The following represent highlights from the questions, comments, and elicited responses:

- Comment: If the system is not changed in a retrofit, it may be necessary to radically change the operating characteristics. Steam heating in a super-insulated enclosure is an

example of a system that may need to be operated differently than in the scenario of a typical-performance enclosure.

- Comment: Water heating remains a sticking point as far as fuel choice. Electric resistance is not an efficient option. When can we expect to see US availability of heat pump water heaters that extract heat from interior or exterior?
- Question: Do we need ducts in every building? Response: (Straube) We need ventilation in every room. Therefore, we will be providing ducts in every building. The question is whether to install ducts large enough to provide heating and cooling.
- Comment: Yes, a small air source heat pump or mini-split makes sense for space conditioning but meeting water heating needs pushes us back to gas. Response: If there were a mini-split system with a take-off for hot water and for zones for heating and cooling, we would have a complete system. (Taylor:) DOE is currently testing appliances that provide heating, cooling, dehumidification and water heating.

The following are some of the questions suggested for consideration in retrofit projects:

- At what point does it make sense to get rid of an existing chimney or to use the chimney as an interior chase?
- When does it make sense to use a DHW heater for space heat?
- When loads are significantly reduced and, along with it, space conditioning air flow, is it still possible to get adequate distribution through existing duct work?
- When using a space conditioning ducted distribution for distribution of ventilation air, how low can ventilation air flow be and still maintain decent ventilation distribution?
- When is solar thermal without storage making sense?

**Speaker 8: James Petersen, Petersen Engineering**

Presenter bio: James Petersen began his career in this industry in 1986 and founded Petersen Engineering, Inc. in 1992. Passionate about energy and the environment, he has expanded his expertise from his roots in HVAC and plumbing design to include building science, enclosure design and integrated design. He participates on project teams that successfully integrate the experience and expertise of all project team members that results in high-performance buildings. He is a registered Professional Engineer in New Hampshire, Massachusetts and Maine. He is also a LEED® Accredited Professional. He received a Bachelor of Science in Mechanical Engineering and a Bachelor of Arts in Philosophy from the University of New Hampshire.

Presentation Title: *Mechanical System Selection*

Presentation Summary:

James Petersen, P.E. presented strategies to meet heating, cooling, ventilation and water heating needs in high performance multifamily buildings. He included examples from some of his recent retrofit and new construction projects. A project combining both historic preservation and high performance objectives drew considerable interest from meeting participants.

Mr. Petersen also outlined decision criteria for selecting replacement systems. He suggested that durability and maintenance considerations are paramount. The optimal system is identified by variables beyond cost and nominal or rated efficiency.

Mr. Petersen opined that it is a fair categorization that large building HVAC systems typically do not perform well. He suggested that distribution systems and complicated controls for central systems often prove to be encumbrances to performance. He presented examples of systems that employ equipment that is inappropriate for the service they are intended to deliver and suggested considerations that could help to avoid common pitfalls. He provided examples to illustrate how project design process is very important to outcomes.

Mr. Petersen offered the following key observations during his presentation:

- The decision whether submetering is to be implemented is an important constraint in system selection. If a developer opts to providing heat this may mean that rent are higher and thus, a greater capital expenditure is justified.
- There are many different ways to provide HVAC in a typical project. There will typically also be many different conceptions of what works among participants in the project.
- For the engineer, there is typically more at stake in multifamily system design compared to a single family home because of the number of parties that will be affected by poorly performing or inadequate systems.
- Much of the project outcome has to do with the project process. We want an integrated design and collaborative process but we also need to define and respect responsibility for different aspects of the design.
- Even if the seemingly ideal technology became available in time for the next project, he would not be inclined to apply it unless the party to whom the technology is applied is expressly intent on experimenting with the new technology.
- The difference between systems actually working and systems failing should be the primary focus in system design and system selection. We can worry about refinements after we get systems working.

## **FOLLOW-UP WORK**

Participants in the meeting identified knowledge gaps within the industry to be addressed, research gaps, and code constraints.

### **Knowledge Gaps**

The assembled experts at the meeting possess a demonstrated capacity to solve complex building science challenges in retrofit situations. However, the broader industry does not have the knowledge to successfully resolve common high performance retrofit challenges. The meeting participants, through the course of discussions sparked by the presentations, identified several areas of knowledge to target for broader dissemination.

- **Permeability of material versus permeability of the assembly:** Details are needed to clear up confusion regarding permeability of the material and permeability of the assembly. Confusion is particularly apparent where the use of foam insulation is involved.

