

HIGH PERFORMANCE



Defining Efficiency Goals A process for selling performance in new homes

BY INDIGO RUTH-DAVIS

Most people who approach our company to build a new house are looking for an energy-efficient home. Some have heard about the Passive House standard but don't know exactly what it means, others have heard about heating with mini-split heat pumps and want to get off using fossil fuels, while others just want to be more comfortable and spend less on heating. Regardless of how serious or committed future homeowners are to energy efficiency in early conversations, decisions will have to be made before bids are gathered and pricing is finalized.

Future homeowners want to make smart, informed decisions about their new home. In the same way that you, as the builder,

want to be the one able to offer the best advice on materials and construction details, you want to be the one with the inside scoop on energy efficiency. Helping determine how far to go with energy efficiency is now part of what builders need to be able to do.

I've developed a process for this over the past few years that combines construction cost estimates for four levels of efficiency with Passive House-style energy modeling. This gives homeowners a good idea of what they should expect to pay to heat their home at each level of efficiency, and what that reduction in yearly expenses will cost to build. As the contractor and energy consultant, I am able to provide this completely customized information to the client, information that they will never be able to find on the internet.

Photos by Indigo Ruth-Davis



In this example, the homeowners chose a superinsulated wall system with an exterior insulation curtain composed of 10-inch wood I-joists filled with dense-blown cellulose insulation. A smart vapor and air control membrane was located in the center of the wall between the interior stud frame and the exterior I-joist build-out.

I see five main factors that will determine how energy efficient a project will be. The energy modeling in combination with construction cost estimates will help the builder and homeowner address these questions.

- **Budget:** Can the homeowner afford a Passive House? Can they afford an Energy Star Home?
- **Return on investment:** Is the homeowner thinking long term? Small efficiency improvements pay for themselves quickly, but over the course of many decades, larger upgrades will save more money.
- **Schedule:** Is the added complexity of a super-efficient envelope, or lead time on special-order materials like European windows, going to throw off the building schedule? Higher-performing homes take longer to build.
- **Comfort:** A more energy-efficient home will be less drafty, with warmer exterior wall and window surfaces. These are huge benefits for some people.
- **Commitment to the environment:** Does this future homeowner want to make a statement with their house and be at the forefront

of a movement that is building for a changing climate? Or is saving money up front—or in the future—most important?

PRESENTING THE OPTIONS

I'll use a recent project of mine as an example of how we helped a homeowner figure out their efficiency goals, and how my design and building process helped bring those goals to fruition.

These homeowners had heard about the Passive House standard, and they were interested in seeing if it was possible at their building site and for their budget but were not looking for any certifications or awards. They are environmentally conscious people, but they didn't want to go overboard if it didn't make sense financially. They plan that this house will be the family home far into the future. They had a design that they liked that was roughly 2,200 square feet.

Modeling the choices. My first step was to do energy-model comparisons of different levels of efficiency for their design. An energy model is a computer program that uses information about the building's size and shape, insulation levels, windows, HVAC,



The homeowners chose a rainscreen siding system requiring a drainage-plane membrane and cross-strapping, which resulted in a significant increase in cost compared with the next-lower-performing option.

airtightness, and climate data to predict that building's energy use. Since the Passive House standard was still a possibility for this project, I used Passive House software for my energy-modeling comparisons. In particular, I used the Passive House Planning Package (PHPP), although the Passive House Institute US now requires WUFI Passive as the modeling tool for certifying projects starting this year. There are many other energy-modeling tools that would do this comparison modeling; the PHPP isn't necessarily the easiest, but it does have a proven track record for being detailed and accurate, which is an advantage particularly when comparing very low energy demands.

