Can Passivhaus Bridge the Green Building Gap?

The new enthusiasm for high-performance buildings, whether founded on a desire for sustainability, or a realization of a new cash cow in the building industry, has caused many designers to look outside the box for new building practices and standards. Some have become household names, like LEED, while others are still less renowned. Of these lesser-known (and less widely adopted) standards, Passivhaus, the German super-insulation standard developed by Wolfgang Feist in the early 1990s has seen a rise in interest in America. With new alternatives for achieving the 'green' standard, many sustainable designers are beginning to compare and contrast the multitude of energy efficient building methods and rating systems. Which is more cost effective? Which uses less embodied energy? Which works best in my climate? All of these have answers that can vary based on your geographic location and building products market. America's federal government has made a commitment to achieve LEED Gold rated buildings after 2011 (Clapper), but a movement towards a wide adoption of Passivhaus building practices has not been seen. Less than a dozen certified Passivhauses exist in the U.S., and though there is an American branch of the Passivhaus Institut, it seems that the U.S. and its building designers are not drawn to choose Passivhaus over other available green building methods and rating systems.

The Passivhaus standard came into being after Feist founded the Passivhaus Institut to "refine North American design principles for use in Europe" (Holladay, Passivhaus For Beginners) which yielded a prototype house in 1990-1991. Further research was conducted through the funding of the CEPHEUS (Cost-Efficient Passive Houses as European Standards) project, which, from 1997-2002, sent researchers to "gather data on 221 super-insulated housing units at 14 locations in five countries" (Holladay, Passivhaus For Beginners). Feist's inspiration for the standard came, surprisingly, from North America. The Saskatchewan Conservation house and a similar super-insulated house built by Gene Leger, a

Massachusetts builder, where built in the late 70s in Canada and New England respectively. Both had tenets of design that closely mirror Feist's Passivhaus standards; their walls were 12 inches thick with R-values of 44 to 60. William Shurcliff wrote, in June 1979, that:

> "They fit none of the…listed categories [of solar houses]. The essence of the new category is: 1) Truly superb insulation. 2) Envelope of house is practically airtight. 3) No provision of extra-large thermal mass. 4) No provision of extra-large south windows. 5) No conventional furnace. 6) No conventional distribution system for such auxiliary heat. 7) No weird architecture. 8) No big added expense." (Holladay, Forgotten Pioneers of Energy Efficiency)

Of this list, written a decade before Feist came up with Passivhaus, the first two describe prescriptive requirements of the standard, while the last six are more aspects to contrast this new building standard from the conventional solar houses of the 60s and 70s. The methods with which you achieve the standard are not mandated; it is the end performance result that matters. The last comment by Shurcliff is one that will be discussed in more depth later.

The standard has now been concentrated into a set of parameters, to be accomplished by whatever means the designer chooses:

- Airtight building shell **≤ 0.6 ACH @ 50 Pascal pressure**, measured by blower-door test.
- Annual heat requirement **≤ 15 kWh/m2/year (4.75 kBtu/ft^2/year)**
- Primary Energy **≤ 120 kWh/m2/year (38.1 kBtu/ft^2/year)**

In addition, the following are recommendations, varying with climate:

- Window u-value **≤ 0.8 W/m^2/K**
- Ventilation system with heat recovery with **≥ 75%**
- efficiency with low electric consumption @ **0.45 Wh/m^3**
- Thermal Bridge Free Construction **≤ 0.01 W/m·K** (Klingenberg, Passive House Institute US)

To accomplish these performance requirements, a building method has emerged. The shell of the building is heavily insulated; "wood-framed buildings usually have 16-inch-thick double-stud walls…masonry buildings are usually insulated with at least 10 inches of exterior rigid foam" (Holladay, Passivhaus For Beginners). To meet the window requirements, specialized markets are emerging in

Europe for extremely high-performance windows. Two mechanical items are usually employed as well: the heat recovery ventilator (HRV), and, if necessary, a small heat source (a boiler or something similar). It should therefore be noted that the term "Passivhaus" is a bit of a misnomer: no Passivhaus-certified house will ever be a completely passive, or net zero energy, house. "In the heating climates, a Passivhaus building is not a net-zero energy building – you still need to heat it. [Similarly, in hot climates,] you will need a small cooling system or a small dehumidification system." (Holladay, A Conversation With Wolfgang Feist)

