Cost Premiums For Select High Performance Building Components

Completed for
NORTHWEST ENERGY EFFICIENCY ALLIANCE

Prepared by
EARTH ADVANTAGE

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ABOUT EARTH ADVANTAGE

Earth Advantage is a Portland, Oregon based nonprofit whose mission is to accelerate the creation of better buildings. They provide knowledge to building professionals, and information to consumers through certification, research, education, and product development.

Learn more at earthadvantage.org

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Executive Summary

The Northwest Energy Efficiency Alliance (NEEA) sought assistance from Earth Advantage to obtain cost data for measures related to high performance home construction in the Northwest. Specifically, Earth Advantage obtained construction cost premium estimates for 11 wall and ceiling assemblies and one performance testing measure from 23 homebuilders in Oregon and Washington between August 1, 2013 and September 6, 2013. These wall and ceiling assemblies contain more insulation and/or reduce thermal bridging.

The survey conducted by Earth Advantage showed that overall Northwest builders:

- Pay a small cost premium (averaging $0.39/sq. ft. of home floor area) to insulate stud wall cavities with blown-in fiberglass instead of batts.
- Achieve little cost savings from implementing advanced framing techniques.
- Pay a larger cost premium for walls with more insulation ($1.16/sq. ft. for 2x8 walls with batt insulation or $1.55/sq. ft. for alternative-framed 8" thick walls with blown-in insulation).
- Pay significantly lower cost premiums for increasing insulation in attics than in walls (an average of $0.60-$0.70/sq. ft. for three of the four referenced roof assemblies in the survey).
- Pay an average of $296/house for PTCS "duct blaster" duct airtightness testing.

Earth Advantage obtained insufficient responses to determine an accurate amount of cost premium for other measures. However, responses show builders are concerned about the durability of walls covered with a layer of exterior insulation even though the cost premium ($1.00/sq. ft. with batts or $1.40/sq. ft. with blown-in fiberglass) is not as great as the cost premium for 8 inch thick walls.

Two-thirds of builders are unclear about the cost of 6" thick SIPs cost. The few builders with experience utilizing SIPs either are strong advocates for the technology and believe there is no cost premium (2 builders) or report a steep SIP premium (3 builders).

Research Methodology

Between August 1 and September 6, 2013, Earth Advantage contacted 53 builders in Oregon and SW Washington by email and phone to request the confidential access to cost data for select high performance buildings features[1].

It should be noted that Earth Advantage uses "sq. ft." throughout this report to denote the square foot floor area of a home except as specially noted when describing area of an assembly such as square feet of walls or ceiling. A few builders calculated wall construction costs by square feet of wall; however, most did not. Some based costs on lineal feet of wall. They knew the number of studs per lineal feet of walls.

Most builders simply tracked their costs on a "per house" basis. They knew their "bulk" pricing for their "framing package" (framing lumber) or "truss package" (truss material). They knew their framing labor costs almost exclusively on the basis of the floor area of the house. For these reasons, Earth Advantage converted almost all cost estimates into cost per square foot of floor area.

DATA TABLES

The four spreadsheets attached to this report provide details on the data collected by Earth Advantage during the survey. This data is sorted respectively by the builder's volume, region, sales method, or typical house size to assist in determining how the characteristics of the builder or the house size affects the estimated cost premium for the assembly or PTCS duct blaster testing.

BUILDER CLASSIFICATION

The data collected in this study classify the representative builders by volume, territory, and sales method.

Builder volume is either:

- Small (building 10 or fewer homes/year);
- Medium (building more than 10 but fewer than 50 homes/year); or
- Large (building more than 50 homes/year).

Builder regions are delineated as:

- Coast ("C");
- Valley (including Southern Oregon as "V");
- Central Oregon (including Bend as "CO"); or
- Portland metropolitan area ("M")

Builder's sales methods are classified as:

- Speculative ("S");
- Custom ("C"); or
- Both ("B")

[1] Even with this assurance, at least one builder refused to provide its exact cost for one measure (PTCS duct blaster testing).

Because the sales method appears to be a significant influence on estimated cost for the assemblies (custom home builders quoting significantly higher costs), a custom builder that sells a small fraction of houses on a speculative basis was categorized as a "C". Likewise, a builder that is primarily a speculative builder but sells some of its homes on a custom basis is categorized as a "S" builder.

HOUSE SIZE

When Earth Advantage interviewed builders, they were asked for their cost estimates for a home of the same size they typically build. The builders typically build a range of sizes, but especially with the large, speculative builders, they predominate to one or two average sizes.

Since the builders provided whole-house costs, we requested they provide those costs for a specific size house which is approximately the size of their typical house. The "Avg" spreadsheet column shows the builder's typical house size.