The process of energy modeling itself is simply a matter of inputting all the relevant data into the computer. This includes the square footage of living space, the orientation and square footage of exterior envelope, the size and orientation of each window, the climate where the building will be located, and the R-values of each envelope assembly and U-values and solar heat gain coefficient (SHGC) of the windows. The most time-consuming part of energy modeling

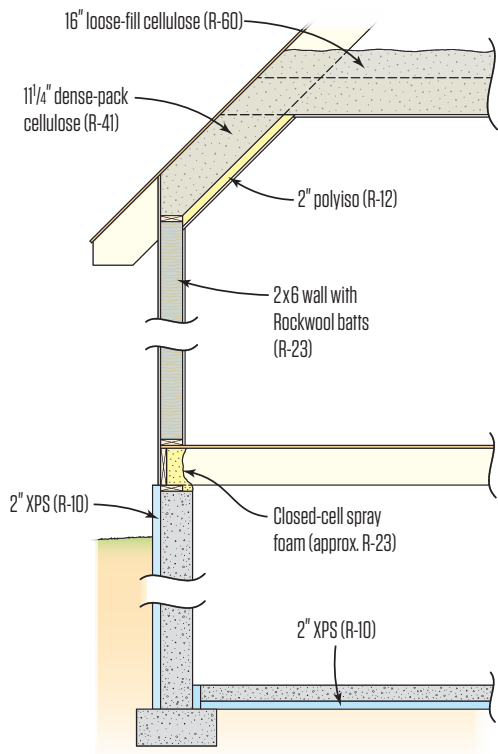
is inputting the areas and window list. Once that is done, it is easy and fun to try out different levels of insulation and window specs.

I use four benchmark levels of efficiency for my comparison modeling: the Vermont Residential Building Energy Code, Energy Star (with some upgrades to meet Efficiency Vermont's Base Level Certified Home), Efficiency Vermont's High Performing Certified Home, and Passive House Institute US Certified Passive House. These four levels make sense for my area but could differ by region. The efficiency specs and how I planned on satisfying them for this project are presented in the tables on the following pages.

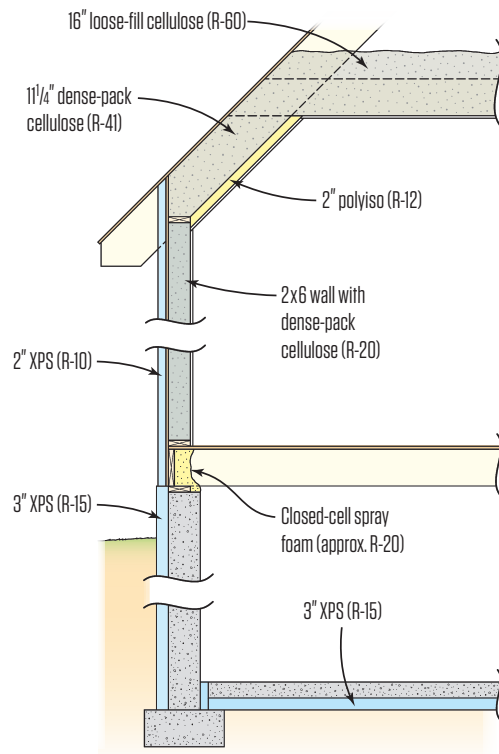
By the way, the Vermont energy code offers five "packages" or combinations of different insulation levels for compliance. I chose Package #4 to model, because it seemed the most cost-effective option for this house design.

Estimating energy use. With each level of efficiency modeled, the energy use of each level of performance can be prepared. The metric I use for comparison is the heating and cooling demand per square foot of living space in a typical year, or kBtu/square foot/year.