The question of larger adoption abroad needs to be addressed: why is the Passivhaus standard not seeing the sort of widespread enthusiasm like that of the solar houses of the 60s and 70s? Is the standard too strict, too expensive to implement, or not compatible with Northern American building methods and materials markets? It seems to be a combination of all of these things. The first post-Feist Passive House was built in America in 2003 by Katrin Klingenberg, the pioneer of the US Passive House Institute. The first media coverage of the standard began around 2008; an interview of a Passivhaus owner in Germany (Rosenthal). Then, in 2010, another New York Times article ran, this time, addressing Passivhaus and its new reach into America. "While some 25,000 certified passive structures...have been built in Europe, there are just 13 in the United States…" (Zeller). In seven years, one dozen Passive Houses have been built. Whereas, in the 1970s' energy crisis, the passive solar home became a building fad, the Passivhaus movement seems to not be catching on in the United States.

The reasoning cannot be blamed on a lack of an energy crisis, but perhaps more on the ready availability of green building methods and standards suitable for conventional (used lightly) American construction. Examples of LEED, Energy Star, and passive solar buildings abound, while Passivhaus lags behind.

A similar question was raised by individuals in the UK; despite their close geographical locations, Passivhaus has not been generally recognized in the UK building sector. Projects like BedZED and the Code for Sustainable Homes, as well as the BREEAM toolkit are all successful in the UK, but uptake has so far been slow. It was posited that this may be due to Passivhaus' lack of holistic environmental standards; perhaps a more comprehensive assessment of the built environment is necessary for the British building community. Lastly, the UK widely embraced the Solar House concept: "the most recognized project example in the UK". (Morbitzer) Britain might be having a problem with seeing Passivhaus as a new viable building 'fad' to pay attention to.

In many articles and academic Passivhaus debates, cost differentials become evident. "In Germany, passive houses cost only about 5 to 7 percent more to build than conventional houses" (Rosenthal). A study conducted for the Sustainable Building Task Force concluded that "the average premium for these green buildings is slightly less than 2% (or \$3-5/ ft^2), substantially lower than is commonly perceived." (Kats) By 'green buildings', the authors are referring to buildings in California designed for the LEED standard. Evidently, Passivhaus in Germany is two to three times more expensive than LEED in America, even when each standard is used in their respective country of origin.

Though there are now translated programs to deal with the language barrier as well as the metric versus English units issue, there is quite a bit that is 'lost in translation' about the Passivhaus standard. First, the performance requirements of the standard are in metric units, and much of the literature and informational courses are still in German. The only initiative America has is the US Passive House Institute, which offers workshops and training to acclimate American users to the standard.

Much of the mechanical equipment and building components recommended by Passivhaus enthusiasts are only mass-produced in Western Europe (Rosenthal). Feist himself has encouraged US users to use any components that are readily available in their local area: "My recommendation is not to import windows from Europe, but to foster the development of really efficient American types of equipment." (Holladay, A Conversation With Wolfgang Feist) Problematically, in order to build a certified Passivhaus, one often has to resort to ordering machinery, windows, or other building components from Germany. If you want to get certified, you often have no local market to choose from. The homeowner, Mr. Landau, from Rosenthal's New York Times article said "We theoretically could have used North American windows, but they aren't specifically passive-house certified." He offers this concession: "Everything you need to build a passive house can be found in the United States…though [it still comes at a greater upfront cost]."

Though it will most likely be a problem that will go away over time, the pursuance of home insurance can also present considerable hurdles. Several insurers denied the Landau's coverage due to their concerns about the pipes freezing during the winter. (Zeller) Without a large knowledge base of successful American precedents, US insurers are going to act with apprehension towards the new and unfamiliar Passivhaus standard.

Because LEED and Energy Star are well-known in America, the federal government has taken action, deservedly, to offer tax credits and other incentives. "The passive-home standard, perhaps because it's unfamiliar to many officials who create efficiency stimulus programs, is eligible for few direct government subsidies." (Zeller)

As stated above, the premium on a Passivhaus in Germany is 5 to 7 percent, a considerably higher percentage than a LEED or Energy Star building would command. Even worse, the Passivhaus premium in the United States, compared to Germany, is currently estimated by Katrin Klingenberg of the US Passive House Institute to be at a minimum of 10 percent, while some have estimated an even higher 15 percent. This begs the question: is Passivhaus worth the fivefold higher investment that it demands?