ASSEMBLIES AND MEASURES

For clarity in communication, Earth Advantage broke survey data collection request into categories featuring five different assemblies and one measure (PTCS duct blaster testing). Earth Advantage collected the estimated cost premium for the five assemblies and listed the cost premiums in the columns of the attached worksheets. Some columns include more than one cost premium. If NEEA specified variations on how each of the five assemblies was constructed, Earth Advantage obtained the builder's cost premium for the specific variation.

Therefore, depending on the responsiveness of the builder, there may be up to three separate construction cost premium estimates (one for each of the variations on each assembly) in each column. The assemblies are categorized as follows:

1. **2x6 framed walls with greater insulation with in three variants:**
   a) ***Standard framing w/ R21 batts and at least 0.5 inch additional insulation***
   b) ***SAA except blown-in insulation ("b-ifg" for blown-in fiberglass insulation)***
   c) ***Advanced framing with blown-in insulation***

2. **8 inch thick wall in three configurations**
   a) ***Standard framing of 2x8 studs w/ R21 batts***
   b) ***Standard framing (2x6) with 2x2 horizontal strapping at plates and 24" o.c. with b-ifg***
   c) ***Staggered framing of 2x4 studs with bifg***

3. **6 inch thick structural insulated wall ("SIP")**

4. **Flat ceiling with two levels of insulation**
   a) ***Approximately 14 inch high heel truss with R38 blown-in insulation***
   b) ***Approximately 7 inch high heel truss with R60 blown-in insulation***

5. **Vaulted ceiling in two alternatives**
   a) ***Approximately 13 inch "high heel" truss with R38 batts***
   b) ***2x12 rafters 24 inches o.c. with R38 batts***

Results

1. **2x6 framed walls with greater insulation:**
   a) ***Standard framing w/ R21 batts and at least 0.5 inch additional insulation***

AVERAGE COST

Not derived. Earth Advantage cannot provide this cost with a reasonable degree of confidence. This uncertainty is based on multiple factors.

EXPLANATION

A very small of number of the builders interviewed provided cost estimates for the 0.5 inch additional insulation in/on sheathing that Earth Advantage cannot provide a reliable average cost estimate. In particular, Earth Advantage was able to obtain this cost from only one of the four large builders interviewed. Additionally, Earth Advantage determined that unlike the other cost estimates that the builders provided, many builders simply made their best guess about the cost of these two assemblies. They did not provide an estimate. At most, they guessed (and it was clear that their guess was not a particularly educated guess). It was not an estimate based on experience building the assembly.

Only three builders had actually built this assembly, and one of those builders abandoned the practice several years ago. The other built it only once years ago as an experiment. The third builds it routinely (with 1.0 inch of rigid foam insulation on top of the sheathing), but it has been so long since he built a home with standard 2x6 framing and batts that he could only guess the cost premium. None of the builders quoted a material cost for the exterior insulation. And most of them expressed considerable uncertainty about the labor cost. Some mentioned that they were not sure if their framer, insulator, or sider would install this layer. In addition to the uncertainty about cost, there was considerable resistance to building this assembly.

Four builders, including builders that Earth Advantage knows to have excellent reputations for quality and business acumen, said they would not build either assembly for reasons unrelated to cost. Many others were leery and extremely hesitant about the exterior insulation. Most were leery about it (or adamant that they would refuse to build it) because of their concerns about durability arising from moisture being trapped between the sheathing and exterior foam. One reluctantly provided the cost estimate but indicated he was "concerned."

Others expressed other concerns or a mixture of concerns, including potential fire hazard because foam is flammable a concern in given this builder's regional weather). Another refused to consider building it because there were far more cost-effective assemblies to achieve equal or greater thermal performance without any durability risk.

Only 9 builders provided their cost premium for both assemblies[2]. They are listed below:

[2] Earth Advantage attempted to not specify where the 0.5 inch minimum thickness insulation would be installed or what material would be used, as the intention was to ask builders the cost of including an insulation layer that would be continuous (unlike the cavity insulation) without dictating where it would be located in the wall. Earth Advantage found that builders needed additional specification to avoid confusion and wasting time during the survey. For example, Earth Advantage ultimately decided to tell the builders that the insulation layer should be either in lieu of structural sheathing like OSB or plywood or on top of it. This is because some builders argued that it was impossible for their engineers to approve the 0.5 inch layer between the studs and the structural sheathing. Only one or two builders were familiar with the practice common in other regions of substituting rigid, high-R panels for OSB or plywood for at least a portion of each wall. In the end, Earth Advantage did not lead the builders to any conclusion but merely suggested that common external insulation is EPS, XPS, or polyisocyanurate foam panels.]

