Lessons Learned from Self-Building a Super-Insulated House

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Pre-renovation: the 1904, semi-detached east Toronto house.


Post-renovation: the 1904, semi-detached east Toronto house, modernized!

The journey in pursuing my own, hands-on approach to complete a deep energy retrofit began in 2014, when I purchased a 1904 semi-detached home in the east end of Toronto. My formal education is in civil engineering, but my real passion is building science; so, what better way to learn than to get my hands dirty with my own self-build?

Our first winter of 2014-2015 revealed the house's major energy inefficiencies: the HVAC ducts were neither insulated nor air sealed, there was a large hole in the foundation wall for HVAC "fresh air," and the walls were largely uninsulated—all aspects made the house perfect for a deep energy retrofit.

PROJECT GOALS

Like any high-performance build should aim to achieve, the goal was to improve the building's durability, occupant comfort and health, and energy efficiencies. My goal was to improve the building with principals from the "pretty good house" movement. I followed the exterior insulation method outlined in the *Mass Save Deep Energy Retrofit Builder Guide* by Building Science Corp. (see Figure 1 on page 18) and the forum discussions at www.greenbuildingadvisor.com.

I also worked through smart efficient details to better understand the high-performance systems and materials, building an architecturally aspiring green home (what's the point of a high-performance house if it's an ugly box destined for the landfill within a few decades?), and maximizing passive heating and passive cooling systems. At the time, going off fossil fuels wasn't a goal; today, however, it most certainly is.

PERFORMANCE HIGHLIGHTS

Super insulation was one of my main focuses. An overview of the project's thermal insulative performance is shown in Figure 2 on page 19 and is compared against code-built project and the original project prior to the deep energy retrofit. The figure also highlights how windows de-rate the effective R-value of walls, even with high-performance windows and a 20 per cent window-to-wall ratio.

Continuous exterior insulation and batt insulation used within stud cavities helped achieve high performance. To provide an uninterrupted blanket of continuous insulation, the existing roof overhangs were cut off. Thereafter, new eave overhangs were installed for good water control and to maintain architectural intent. New, high-performing windows were installed to maximize the overall building performance. More on this, later.

INSULATION SYSTEMS

Four-inch-thick exterior insulation in two staggered lifts of expanded polystyrene (EPS) foam board and graphite-impregnated EPS (GPS) wrapped the exterior walls, and seven-inch-thick EPS and GPS insulation wrapped the warm roof. Pine strapping (one-by-three) on the walls and roof allowed the attachment of siding and roofing (see photo on page 19), and provided a vented rainscreen cavity. Long screws secured the strapping to the framing at the walls and roof. I chose EPS and GPS foam board insulations based on good insulative properties, lower costs, and lower global warming blowing agent potential (see Figure 3 on page 19) and mineral wool batt insulation to fill walls and ceilings due to its excellent fireproofing, soundproofing, and insulating properties.

Spray foam insulation was decided against based on its very high global warming blowing agent potential, toxicity, and flammability. There are also concerns with its long-term airtightness (one of its primary benefits). In considering other insulation materials, high material costs and proper airtightness also played a part. Do your research to find the best fit for your project.

AIR BARRIER AND VAPOUR RETARDER

The traditional poly vapour barrier was designed out to prevent the risks associated with a vapour sandwich caused by the vapour impermeable poly sheet on the interior and foil-faced EPS on the exterior. These two impermeable surfaces could trap moisture within the wall. If not allowed to dry, trapped

	PROJECT BUILDING		CODE BUILT		PRE-RENO	
	NOMINAL	EFFECTIVE	NOMINAL	EFFECTIVE	NOMINAL	EFFECTIVE
ROOF	R35 ci + R22 batt	**55.2**	R42 spf	**23.0**	R14 batt	**7.1**
WALLS	R15 ci + R14 batt	30.7 +	R7.5 ci + R14 batt	19.2 +	R14 batt	11.7 +
WINDOWS (installed)	R6 (U=0.17)	4.0 =	R4 (U=0.25)	2.0 =	R1 (U=1.0)	1.0 =
20% WINDOW-WALL		**13.1**		**7.1**		**3.7**
BASEMENT	Brick + R20 ci + R6 batt	**19.5**	Brick + R14 batt	**12.1**	Brick	**6.1**
TOTAL		**17.2**		**10.1**		**5.3**

Figure 1: A thermal insulative performance comparison between my self-build, a standard code build, and pre-renovations.

moisture could lead to building failure. Moisture could enter from the interior in the form of water vapour through an electrical receptacle or from liquid water penetration around a window. It's a factor of *when*, not *if* there will be moisture penetration.

The building's vapour retarder was provided by latex paint on drywall using the air-tight drywall approach, a method approved by the *Ontario Building Code*. Disclaimer: this method is incredibly tricky to do correctly and should only be completed by experienced professionals. A smart vapour retarder was used in the bathrooms. Although a robust design, an even more resilient design would have been to drop the foil facer on the exterior and provide a smart vapour retarder on the interior behind a service cavity; out of harm's reach, from electrical, plumbing, and other service penetrations. At the building's rear extension and over the roof structure, the air barrier was oriented strand board (OSB) sheathing with taped seams. Elsewhere, the air barrier (and water control layer), was provided by the foil-faced taped insulation seams. It's best to provide the air barrier toward the building interior, which I did for the rear extension. The air barrier could also double as your vapour retarder if installed correctly. I used red tuck tape to tape the foil-faced insulation, which was an effective, low-cost solution at the time. However, it was later found to de-bond indiscriminately on the roof and walls to the foil facer, so I replaced the tape with a high-quality, acrylic adhesive tape with outstanding results. I guess you get what you pay for.