A point that many Passivhaus opponents point out is that more effective green building strategies would be more sensible to employ, at a lower cost. “The Passivhaus concept risks overinvestment in conservation if a point is reached in the optimization process where adding solar electricity is a lower cost option than adding the next unit of insulation or air tightness.” (Parker) Others echo Parker’s observations:

“Few American designers are likely to adopt the Passivhaus approach if it calls for insulation specifications that cost more and yield lower energy savings than a PV system…a designer who advocates installing insulation that costs more than PV is anticipating a future with fuel costs that exceed the current cost of PV-generated electricity. That’s an unlikely scenario, considering the fact that…PV prices are still dropping.” (Holladay, Passivhaus Crosses the Atlantic)

Passivhaus defenders respond to this concern by arguing that comparing photovoltaic solar panels and insulation is like comparing apples to oranges. “While PV modules may wear out in 30 or 40 years – and may require maintenance or repairs along the way – insulation is likely to last far longer and is virtually maintenance free.” (Holladay, Net-Zero-Energy Versus Passivhaus) The author goes on to clarify that in his personal opinion, very deep layers of insulation save only handfuls of kWhs a year, and “it’s worth stepping back and considering the situation from a neighborhood perspective…[is] installing very thick layers of insulation in a handful of houses a good use of the worlds limited resources?”

Defenders also posit that the PV argument works on the assumption that electricity is best produced on a residential roof. Issues such as maintenance and repair of complicated energy-generation systems being too much for homeowners, the increased cost-effectiveness of small wind turbines compared with PVs, the probability of roofs being shaded by surrounding buildings and trees, and increased difficulty of re-roofing all show that PV panels are not the utopian answer either.

Even Passivhaus supporters contend that the cost of getting a certified Passivhaus is not worth the extra cost. Phil Kaplan, an architect based in Maine, found that in his Passivhaus project for a client, even his retrofit insulation measures were short of the certification goal. “[The additional insulation] would add at least $2880 to the cost of construction, while only saving 950 Btu/ft^2/year…[and would] have a payback period of about 58 years." (Holladay, Net-Zero-Energy Versus Passivhaus) In the end, Kaplan did not install the extra insulation, as the owner of the house felt the expense could not be justified.

In Passivhaus' defense, Klingenberg presents a Powerpoint entitled "The Role of the German Passivhaus Standard in America", and she defends its applicability in the US with these points:

- Passivhaus is applicable in all US climates
- Applicable to new and retrofit construction, residential and commercial
- PH is cost effective today
- Passivhaus projects create jobs
- Energy independence
- Higher quality construction
- Increased health and comfort
- Carbon neutrality within reach today

Several of these points are pure conjecture (what is her definition of cost effective?), and some of them are applicable to all green buildings; Net Zero Energy Homes are just as capable of being carbon neutral, all construction projects create jobs, and all green buildings in some way help contribute to energy independence. The climate issue is one that has yet to be proven. To date, only one certified Passivhaus has been constructed in a warm climate, and it has only been in existence since 2009. (Clearfield) Two years of data from only one building does not garner enough evidence to prove conclusively whether PH is applicable in all climates.

A healthy, if not a bit hostile, debate has been simmering over the past few years in regards to Passivhaus and its worth compared to other cold climate low-energy houses. John Straube, Ph.D., P.E., published an article in 2009 that stated "There are, however, many recommendations in the PH program that are not likely good decisions for cold climate (DOE Climate Zones 5-7) North American housing, and some are very impractical with little or no benefit to the environment or the homeowner." (Straube, The Passive House (Passivhaus) Standard: A comparison to other cold climate low-energy houses)

Straube posits that the PH ventilations standards do not make mathematical sense; a house abiding by the Passivhaus PHPP 2007 software recommendations would over-ventilate by 2.3 times the ventilation rate of ASHRAE 62.2. Also, "A standard-efficiency 65% efficiency HRV operating at 50 cfm and 0.6 W/cfm will use less energy than a very expensive 75% efficient HRV operating at 80 cfm and 0.75 W/cfm." In America, an HRV may also not be the best choice, as "many North American HRVs consume excessive amounts of electrical energy…central fan-integrated ventilation systems consume only very little additional energy than a high performance HRV, but provide equivalent quality ventilation at a fraction of the capital cost."

Straube concludes that:

> "The Passivhaus approach in cold-climate zones of North America can lead to more expensive, less architecturally flexible, and even potentially more energy intensive houses than a more flexible approach that focuses only on the least cost, most durable means of achieving a primary energy use per area target value."