Option #1 Vermont Energy Code

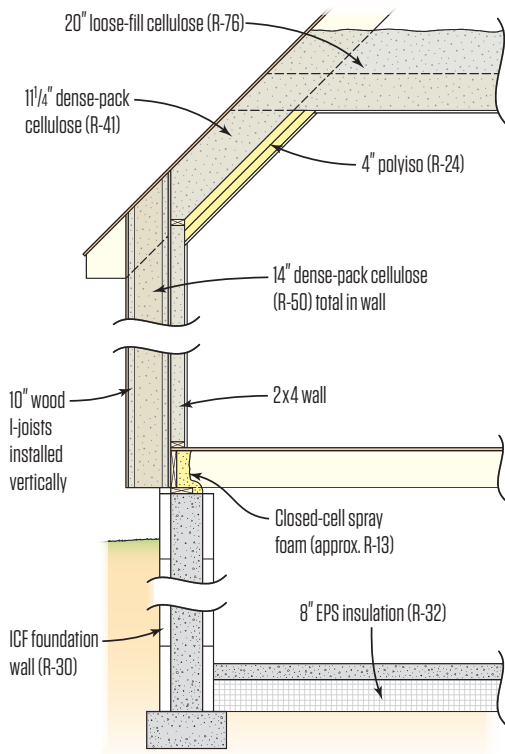


Option #2 Improved Energy Star

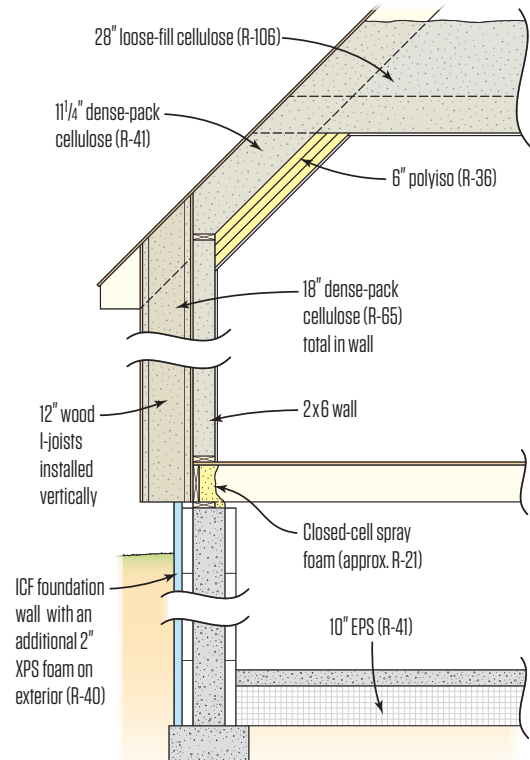


	Option #1 Vermont Energy Code	Option #2 Energy Star
INSULATION		
Sub-slab	R-10 [2" rigid XPS foam board]	R-15 [3" rigid XPS foam board]
Walls	R-23 [2x6 stud walls insulated with Rockwool batts]	R-30 [2x6 walls insulated with dense-pack cellulose with 2" rigid foam on the exterior]
Ceiling Slope	R-53 [11.25" dense-pack cellulose with 2" polyisocyanurate rigid foam]	R-53 [11.25" dense-pack cellulose, 2" rigid foam]
Ceiling Flat	R-60 [16" loose-fill cellulose]	R-60 [16" loose-fill cellulose]
WINDOWS		
	Double pane	Double pane
		U-.27 or less
HVAC		
Heating	Woodstove and mini-split	Woodstove and mini-split
Ventilation	Exhaust fans in the bathroom	HRV (75% heat recovery)
AIRTIGHTNESS		
	3 ACH50	2 ACH50

Option #3 High-Performing Home



Option #4 Passive House



Option #3 Efficiency Vermont Certified High-Performing Home		Option #4 PHIUS Certified Passive House
INSULATION		
Sub-slab	R-32 [8" rigid EPS foam board]	R-41 [10" rigid EPS foam board]
Walls	R-50 [13.25" dense-pack cellulose. 2x4 walls with 10" TJ1 insulation curtain to the exterior]	R-65 [18" dense-pack cellulose. 2x6 walls with 12" TJ1 insulation curtain to the exterior]
Ceiling Slope	R-64 [11.25" dense-pack cellulose, 4" rigid foam board]	R-76 [11.25" dense-pack cellulose, 6" rigid foam board]
Ceiling Flat	R-76 [20" loose-fill cellulose]	R-106 [28" loose-fill cellulose]
WINDOWS		
	Triple pane	Triple-pane Passive House-style windows such as Kleerwall or Schuco
	U-.21 or less	U-.1
HVAC		
Heating	Woodstove and mini-split	Mini-split
Ventilation	HRV (75% to 85% heat recovery)	HRV (80% to 90% heat recovery)
AIRTIGHTNESS		
	1 ACH50	.6 ACH50

