Zero Energy Home Design

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As I travel and speak to builders and designers across North America, I am so pleasantly surprised by how those I meet are responding to the compelling trend towards net-zero or zero energy homes and buildings. For example, in my own home market of Toronto, Canada, where we work as energy raters and consultants with 60-80 homebuilders and high-rise, multi-family builders, we currently have 25 net-zero energy projects on the go. The most gratifying aspect to me is how builders see this trend as an "it's not if, but when" opportunity. They are approaching it in a responsible and appropriate way, not as a fad, but as something to research, explore and demonstrate to ensure it can be done profitably and within the context of the demands and realities of production home building. As a result of this measured approach we have already learned a great deal about the design, technology, process and cost challenges that can be overcome to make these highly efficient homes more mainstream.

As an industry, the first challenge was in defining what net-zero energy means, so as not to create unrealistic expectations or to burden designers and builders with insurmountable challenges. There are, or were, at least 5 possible definitions ranging from a simple concept of average zero annual energy bills for building owners to full carbon neutral developments that account for embodied energy of all components and future energy. Fortunately, in the fall of 2015, the Department of Energy published a simple and remarkably helpful definition of a Zero Energy Building as "an energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy." Notice first that the DOE has dropped the term "Net-Zero" in favor of simply Zero Energy; a term that frankly needs less explanation to busy, over tasked homebuyers. Second, it empowers designers to consider the new metrics of energy usage versus energy production or exportation. Thus, the design and specification process is no longer one insulation company versus another or a gas furnace versus a heat pump but now adding the trade-off or consideration of favorably oriented roof designs to optimize solar production, passive solar gain through strategic glazing as well as consideration for occupant loads such as lights and appliances. This should be seen as an exciting opportunity and our builders' experience has been that it is not that difficult to do. I encourage all designers to visit the DOE Zero Energy website at http://energy.gov/eere/buildings/zero-energy-ready-home to see the full specifications for both Zero Energy Homes and the very popular Zero Energy Ready home – a first and most cost effective step towards zero energy where, as the name implies, focuses on getting the envelope and mechanical systems ready for when solar panels are more cost effective.

Here are four things we have learned that may be helpful to you as you consider your first zero energy home design. There is a caveat that design parameters will change depending on the climate zone you live in, although we are finding that the variations between climate zones are not as much as you might think.

Often the first challenge is to find a wall system that respects the need for high **effective** R-values and that is cost effective to build. That term effective R-value should be familiar to all designers by now. It considers the thermal transfer through an entire wall assembly and to get to zero energy in any climate zone it means a respect for thermal bridging. While you can try various iterations of double wall or staggered stud framing, it has been our experience that you will end up with continuous exterior insulated sheathing as the most practical approach. For example, a builder by the name of Reid's Heritage Homes in Guelph, Ontario, Canada constructed five Zero Energy homes as part of a partnership between Natural Resources Canada and Owens Corning called the ecoEII project. *For more information on this national project that includes four* *other builders across Canada, visit www.zeroenergy.ca*. As Reid's Heritage Homes looked for the sweet spot between added enclosure and systems costs versus the required renewable energy capacity, they tried different wall sections on different homes. In the first home they used a 2x6 wall at 24" O.C. with 3" extruded polystyrene insulation on the exterior for a total effective R-value of just over R35. If you grimaced at the R15 (3" XPS) insulated sheathing on exterior walls, you weren't the only ones. This item was one of the first on the chopping block for the next four homes. It alone caused substantial foundation costs, unnecessary complexity for brick ties and siding fastening, and significant process changes that proved detrimental to air sealing. On their second Net Zero home they considered 2x8 top and bottom plates with staggered 2x4 double studs. In the end, the framing crew had the last say and elected to use simply 2x8s in the entire wall. Exterior insulated sheathing was limited to R10 or 2". Compared to the first Net Zero wall assembly, framing and sheathing time was cut in half and the process differed very slightly from their standard ENERGY STAR walls; with 1" thicker exterior insulation and 2" thicker studs. Most importantly, all air-sealing details were consistent between Reid's Heritage Homes' normal ENERGY STAR process and these Net Zero homes. That 2" exterior insulation (R8 to R10 depending on the type of insulation you choose whether it be EPS or XPS foam or semi-rigid rock wool insulation board), in our opinion, will be a common element in all zero energy walls. In climate zones 1-4, that could be 2" exterior insulation on a 2x4 wall, in climate zones 4-6 it would be 2" on a 2x6 wall, and in very cold climates it would be the R10 over a 2x8 wall.