- **Phased retrofit details:** Details are needed to demonstrate appropriate details for phased or staged retrofit. For example, these would demonstrate what to do when the roof is insulated and the wall is to be addressed later. A particular challenge that these details must address is transition of water-, air flow- and thermal control functions.
- **Risk management in retrofit:** A guide for deep energy retrofit should include an assessment or ranking of the relative risk of assemblies and indicate the failure mechanisms corresponding to the risk for each recommended assembly. Indications of risk might also distinguish between systemic risk, and the specific risk; i.e., systemic risk will cause widespread problems and is represented by assemblies that have a high risk of failure, whereas a specific risk such as a window leak will cause a problem in a specific location.
- **Effective water management as a precondition for deep energy retrofit:** Establish improved water management as a goal to motivate deep energy retrofit. Communicate, for example, that a leaky window in a wall that includes a polyethylene vapor barrier should be regarded to be as damaging as a leaky roof.
- **Risk awareness in weatherization industry:** Risk factors in retrofit should be communicated to weatherization contractors currently being trained to deliver a wave of improvement services.
- **Effective strategies for isolating basements and crawlspaces:** Define effective strategies to insulation at basement/crawl space ceilings but also communicate the risk.
- **Risks of standard practice regarding basements and crawlspaces:** Communicate the risk of less than full inclusion and less than full exclusion of basement and crawl spaces.
- **Acceptable practice for back ventilated and drained cladding:** Communicate, for example, that horizontal furring at openings is not acceptable practice.

### Research Gaps

Meeting participants were able to identify several important questions that would require further research in order to provide recommendations to the retrofit industry. The assembled group also identified products, methods or applications to be developed in order to enable more widespread implementation of high performance retrofits.

- **Attachment of cladding, porches, and overhangs over thick exterior insulation:** Demonstrate the structural feasibility of installations over rigid foams. Identify suitable means of attachment over semi-rigid or non-rigid insulation materials.
- **Transition of control functions:** Refine identified methods and develop a greater variety of viable methods to transition drainage and airflow control functions at challenging assembly interfaces such as at windows, roof-to-wall, and above grade wall-to-foundations.
- **Coatings for masonry:** Develop safe and effective coatings that significantly reduce wetting of brick masonry without changing the aesthetics and also without reducing vapor drying of the brick to levels that would cause damage.

- **Wood structural elements embedded in insulated masonry assemblies:** Develop and identify methods to address the vulnerability of wood structural elements embedded in insulated masonry assemblies.
- **Thermal separation at basement/crawl space ceiling:** Develop a variety of effective, safe, and practical methods to provide thermal insulation and air separation at basement and crawl space ceilings.
- **Above-grade exposure mitigation of capillary transport in foundations:** For common foundation materials and foundation treatments, identify the threshold of above-grade exposure above which it is reasonable to omit a capillary break between the foundation and sill.
- **Window attachment in super insulated walls:** Demonstrate the structural feasibility of window attachment in super insulated walls. Call upon window manufacturers to develop sizing guidelines for window attachment hardware and to provide attachment hardware appropriate to window size and loading.
- **Air flow control over board sheathing:** Develop methods to implement effective air flow control over board sheathing.
- **Mechanical systems for phased retrofit:** Identify appropriate mechanical system strategies for application in phased retrofit projects.
- **High performance heat pump technology:** Promote the development and commercialization of heat pump technology capable of meeting multiple functions including, at a minimum, heating, cooling and water heating loads.
- **Performance rating:** Refine performance rating methodologies to better represent operating performance.

### **Code Constraints**

Meeting participants identified code issues that form constraints to effective deep energy retrofits. There were also issues identified where better clarity on the part of building codes would benefit high performance retrofit work specifically as well as the building industry generally.

- **Permeability of assemblies:** Building codes should address permeability of assemblies.
- **Fire protection for insulations:** Provide a greater variety of options relative to fire protection for insulations used in foundation and masonry wall assemblies.
- **Partial thermal separation of basements and crawl spaces:** Current buildings codes appear to permit basements and crawl spaces to be only partially excluded from- or partially included in conditioned space.