FUEL-USE SPREADSHEET

Option #1 Vermont Energy Code	Wood	Heat Pump
Energy (million Btu/cord; kBtu/kW)	21	0.293
Cost Per Unit	\$300.00	\$0.17
Yearly Use (cords; kW)	6.28	11,512.68
House Size (square feet)	2,250	2,250
Heating Unit Efficiency	0.65	2.18
% Usage	50%	50%
Yearly Use (kBtu/square foot)	38.07	38.07
Yearly Cost	\$941.29	\$978.58

In other words, this is a measure of the amount of heat that is leaving the building through the outside walls for every square foot of living space for a whole year. In my climate, a code-built house uses about 35 to 45 kBtu for every square foot of living space in a year depending on the design, while a Passivhaus certified by the German Passivhaus Institute uses no more than 4.75 kBtu per square foot per year, regardless of the climate zone. The kBtu/square foot/year is a useful metric because it doesn't tell someone how big a building they should build or how it should be used, but it does tell them what each square foot of living space will need for heating and cooling. It is also rooted in the projected performance of the building in the climate where it is located, which is a better guide in maximizing performance than purely prescriptive measures like increasing R-values and U-factor levels.

While kBtu/square foot/year is useful during energy modeling, it doesn't necessarily mean that much to the average homeowner. The real goal is to be able to tell the homeowner about how much their house will cost to heat or cool. To do that, I take the kBtu/square foot/year data and input it into a spreadsheet that gives me the cost per year to heat based on the type of fuel used (see Fuel Use Spreadsheet, above). The approach for the heating system on this project was to use a woodstove and mini-split heat pump combination. The example above is for Option #1 Vermont Energy Code, which, given a 50%/50% split between wood heat and mini-split heat, was estimated to cost about \$1,919 per year for heat. For each level of efficiency, I convert kBtu/square foot/year to yearly heating costs.

COMPARING CONSTRUCTION COSTS

The next step is to do construction cost estimates for each level of efficiency. Estimating construction costs is the most time-consuming part of this process and as any builder would tell you, the thought of quadrupling the amount of time you would normally spend on estimating isn't exactly the most appealing. Without getting into a debate about whether estimating is part of sales (and

therefore nonbillable) or a service an experienced contractor is providing to the customer (and therefore billable), an accurate estimate for each option is critical to the success of this whole exercise. Whether you are charging the client directly for your time estimating different options or are hoping you will get the job and compensate yourself with potential future profits, taking enough time to think through all the potential costs for each option is important.

Each level of efficiency will involve different wall assemblies, different size heating systems, a different ventilation approach, and different windows, each with different labor and material costs. On this project, Options #1 and #2 were similar, while Options #3 and #4 had big differences. To achieve the Passive House heating demand, Option #4 required more windows on the south and more insulation, which meant a different wall construction.

With regard to airtightness, Option #1 required the least effort and cost. For Option #2, reaching 2 ACH50 would be easily accomplished by taping the seams of the rigid-foam insulation layer. General air-sealing would be done in the attic prior to installing loose-fill cellulose. Options #3 and #4 required labor-intensive Passive House air-sealing techniques. Sticking to not more than four options will limit the amount of time you spend on estimating. Some homeowners will want to explore every option available, but for this process, four is more than enough. The final building assembly and price can be fine-tuned later.

The final step is combining the construction cost estimates and heating cost estimates to calculate payback periods. I use a spreadsheet for this (see facing page). I don't attempt to account for energy cost inflation because energy prices move up and down seasonally and year to year.