He introduces his prescriptions for buildings, listed below, that deliver total energy and environmental performance that approaches the Passivhaus standard in cold climates. These houses "accommodate a broader range of architectural styles, can be modified easily for different climate zones, and can even be built by production builders."

- Minimum R-5:10:40:60 enclosure, see (Wilson)
- 1.5 ACH @ 50 Pascal airtightness or better
- Condensing (>95%) gas furnaces with ECM fan motors
- Right-sized (ASHRAE 62.2) efficient (>65%,>0.6 W/cfm) HRVs
- Condensing (>92%) hot water natural gas water heaters
- Appliances in the top 10% of Energy Star combined with CFL lighting

In Straube's opinion, a better use of resources is made with more sensible and applicable sustainable building practices than the 'arbitrary' prescriptions of the Passivhaus standard.

A blog post returned the volley back to Straube shortly after his article, responding to (and correcting) some of his points. To Passivhaus' disregard for climate zones, Rosenbaum and White respond by saying that the energy requirement may be the same for all zones, but that just "necessitates more stringent design as the climate gets colder…should people in colder climates use more energy…or should everyone have a budget no matter where they live?"

In response to Straube's comments on Passivhaus requiring simpler building shapes, they ask another question: "Why should building form not contend with environmental performance? Tightly massed, simple shapes were the norm in cold climates until the advent of cheap non-renewable energy." I respond by asking: If other green building strategies allow for more complex building shapes, why show such a dogmatic insistence on Passivhaus?

Rosenbaum and White continue by noting that Straube is incorrect in comparing Passivhaus standards to ASHRAE 62.2.

> "ASHRAE 62.2 explicitly assumes 0.02 cfm/ft^2 of infiltration as a component of the total air change in the building. [Straube's example building's] 50 cfm of ventilation for the 2000 ft^2 three bedroom house is added to 40 cfm of assumed air leakage, resulting in a 90 cfm ASHRAE expectation in this house. The PH requirement is about 80 cfm…close to ASHRAE 62.2." (White)

They also go on to compare Straube's example building with a Passivhaus of the same size, concluding that the Passivhaus consumes 365 therms less per year.

In the same month, Straube responded to his critics with another journal article:

> "My apparently dangerous and provocative questions of the PH standard arise from the reasoning behind the choice of these targets and "requirements". The choice of 120 kWh/m^2/year is essentially arbitrary…There are many homes that have achieved [that] target by generating renewable energy on site, but this is not allowed in the Passivhaus. Why not?" (Straube, Passivhaus Becomes Active - Further Commentary on Passivhaus)

Though Straube realizes that relying on the purchase of photovoltaic panels or complex and expensive heating/cooling systems to reduce the energy use of a building is irresponsible and a waste of resources, he also posits that Passivhaus risks doing the same thing by using excessive levels of insulation, airtightness, and window performance rather than using more environmentally smart and economical supplies of energy.

He also cites other research groups, IBACOS and the Florida Solar Energy Center (see Parker quote on page 6), that both concluded that the Passivhaus standard may not always result in an optimal design. IBACOS concluded that “following the PH standard in the cold and hot-humid climate zones [of the US] was ‘very challenging’”.

The issue of German vs. American also comes back into play, says Straube, when the floor area is measured. References used are also European:

> “The air leakage test referenced is EN 13829, rather than the very widely used ASTM test, the HRV efficiency is measured by the Passivhaus Insititut in Germany rather than the HVI CAN/CSA C439, the window U-value is measured by ISO 12567, not the widely-used NFRC 500…the use of German or Euro standards result in small but sometimes significant impacts. Why would one not accept products based on North American Standards if they are shown to be equal or better?”

The debate is ongoing, but it seems that both Passivhaus defenders and opponents have valid points. Overall, it is apparent that Passivhaus is an effective building standard that is being adopted by adamant supporters, but aspects of its strict requirements often make little fiscal sense compared to other green building options. Its small presence in America can be credited to lack of familiarity, availability of other building standards, lack of PH-grade building materials and mechanical systems, difficulty for PH designs to use unconventional architectural shapes, and its expensive upfront cost. It does not make sense to apply Passivhaus strategies exclusively when equally innovative and effective approaches exist and are applicable in a project’s climate. In cases where attempting to become Passivhaus certified force the project to become more costly and complex without delivering lower energy consumption, Passivhaus strategies in their entirety should not be implemented.

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