## Appendix A: Expert Meeting Agenda



## Building America Expert Meeting

# Details for Deep Energy Retrofit

Meeting Manager: Betsy Pettit, Building Science Corporation

Date/Time: **Friday, March 12, 2010**

**9:00 am to 4 pm**

Location: Seaport Convention Center, Boston, MA

### Featured Speakers:

9:00 – 9:30	Joseph Lstiburek , Roof/Re-cladding Options
9:30 - 10:30	Discussion – Builder Experience
10:00 – 10:30	John Straube, – Walls/Re-cladding Options
10:30 – 11:00	Discussion – Builder Experience
11:00 – 11:15	Chris Schumacher – Testing Brick Units Before Insulating Walls
11:15 – 11:30	Discussion – Builder Experience
11:30 – 12:00	Kohta Ueno – Foundations
12:00 – 12:30	Discussion – Builder Experience
12:30 – 1:00	LUNCH PROVIDED
1:00 – 1:30	John Straube - Window Replacement/Repair/Storms
1:30 – 2:00	Discussion - Builder Experience
2:00 – 2:30	Marc Rosenbaum - Single Family Mechanical Systems/Ventilation Replacement
2:30 – 3:00	Discussion – Builder Experience
3:00 3:30	James Peterson - Multi-family Mechanical Systems /Ventilation Replacement
3:30 – 4:00	Discussion – Builder Experience

The objective of this session is to explore the enclosure and mechanical system replacement design successes, failures, and specific future needs for future Deep Energy Retrofits. The goal is to provide details for a guidance document that can be used by homeowners, builders, architects, and building owners to improve the energy performance of their building. This is important to insure the persistence of energy savings toward the Building America target of zero energy retrofit of homes by 2030.

### Key questions regarding this meeting:

- Re-cladding - Structural concerns – fire concerns – constructability, masonry freeze thaw
- Foundation – crawls, slabs, basements freeze/thaw, condensation, insects
- Window Replacement – location (innie/outie), storms/replacement, sash replacement versus frame
- Roofs – vented/unvented – interior vs exterior
- SF Mechanical – fuel source – removal vs replaced
- MF Mechanical – fuel source – combined/distributed
- When exterior insulation needs to transition to interior insulation at the building sill
- Where basement stairs run down right alongside the foundation, preventing adding insulation to the foundation wall at that area
- Roof-to-exterior-wall transitions at the eaves, in those cases where the "chainsaw retrofit" is not a viable option
- Accommodating porches and decks
- Performance metrics that can meaningfully be incorporated into specifications/contract documentation (clients for these retrofits do expect some accountability and/or guarantees regarding outcomes, for example: a particular HERS index, or blower door number, or other metric)
- Strategies for phasing retrofits
- What to do with basements (when you can't spend the money to do it right - there are so many troubled basements and the energy savings aren't enough to pay for doing the complete job) and
- How to deal with air barriers with board sheathed buildings.
- Masonry bearing walls - how to deal with wood joists bearing in the masonry if it's an interior retrofit
- Masonry bearing walls - how to deal with the thermal bridge at the ground if it's an exterior retrofit

Appendix B: Expert Meeting Attendee List (based on sign-in sheet)

First Name	Last Name
Franziska	Amacher
Peter	Baker
Pierre	Belhumeur
Gary	Bergeron
Michael	Bress
Mike	Brown
Brian	Butler
Alex	Cheimets
Eric	Coffman
Bruce	Coldham
Keith	Collins
Roger	Cooney
Jonah	Decola
Chris	Early
Paul	Eldrenkamp
Cheryn	Engbrecht
Henri	Fennel
Cathy	Gates
Rick	Gilles
Jordan	Goldman
Ann	Gulbrandson
Katie	Gunsch
Chris	Hoch
Stephanie	Horowitz
Bill	Hulstrunk
Shawn	Jeffords
Dave	Joyce
Declan	Keefe
Dave	Keefe
Stefan	Knust
Ryan	Lacey
Mark	Ledwell
Dave	Legg
Joseph	Lstiburek
Alex	Lukachko
Henry	MacLean
Mike	Marotta
Ben	Marshall
Lawrence	Masland
Janet	McFlvaine
Dan	Morrison
Ken	Neuhauser
Paul	Panish
James	Peterson
Betsy	Pettit
Art	Pichette
Duncan	Prahl

First Name	Last Name
Mark	Price
Cador	Price-Jones
Marc	Rosenbaum
Armin	Rudd
Darroll	Salesman
Chris	Schumacher
Chuck	Silver
Doug	Snyder
John	Straube
Sam	Taylor
Jeremy	Toal
Peter	Troast
Kohta	Ueno
Fred	Unger
Linda	Wigington
Rob	Wotzak
Kevin	Young
Bill	Zoeller