Builder Class	Region	Builder Type	Avg. Home Size	a) cost/ sq. ft.	b) cost/sq. ft.
Small	Valley	Custom	2000 sq. ft.	$1.00-$1.25	$1.25-$1.50
Small	Coast	Custom	2000 sq. ft.	$0.75	$1.25
Med	Metro	Custom	1600 sq. ft.	$1.25	$2.00
Small	Coast	Both	2500 sq. ft.	$1.00	$1.33
Med	Valley	Both	2500 sq. ft.	$1.40	$2.00-$2.20
Small	Valley	Custom	3000 sq. ft.	$0.70-$0.80	$1.00-$1.10
Large	Metro	Both	2000 sq. ft.	$0.50	$0.75
Med	Metro	Spec	2400 sq. ft.	$1.05	$1.42
Small	Metro	Custom	2000 sq. ft.	$1.35	$1.85

Although Earth Advantage does not consider these cost estimates reliable, the average estimated cost for the "a" wall assembly is $1.00/sq. ft. (low end of range) to $1.04/sq. ft. (high end).

With the same caveat, the average estimated cost for the same wall with blown-in fiberglass insulation is $1.43/sq. ft. (low end) and $1.49/sq. ft. (high end).

b) Blown-in fiberglass insulation

AVERAGE COST

$0.43/sq. ft. of living area.

EXPLANATION

Although Earth Advantage does not have confidence in the average cost estimate for 0.5 inch additional insulation in/on sheathing, Earth Advantage does have great confidence in the average cost of blown-in fiberglass wall insulation.

Earth Advantage's confidence is based on a large number of responses, builders' substantial experience with the material, and builders quoting the exact prices that they are currently paying.

Earth Advantage asked 24 builders for their cost premium for blown-in fiberglass[3] instead of fiberglass batts for stud wall cavity insulation and obtained the builder's cost from 21 builders.

[3] Although a few builders reported that they use blown-in high-density cellulose instead of fiberglass, the vast majority referred to blown-in fiberglass. For this reason, Earth Advantage uses "bifg" for this measure.

- Two of the 24 builders build all of their walls with SIPs and could not provide a cost for bifg.
- One of the 24 builders uses only batts in walls and had no idea of the cost of bifg (or interest in ever using it). That builder insisted that in the builder's climate it could not safely build with blown-in stud cavity insulation.
- All of the other builders either had experience purchasing blown-in stud cavity insulation or had obtained price quotes. Some builders had used only blown-in insulation in their stud walls for such a long time that they had difficulty remembering how much less batts cost.

Of the 21 builders' bifg costs, Earth Advantage omitted one in determining the average cost. That builder's cost was approximately four times the average. The builder is a small, custom builder of homes averaging 4,000 sq. ft. Earth Advantage did not probe for the reason for the premium cost that the builder quoted out of concern to not offend the builder or affect the builder's responses to the balance of the survey questions.

An additional reason for Earth Advantage's confidence in the cost is that 15 of the 20 builders provided a single, exact cost instead of a cost range. Earth Advantage found that when the builders were uncertain of a cost (e.g., estimating it instead of reporting when they actually are paying), they often expressed the cost as a range. With bifg, they almost always provided the exact cost they are currently paying down to the penny.

For computing the average, Earth Advantage took the low figure of the five ranges. Taking the high range moved the average cost only three cents per square foot to $0.46/sq. ft.

A final reason for Earth Advantage's confidence is that the costs are relatively consistent and show little variation as the table below shows.

Cost	< $0.29	$0.30-$0.39	$0.40-$0.49	$0.50-$0.69	$0.70 & more
Number	3	7	3	4	4

The median cost premium was $0.35/sq. ft.

c) Advanced framing with blown-in fiberglass insulation

AVERAGE COST

Not derived.

Earth Advantage made no attempt to determine if the blown-in wall insulation was "conventional" fiberglass blown into cavities behind polyethylene mesh or Johns-Manville's "Spyder" bifg. However, no builder mentioned Spyder, and based on the prevalence of the former system and the builders' numerous references to the insulators installing the mesh, Earth Advantage believes none of the cost estimates is for Spyder.

EXPLANATION

Earth Advantage did not find any pattern or consensus on the estimated cost of advanced framing ("AF"). Almost all builders are familiar with AF, but builders have a wide range of opinions on AF. Many builders have tried AF and rejected it. The most common reason for rejection is that when the sheathing gets wet, it warps. Even after it dries, it is bowed. At least two builders said that there was no cost savings from AF after they had to install horizontal blocking to bring the warped sheathing back into alignment.

Others reported that it took so much time and oversight to ensure the framers followed AF that their added time and effort eroded or dwarfed the material cost savings. Others reported that AF required new analysis from their structural engineers and in some cases, additional hold-downs which are relatively expensive. Both the additional engineering costs as well as even a few additional hold-downs will equal or exceed any material cost savings.

- One builder predicted this wall would cost more than a standard framed wall with bifg.
- Only three builders reported the material savings from AF offset the entire additional cost of bifg so that the AF wall was equal or lower cost than a standard framed wall with batts.
- Four builders estimated the cost savings from AF was slightly less than the premium for bifg (e.g., $0.40/sq. ft. when bifg premium is $0.50; $0.20-$0.25/sq. ft. when bifg premium is $0.41-$0.46/sq. ft.; $0.60/sq. ft. when bifg premium is $0.60-$0.80/sq. ft.; and $0.35/sq. ft. when bifg premium is $0.70/sq. ft.).
- Eight builders said there was no cost savings or premium from AF with bifg. It was cost cost-neutral.