The second challenge designers can help with is achieving high levels of air tightness. Start by identifying air barrier elements and details on your plan sets. Air tightness is not about specific material choices as just about any building material used qualifies as an air barrier. Wood, OSB, drywall, rigid foam sheathing and good quality house wraps can all be part of the air barrier. You can help by identifying the transition points in the assemblies and how to bridge the air barrier continuity. This would include wall to ceiling, floor joist assemblies, cantilevers and wall to foundation transitions. Zero Energy homes are most cost effective when air leakage rates are less than 1.0 to 1.5 Air changes per hour at a 50 Pascal pressure difference (this is the common metric for blower door testing). If air tightness testing isn't familiar to you, then in the next year plan to experience a test and identify air leakage points, that you could help resolve, with better details on your plan sets. In the end, our experience has shown that builders can achieve extremely low air leakage rates, under 1.5 ACH50Pa, in a typical house for less than $1000 to $1500, if designers can help identify framing details to ensure continuity of the air barrier.

It should be no surprise that we need to address windows. Of course, every homebuyer and designer wants to maximize window area and yet windows can be a big burden on energy usage. The issue is climate zone specific and professional energy raters in your market can help you find the balance between responsible energy use and the big open looks your client desires. You can help mitigate the effect of windows with a few simple guidelines. Incorporate location specific overhangs to optimize solar gain in winter and minimize overheating in summer. Look to incorporate north facing glass in southern climate zones and south facing glass in northern climate zones. Specifying appropriate low E coatings depending on the glass orientation and recognizing that in at least climate zones 5 and higher, triple glazed windows will become the norm.

One final consideration for designers is to ensure provision for renewable energy production. Currently that means enough roof area, in the right orientation and at the right pitch for optimized PV solar panels. In spite of best efforts to reduce energy consumption, a typical household needs a PV system with a capacity rated at 7 to 10kW to meet the DOE definition of Zero Energy. There are exceptions, but from our experience this represents the sweet spot between envelope and HVAC system costs and the cost of solar PV. With the most efficient panels available today, a 7 to 10 kW array would require approximately 600 to 800 sq.ft. of roof area, facing somewhere between southeast to due west at a pitch between 6/12 and 9/12. The optimum pitch and orientation varies by geographical location and can impact PV production by as much as 20%, so check with a solar design company in your area to get the specifics.

Let's go back to that Reid's Heritage project and see what the final specifications were for their lovely 1,750 sq.ft. home in a suburban subdivision. These are the specifications for the fifth of the series of zero energy homes built.

Component	Target Effective R-Values	Construction Elements
Ceiling	R60+	R60 blown fiberglass with 10" raised heel truss
Above Grade Walls	R35+	2x8 @24" OC, R23 batts + R10 XPS exterior sheathing
Foundation Walls	R25+	2x4 @24" OC, held out 2" for R23 batts + R10 XPS continuous tight to the wall
Foundation Slab	R10+	2" XPS under slab, with 2" XPS slab edge insulation
Windows	R5+	Triple-glazed, double Low E coating
Air Tightness	<1.5 ACH@50	1.0 ACH@50
Ventilation	75% effectiveness	Energy Recovery Ventilator
Heating / Cooling	Air source heat pump with natural gas as furnace back-up	Air source heat pump with a condensing, variable output gas furnace 95% AFUE and ECM fan motor
Hot water	Heat pump water heater	An energy factor of over 2.0

Notice that the mechanical specifications include both an air source heat pump and a heat pump water heater. It is really hard to deny the efficiency of heat pumps, even when the cost of natural gas is about one third the cost of electricity in most markets. In most of the zero energy projects we are working, natural gas is used as a back-up for both space heating and domestic hot water, often using a condensing tankless water heater. All zero energy homes benefit from application of energy recovery ventilators both for their energy efficiency and also the improved air quality control.

Over the building of five Net Zero homes, Reid's Heritage Homes gained enough valuable experience in the process to decrease the incremental cost by over 25%. The DOE has suggested in their Zero Energy Ready program that the incremental envelope and HVAC system costs could be as little as $15000 to $20000 today and I think designers can see this to be plausible given the specifications listed above. It's compelling because the changes needed are not that daunting in any climate zone and because getting to at least zero energy ready can easily be defended as cost effective. All designers should be ready and willing to take on the challenge of zero energy homes.