For this example, the largest jump in cost was from Option #2 (the Energy Star Home) to Option #3 (the High-Performing Home). For the homeowners to be willing to make this jump, they would have to plan on living in the house for a while—almost 20 years—before seeing a return on their initial efficiency investment. After that point, however, the savings start to add up quickly. The reasons for this jump in cost for this particular house were threefold: the cost of upgrading to triple-pane windows (about \$7,000), the cost of the added insulation (about \$8,000), and the cost of the additional frame needed to hold the insulation (another \$8,000). The ratio of dollars spent on upgrades to dollars saved changes drastically at the High-Performing level because of these big-ticket upgrades.

For most projects, the construction cost jump from Option #2 to #3 is difficult to avoid. There will be significant increases in frame costs whether you do a double stud wall or a TJI curtain wall, triple-pane windows will cost at least 20% more, and, obviously, the insulation itself will cost more. If a homeowner is looking for something between these two levels, an over-insulation approach will give the most flexibility. With exterior foam, 1 inch of insulation can be added at a time with little increase in labor cost, and the frame costs don't change significantly. On this project, we were trying to avoid foam as much as possible mostly for environmental reasons, which meant the homeowners were going to have to commit to a cost jump or stick with Energy Star.

CONSTRUCTION COST ESTIMATE				
Efficiency Level	Construction Estimate	Annual Heating Cost	Annual Savings Over Code Built	Payback Period (Years)
Option #1 Vermont Energy Code	\$324,178.00	\$1,919.87	–	–
Option #2 Improved Energy Star	\$327,738.00			
Efficiency VT Incentive	-\$2,000.00			
TOTAL	\$325,738.00	\$1,311.18	\$608.69	2.6
Option #3 High-Performing Home	\$347,538.00			
Efficiency VT incentive	-\$3,000.00			
TOTAL	\$344,538.00	\$813.44	\$1,106.43	18.4
Option #4 PHIUS Certified Passive House	\$356,968.00			
Efficiency VT Incentive	-\$3,000.00			
TOTAL	\$353,968.00	\$380.94	\$1,538.93	19.4

THE HOMEOWNERS MAKE THE CALL

These homeowners were willing to make the jump. The biggest factor is always the budget, and for this project, we were able to provide Option #3 within their budget. Because they plan on living in this house far into the future, a payback period of 20 years was worth it for them. The additional comfort this option provided was a bonus.

Going a step further to Passive House at first seemed to make sense based on this analysis, but the devil was in the details. In order to keep the Passive House budget close to the High-Performing Home budget, a few compromises had to be made in the construction cost estimating. The woodstove wasn't needed and therefore was eliminated; we had to switch from domestic-wood-interior/clad-exterior windows to European uPVC windows with limited color options; and the design needed to be altered for more solar gain. With the woodstove and comparable-looking Passive House windows added to the Option #4 budget, Passive House was out of reach. The payback period without these compromises would be 32 years. Passive House performance ultimately involved too many compromises for these homeowners, and they decided to stick with Option #3, the High-Performing Home.

The ability to provide heating cost estimates along with construction cost estimates is a valuable tool that enables builders to have meaningful conversations with future homeowners about energy-efficiency decisions. The size of the house, where it's located, and what its components are (the envelope R-values, the type of

windows, the ventilation, and heating systems) have a direct effect on how much the building will cost to live in, and without energy modeling, there is no worthwhile way to have this conversation. Being able to tell these homeowners that they could expect to save roughly \$1,000 a year on heating and live in a more comfortable home with the High-Performing option made all the difference.

The four-tiered energy-modeling approach I've started using shows that just about any level of energy efficiency upgrade will eventually pay for itself in this climate. There is no magic point along this continuum of efficiency that every future homeowner should try to attain. If they are building with the future in mind, high levels of efficiency will pay for themselves eventually and the savings will add up over the long term. If the budget is tight, small, simple improvements to airtightness and insulation levels can save a surprising amount on heating and pay for themselves quickly.

Attaining the highest levels of efficiency will most likely involve design modifications, and except in the rarest cases where budget isn't an issue, some compromises will probably need to be made in material choices. For most people in our area who are interested in energy efficiency, Efficiency Vermont's High-Performing Home level is a good benchmark, but with a site well oriented for passive solar gain and with a few compromises, a certified Passive House isn't that far off.

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