2. 2x8 Walls

a) 2x8 studs with R28 batts

AVERAGE COST

$1.16/sq. ft. to $1.29/sq. ft.[4]*

EXPLANATION

Earth Advantage obtained 17 responses, resulting in a Medium/High confidence in the results.

The estimated costs are relatively consistent. Most of the builders did not have lumber costs for 2x8 readily available or memorized. Further, many of them expected that 2x8 costs would decline if it became more common plate stock and studs. Many of the builders expressed their estimate as a range to account for these factors and other unknowns. However, even with those caveats, they estimated a relatively narrow range (e.g., $0.56/sq. ft.-$0.60/sq. ft. or $2.00/sq. ft.-$2.25/sq. ft.).

[4] **About half of the builders expressed a price range, and these are the mean for 16 high and low-end of range cost estimates (after rejecting estimated cost from one small custom builder working in an affluent market whose estimated cost were more than double the average estimate)**

Although the distribution of cost estimates is relatively wide, this does not diminish Earth Advantage's confidence in the results. Many builders appear to have given some thought to framing with 2x8. It was the most popular 8 inch thick wall.

Although the width of the range of the majority of the cost estimates ($0.50/sq. ft. to $1.50/sq. ft.) is significant (adding from $1,000 to $3,000 to the cost of a 2,000 sq. ft. home), that variation is consistent with the range of costs for framing and finish labor across the spectrum of builders we interviewed (from large, spec builders to small, custom builders).

b) 2x6 wall strapped with 2x2 horizontally

AVERAGE COST

$1.89/sq. ft. to $2.13/sq. ft.[5]

Earth Advantage suspects this cost estimate is a bit low as it includes pricing from two builders whose cost estimates were substantially lower than their comments suggested they would be. In fact, we believe one small, custom builder who builds all of his homes with high-performance measures may have significantly underestimated his cost premium (in part because it had been so long since he build code-minimum walls).

EXPLANATION

We obtained 13 responses, resulting in Medium/High confidence in the results.

At least 3 builders said they would never build this assembly. One thought it was so far-fetched that he would not provide cost estimates even though he provided a cost estimate for the double 2x4 stud wall. Just as with the 2x8 stud wall, the estimated costs are relatively consistent. Most of the builders expressed a great deal of uncertainty about the framing L&M prices for 2x2 strapping. They were confident that 2x2 is inexpensive material, but they suspected additional labor would cause a substantial labor cost premium.

Many builders were dubious about this wall for complications it would cause not only for framing but for bifg insulation, sheetrock, and finish labor and materials. This was the least-favorite of the choices. Most builders felt the 2x8 wall with bifg was the best value, but many considered staggered 2x4s a viable alternative. No builder expressed any enthusiasm for the 2x2 strapping. At least one noted the difficulties for framing corners.
Again, even with the unknowns, most of the builders expressed their estimate within a fairly narrow range (e.g., $1.66/sq. ft.-$2.00/sq. ft. or $2.00/sq. ft.-$2.60/sq. ft.). However, their relative degree of certainty on this assembly is less than that on the 2x8 wall based on the greater width of each builder's range of cost estimates for this wall assembly.

Again, the cost difference between the low and high end of the range of estimates is not insignificant. However, it is far less than the range of costs for framing and finish labor and materials across a wide spectrum of builders.

[5] About half of the builders expressed a price range, and these are the mean for 13 builders who provided cost estimates. We did not reject the estimated cost for this wall assembly from the same small custom builder whose estimate we rejected above his cost estimate was near average for this assembly.

c) Double, staggered 2x4 wall

AVERAGE COST

$1.55/sq. ft. to $1.71/sq. ft.[6]

EXPLANATION

We obtained 17 responses, but perhaps from "survey fatigue" after racking their brains on the 5 preceding questions, several builders responded "close to [b]," "same as [b]," "same as [a]," or "a bit more than [a]." We extrapolated from their prices for a and b based on their comments. However, we got a new, different cost estimate for this assembly from 10 builders. Therefore, our confidence in these results is Medium.

- None of the builders said they would avoid building this assembly, but one felt it achieved little more than the 2x8 wall and was not worth considering.
- One noted that it would be better to align the inside and outside studs to provide a sufficient barrier to allow dense packing of the bifg insulation (which would otherwise slip horizontally absent netting between the staggered studs and prevent the insulator from achieving the desired density).
- Builders were confident of their lumber pricing since they already purchase 2x4s, but few did detailed calculations to determine the extra number of studs they would need to purchase.
- Just as with the 2x8 stud wall, the estimated costs are relatively consistent.
- Perhaps more than the 2x8 stud wall but less than the 2x2 strapped wall, the builders had to think quickly about how much these walls would complicate the work of the other trades (and potentially increase costs). One noted that the electrician would enjoy not having to drill holes (but would likely not discount its prices).