WINDOWS

The windows were high-performance, triple glazed, double low-e coated, fiberglass-framed windows. To deal with the thicker walls, factory installed interior jamb extensions were fitted to allow the windows to align with the exterior insulation plane, which maximizes thermal performance. The low-e coating and glazing surface were customized on each window elevation to maximize solar heat gain in the winter and minimize it in the summer.

MECHANICAL HEATING, VENTILATION, AND AIR CONDITIONING (HVAC) SYSTEMS

High-performance heat recovery ventilators (HRVs) are critical for high-performance, air-tight buildings. The HVAC systems, or as I call them, the comfort

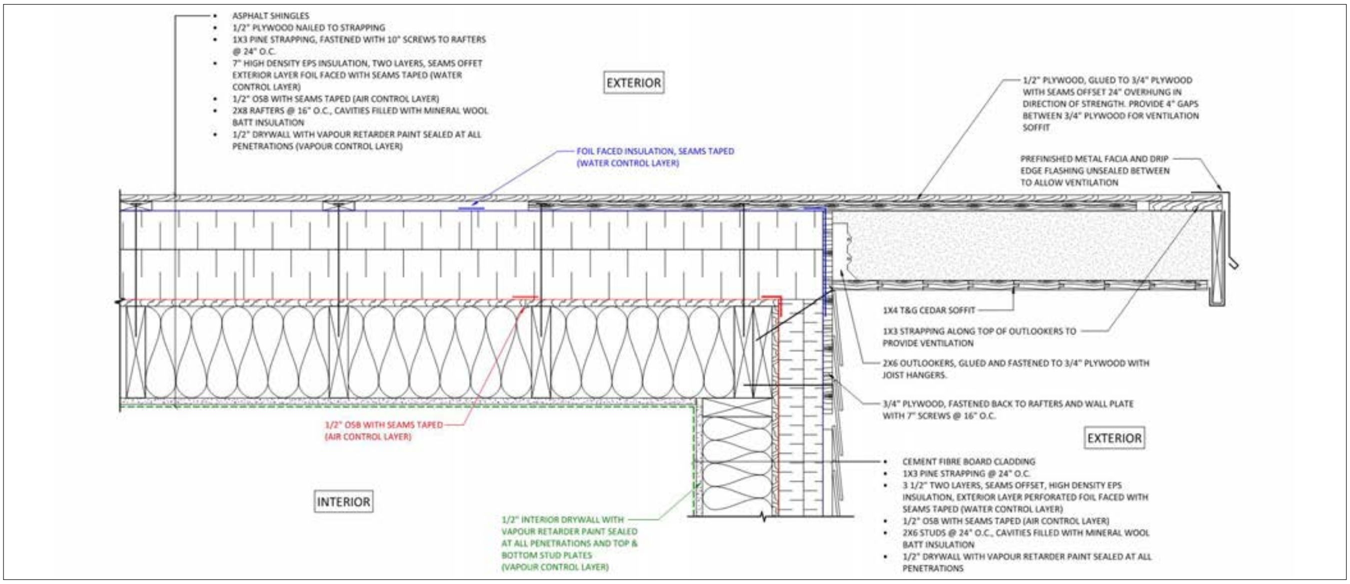

Figure 2: Wall-to-roof interface detail; note the continuous control layers and the exterior insulation that wraps continuously from the roof to the wall.

systems, are comprised of a combined HRV and heat pump system. This specialized, all-in-one unit provides fresh air with HEPA filtration, heating, cooling, and dehumidification, operating based on sensors of temperature and humidity. The unit, with a coefficient of performance (COP) of four, lives in the conditioned knee wall to optimize space. For future builds, I would prefer a standalone HRV and heat pump, as each system has its own job. These combined systems could be reserved for very small buildings, such as multi-unit residential buildings.

A mid-efficiency (67 per cent) gas fireplace was selected for supplemental heat and ambience. It provides a resilient heat source that operates without electricity during power outage and is sized to heat the entire house in winter, if needed. The fireplace incorporates a direct, co-axial vent to draw and preheat combustion air from the exterior. This provides three benefits:

1. Sustains an air-tight building assembly;
2. Maintains a pressure-equalized space, so not to draw in uncontrolled and unconditioned exterior air; and
3. Improves efficiency.

I installed a high efficiency (95 per cent) direct vent condensing tankless gas water heater. While these gas units are very efficient, there have been large leaps in electric-driven hot water technologies over the past decade. Heat pump water heaters have extremely high COP levels, with one manufacturer having a published COP of six!

Foil-faced insulation seams taped to provide a continuous water control layer, along with one-by-three wood strapping over-top and screwed to the structure. Two inches of foil-faced EPS insulation over five inches of GPS insulation with staggered seams over the roof structure were then installed.

	R-Value (per inch), approx. LTTR , @21C	Cost	Global Warming Blowing Agent Potential	Water Retention	R-Value Change In Lower Temperature	Permeability
EPS	R4	$	Low	Low	Increases	Semi-Permeable
XPS	R5	$$$	High	Low	Increases	Semi-Impermeable
GPS	R4.9	$$	Low	Low	Increases	Semi-Permeable
Polyiso	R5.6-5.9	$$$	Low	High	Decreases	Impermeable (with foil facing)

Figure 3. Comparing foam board insulations: EPS, XPS, GPS, and polyisocyanurate.

CLOSING

While this build did not pursue any high-performance certifications, it certainly entailed a lot of high-performance systems and is leaps ahead of the standard code minimum build. The hands-on experience taught me many lessons. For me, the project was a success, both in performance and architectural aesthetics. For others pursuing a high-performance project, the team's experience and collaboration will be most critical for the success and cost of the build. ■

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