Most of the builders expressed their estimate within a fairly narrow range (e.g., $1.33/sq. ft.-$1.66/sq. ft., $2.50/sq. ft.-$2.75/sq. ft.). I believe they had a greater degree of certainty on this assembly than the 2x2 strapped wall, but that is simply from their comments and not a conclusion supported by their cost estimate ranges.

Just as with the 2x8 stud wall, many builders appear to have previously given some thought to framing with staggered 2x4 walls. It was the second most popular 8" wall.

The cost difference between the low and high end of the range of estimates is greater than Earth Advantage anticipated. Earth Advantage attributes it in large part to builders struggling for additional cost information and trying to do the math off the top of their heads after doing the same for 5 other assemblies. Earth Advantage noted that when we moved on to the ceiling/roof assembly questions

[6] About ½ of the builders expressed a price range, and these are the mean for 17 builders who provided cost estimates. We did reject the estimated cost for this wall assembly from the same small custom builder whose estimate we rejected above (for a) and did not reject (for b). His cost estimate was nearly triple the average for this assembly.

(and told the builder there was just one more category of questions), they perked up and seemed to get more precise with their estimates.

Thus, although we have a high level of confidence that the 2x2 strapped wall is the least favorite and that the 2x8 stud wall is the favorite, it would take a more detailed survey where builders had more time to prepare and estimate their costs to get a more precise and reliable comparison of their costs for the 2x8 and staggered 2x4 walls.

3. 6 Inch SIP Wall

AVERAGE COST

Not derived. Earth Advantage cannot provide this cost with a reasonable degree of confidence. This uncertainty is based on multiple factors.

EXPLANATION

First, so few builders provided cost estimates for the 6 inch thick SIP wall that Earth Advantage cannot provide a reliable average cost estimate.

- Thirteen builders said they had "No idea." Not only did they lack personal experience with SIPs, they appeared to know almost nothing about them from fellow builders, trade shows, publications, suppliers, or other sources. In fact, two builders didn't know what "SIP" meant. Even when spelled out as a "structural insulated panel" and described.
- Six builders provided cost information, but only three provided a specific cost premium. Their information is below.
- Two builders use SIPs almost exclusively and are adamant there is either no cost premium or only a small premium. However, in both cases, they stick-frame so few homes that they were not confident they knew framing labor and material costs for comparison.
    - One builder who switched to SIPs almost exclusively several years ago is located about 150 miles North of the Portland metro area. He is a small builder building about 6-10 homes per year. They range from spec homes less than 2000 sq. ft. to custom homes costing over $2M. He builds a high performance home that he estimates costs about $10,000 more than a code house to construct. However, he attributes none of the cost premium to SIPs, but only to other measures he incorporates into his homes.
    - The other builds throughout Oregon and Washington, but primarily in rural areas and remote locations where remote building sites incur framing labor and material cost premiums based on long distances and high transportation costs or a small market for labor and materials. One can easily imagine SIPs being competitive in cost in those markets.

SIP cost premium information

Cost premium of $4.50/sq. ft.-$9.50/sq. ft.

From a small, valley custom builder of 2000 sq. ft. homes: This builder uses SIPs occasionally, but "hates the price premium." He said that for one house, SIPs cost $34,000 instead of $15,000 for conventional wall framing. This is the same builder whose standard home has 1" of exterior foam over the sheathing, advanced framing, and blown-in high density cellulose cavity insulation. Thus, he is enthusiastic about high-performance walls.

Cost premium of $1.20/sq. ft.-$1.60/sq. ft.
From a medium, valley builder who builds both spec and custom typically around 2500 sq. ft.: He estimates a per-house premium of $3,000-$4,000, but that is not the main reason he doesn't use them. He says that he or his custom clients often customize a plan on the site as construction progresses. He remarks, "We wouldn't do this. We'd end up retrofitting on the site."

At least one other builder echoed this drawback. That builder specializes in 4000 sq. ft. custom homes. He does not use SIPs because his company must maintain the flexibility and the ability to alter course on the path from design to completion. If a customer wants to add a window or door during framing, they must do it.

Cost premium of $3.00/sq. ft.-$4.00/sq. ft.
From a small, metro builder who builds spec homes typically of 2500 sq. ft. He reports SIPs would add $7,500 to $10,000. He remarked, "Who would do that?"

4. Flat Ceilings

a) Approximately 14 inch high heel truss with R38 blown-in insulation

AVERAGE COST
$0.69/sq. ft.

EXPLANATION
Earth Advantage obtained price estimates from 17 builders including three large builders and a few medium-size builders, producing a Medium degree of confidence. However, there was so much variation in the cost premium estimates that Earth Advantage does not have high confidence in the average. One builder's estimate is more than 3 times the average of the 9 low estimates. Three more builders' estimates are double or more than the average of the 9 low estimates. The cost premium ranges are sorted below[7]:

Cost	< $0.50/sq. ft.	$0.50-$0.59/sq. ft.	$0.60-$0.79/sq. ft.	$1.00/sq. ft. & over
Number	4	6	3	4

b) Approximately 7 inch high heel truss with R60 blown-in insulation

AVERAGE COST
$0.75/sq. ft.

EXPLANATION

[7] On this assembly as well as the following ceiling insulation assembly alternatives, Earth Advantage made no attempt to gather information about what kind of insulation was blown-in, but several builders volunteered that they specified cellulose for its superior resistance to air flow (convection and wind).

Earth Advantage obtained price estimates from only 12 builders of the 17 that provided the estimates for the flat ceiling above. Again, there was so much variation in the cost premium estimates that Earth Advantage has Medium confidence in the average.

However, the main reason for the relatively low level of confidence is that the builders rarely took this question seriously. They often expressed incredulity that we asked this question. They saw no good reason to build this instead of the ceiling with 14 inch high heel trusses and uniform-thickness R49 insulation. Many simply answered that the price would be "the same."

A few didn't answer it because they said the assembly made no sense. One stated that he would not build it because there was no good reason to build it instead of the 14 inch high heel truss with uniformly thick insulation.

The cost premium ranges are sorted below:

Cost	< $0.50/sq. ft.	$0.50-$0.59/sq. ft.	$0.60-$0.79/sq. ft.	$1.00/sq. ft. & over
Number	2	5	2	3

5. Vaulted Ceilings

a) Approximately 13 inch "high heel" truss with R38 batts

AVERAGE COST

$0.58/sq. ft.

EXPLANATION

Earth Advantage obtained price estimates from only the 17 builders that provided the estimates for the flat ceiling above, and therefore have a confidence of Medium in these results. Again, there was so much variation in the cost premium estimates that Earth Advantage does not have high confidence in the average. We had estimates ranging from $0.15/sq. ft. to $1.60/sq. ft[8].

In addition, there was less consistency in the cost premiums than there was in the flat ceilings. Three of the 17 builders estimated this assembly would have a smaller cost premium than the 14 inch high heel flat ceiling with R49 insulation. And one medium, spec builder in the Portland metro area who Earth Advantage knows to precisely track his costs estimated that the cost of this assembly would most likely be a bit less or substantially greater than the cost premium for the 14 inch high heel flat ceiling with R49. Ten of the 17 builders gave the same cost premium for this measure as the cost premium for the 14 inch high heel flat ceiling trussed roof.

At first, it seems counterintuitive that the cost premium for a high heel vaulted ceilings would be less expensive than high heel flat ceilings. However, the explanation might lie in the fact that scissor trusses may already have a price premium over flat ceiling trusses. And they may be typically built with a substantial heel (and that flat ceiling trusses are not).

[8] Omitting those outliers, the average was $0.54/sq. ft.

It was not clear if the lower estimated premium may have resulted in the truss package and framing labor being smaller (than that for the flat ceiling) or that there was a smaller premium for slightly thicker batt insulation than substantially more blown-in insulation (in the flat ceiling). None of the builders knew the cost premium for a R38 batt, but they all were able to estimate or quote the cost premium of R49 blown-in insulation.

As Earth Advantage progressed through the surveys, we discovered another potential explanation for this apparent discrepancy. Many builders noted that it was rare that they vault all of the ceilings in a home. Rather, they typically vault the ceilings of just one or two rooms (usually including the master bedroom). Thus, they had trouble estimating the cost for this assembly. They were torn between a whole-house cost premium estimate (noting that they don't typically vault all of the ceilings) and a price for per square foot of the vaulted rooms.

We recommend more careful specification of a particular example house in order to avoid confusion on pricing based on whole-house or just the vaulted rooms.

The cost premium ranges are sorted below:

Cost	< $0.50/sq. ft.	$0.50-$0.59/sq. ft.	$0.60-$0.79/sq. ft.	$.80/sq. ft. & over
Number	6	6	2	3

b) 2x12 rafters 24 inch o.c. with R38 batts

AVERAGE COST

Not derived. Earth Advantage cannot provide this cost with a reasonable degree of confidence.

EXPLANATION

This uncertainty is based on two primary factors.

First, builders explained that it was difficult for them to provide this information because the size of the roof per floor area varies greatly from house to house. Multi-story homes have far less roof area per floor area of living space. Almost as important, the builders explained that the entire roof is rarely vaulted. Usually, builders vault only one or two rooms (commonly the master bedroom). The builders mentioned that the high heel trusses for the vaulted portion of the roof would likely require high heel trusses for the remaining portion of the roof. Otherwise, the home would have two different roof lines.

A second reason for uncertainty is the relative paucity of price estimates for the rafter roof assembly. A number of builders, especially the builders building spec houses had little or no recent experience with a "hand-framed roof" and could not readily provide the cost estimate. Earth Advantage did not press them to speculate on their costs.

Earth Advantage obtained price estimates from only 10 of the 17 builders that provided the estimates for the 14 inch high heel flat ceiling truss roof and the 13 inch high heel vaulted ceiling roof. Again, the

variation in the cost premium estimates does not support confidence in the average. We had estimates ranging from $0.30/sq. ft. to $2.65/sq. ft..

Unlike assemblies where we could look to the large builders and medium builders to provide a reliable estimate based on their volume, here those builders largely declined to answer on the basis that they have little or no experience hand-framing roofs, let alone framing them with 2x12 rafters. In addition, some builders had resistance to even considering this assembly. One said he wouldn't build it because he couldn't ensure sufficient air space for adequate ventilation in his climate (the Coast). Others simply were unwilling to speculate on a cost premium when they would never build this roof in lieu of a high heel vaulted ceiling truss. Although Earth Advantage cannot provide an average cost premium, we estimate (based on the responses that we obtained) that the cost premium will be substantial.

- Two builders who we know track costs exactly and who gave thoughtful answers estimated a much higher cost premium for this assembly.
- The same small, spec Portland metro area builder that tracks his cost exactly estimated the premium for this assembly at $1.10-$1.35/sq. ft.. That is more than double the premium he estimated for the high heel vaulted truss roof ($0.40-$0.55/sq. ft.).
- A medium, spec Portland metro builder's $2.08/sq. ft. price premium is more than five times his $0.42/sq. ft. price premium for the other three roof assemblies.

PTCS Duct Blaster Airtightness Testing

AVERAGE COST

$296*

EXPLANATION

We obtained 14 responses from builders in all classes in addition to knowing Earth Advantage's own price for the PTCS duct testing ($225). Therefore the results have a high degree of confidence. Earth Advantage is familiar with this market since it provides this service and hears testing costs from builders using its services or other testers. In addition, the costs are relatively consistent and show little variation as the table below shows[9].

Cost	< $200	$200- $250	$251-$350	$351 or more
Number	2	4	3	4

Earth Advantage did not include a second builder's reported cost in the average or the table because it was unexpectedly high for a large, Metro area builder. Earth Advantage believes that the builder may have included the cost for mastic sealing instead of simply providing the cost of testing.

[9] For the average and this table, we do not include two builders' pricing. One builder reported that he had not done it except on a project that appeared to be a high-end condominium project. He said the cost was "at least $500 or $600." That cost is almost double the average and appears unreliable. However, the builder is on the Coast where prices might be more variable because of the smaller market.

Note: PTCS duct leakage testing cost was difficult to break out from HVAC system cost. In a few cases, the builder confirmed that he obtains PTCS duct testing but was not sure of its cost on its own as it was bundled into a "enhanced" HVAC system pricing where his HVAC subcontractor included mastic sealing of the ducts and testing either as an optional, add-on package or simply built it into the HVAC subcontract. However, even in those cases, the builder usually could estimate the cost of the testing. Based on this, we speculate that HVAC subcontractor include the specific cost for PTCS duct blaster testing in their bids and contracts. We used the builder's estimate of the only the testing cost (and not the cost of mastic sealing) since our purpose was to isolate the cost of the testing. It appears from the builders' responses that mastic sealing has become sufficiently commonplace to be almost an industry standard, but most careful questioning is needed to confirm this.

Volume-Based Pricing. Many builders expressed their cost as a range. In part this was based on uncertainty; however, for at least one medium and one large builder, it was clear that the builders may enjoy substantial volume-based pricing. One builder reported that it might cost $300/house if the tester tested only one house at a job site but that he could get the same testing done for as little as $150/house if the tester tested multiple houses at one location. A large builder refused to provide his costs but simply confirmed that it was less than $300. Earth Advantage based on the builder's other answers and specific information about PTCS from other builders, Earth Advantage estimates that the large builder enjoys volume-based discount pricing well under $250/house and potentially less than $200/house.

Large Home Premium. A few builders, typically building large, custom homes suggested they pay a higher price for testing their larger homes. Some indicated that the premium was based on the size of the house requiring more work or time by the tester (e.g., more returns or supplies to seal). However, in some cases it appeared that those builders simply had less reason to aggressively seek lower priced testing because they could more easily recover their costs.

Summary of Findings

IMPORTANCE OF BUILDER CHARACTERISTICS AND HOUSE SIZE

Other than noting that custom builders quoted higher estimated costs, we also noted that large houses dramatically increase the cost of PTCS duct testing. We did not ask and cannot draw any conclusions on whether the cost increase is because the testing is more difficult, takes more time, or is simply easier to pass on a higher cost when the sales price is greater or there is no sales risk. A few builders suggested the testing cost is greater because it takes more time on a large house (e.g., sealing more supplies and/or returns).

The reliability of the information that the builder provided depended almost entirely on the builder's attitude towards the survey, interest in the subject, and concern about home performance. At least one custom builder provided little cost information. He explained that he had no idea because he'd never considered these assemblies. He suggested that "his home buyers make so much money that they don't care about utilities."

Other custom builders had employed many of the assemblies and measures as standard practice and had difficulty working back from their costs to the costs of an assembly simply meeting code because it

had been so long since they built such a home. At least of few of them told Earth Advantage that they do not provide a choice to their homebuyer about the upgrades; they simply include it in all of their homes. Others know the cost because they offer (and highly recommend) the measure as part of their "insulation and air-sealing upgrade package."

The large builders had the most precision in pricing, and their cost increments for addition materials and labor were much smaller. For example, most of the custom builders had confidence that even if their framers or finish work subcontractors requested higher pay, they'd limit the cost increases. However, when they quoted framing labor cost increases, they quoted premiums of $0.25, $0.50, and even more per square foot (sq. ft.) of home. The large builders, especially when building primarily or solely spec homes quoted framing labor premiums that they would pay which were much smaller (e.g., $0.02-$0.04/sq. ft.).

For this reason, Earth Advantage believes the cost premium estimates from the large, spec builders is a more reliable estimate of their cost premiums. However, few builders would enjoy such small labor cost premiums. The same held true on the cost of materials. Especially with insulation prices, the large, spec builders had more precise cost estimates and would pay much smaller cost premiums for additional insulation.

UNEXPECTED VALUE FROM SURVEY

In the process of gathering the estimated costs, Earth Advantage learned much hard-won experience and wisdom from builders. Earth Advantage learned that regardless of putative thermal superiority of certain assemblies, those assemblies may have substantial hidden costs.

Further, some of these assemblies concern builders as much as catastrophes they've seen in their industry (e.g., L-P InnerSeal siding, EIFS, etc.). At least one of the builders interviewed is reported to have experimented with one of the assemblies only to abandon it after a number of expensive moisture-related defect claims. Many builders commented, "I will not build it" when Earth Advantage questioned them about one or more of the assemblies regardless of the assembly's apparent thermal superiority. In many cases, their reasoning had nothing to do with cost but convinced Earth Advantage that their views should be seriously considered.

Others provided detailed information about costs that are likely hidden by simple analysis of framing labor and material increases. For example, many builders expect that the cost premium for 8 inch thick walls comes primarily from finish labor and materials, not framing labor and materials ("L&M"). However, this depends on the grade of the finish. A builder using sheetrock window returns may face little premium. Even MDF window wraps will have relatively little cost premium for labor or material. However, door casings may need to be furred out for thicker walls or ordered specially with deeper casings. In addition, finish material costs may explode for 8 inch walls because wood trim prices increase almost logarithmically with width instead of arithmetically.

In Earth Advantage's opinion, the concerns and perspective on the assemblies that the builders shared is perhaps as valuable as the cost estimates.

Recommendations

FOLLOWING-UP ON BUILDER'S CONCERNS

Earth Advantage suggests follow-up dialogue addressing builders' concerns about some of the assemblies under consideration. When a builder says "I won't build it!" or "This cost estimate does not include our increased exposure to warranty claims," they are expressing more than concern about passing on their cost or even their view of the cost/benefit of the measure.

Many builders expressed deep concerns about the assemblies' susceptibility to damage caused by moisture. Their concerns are validated by the general observations of building scientists that thicker, better insulated walls are more susceptible to damage from moisture (either because of cold exterior sheathing which condenses moisture or insufficient warming to dry occasional wetting caused from imperfections in the drainage plane). NEEA, OHBA, and/or could present studies to builders to assure them of the durability of the proposed assemblies before they will be willing to build them.

NEEA may wish to consider adding details to the wall assemblies that make them safer to employ. For example, based on the recommendations of building scientists, Earth Advantage recommends a rain screen gap of at least 3/8 inch depth between sheathing and siding. This is three times the 1/8 inch gap required by the 2011 Oregon Residential Specialty Code. Earth Advantage knows of builders that increase this gap to 0.5 inch or 0.75 inch for even greater protection. And Earth Advantage recommends at least 24" roof overhangs to protect walls from direct wetting by rain.

FURTHER RESEARCH ON ADVANCED FRAMING

For a practice as well-established by some builders as AF, there appears to be considerable disagreement among builders. Earth Advantage made no attempt to consult with engineers about claims by one builder that AF requires re-engineering of house plans and/or additional hold-downs for wind and seismic sheer wall requirements. Earth Advantage is also curious about whether framers are as unintelligent or tradition-bound as builders claim.

Builder concerns about wet weather causing bowing in sheathing appears to be a valid. The builders claimed that even thicker OSB or plywood sheathing would bow when supported only every 24 inches instead of every 16 inches. Perhaps builders in only some regions (or seasons) of Oregon can practice AF. Or it will await advances in water resistance of sheathing material.