Pushing Passive House Forward: Moving Beyond Energy-Efficiency

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Introduction

In November of 2010, Dovetail published a report entitled "What is PassivHaus?"[1] that introduced our readers to a sustainable housing design approach gaining momentum in the United States. In Europe the use of Passive House (referred to as PassivHaus throughout Europe) is already well established. Adoption of Passive House standards has resulted in significant energy performance improvements in residential and even some commercial properties. To date, no other green building program in existence provides energy savings to the extent possible through Passive House.[2]

This report addresses the current state of Passive House – progress that has been made, problems that have been encountered, and the creation of the Active House system, which has been developed in response. This report also explores the outlook for widespread movement toward highly energy efficient structures, as well as existing obstacles to substantial change in construction practices.

The Passive House Movement – Big Changes Since 2010

Passive House's acceptance in Europe has been largely based on its simple structure and targeted focus on significant reductions in energy consumption. The core design elements include thick insulation, a tight building envelope, few or no thermal bridges, insulated glazing, and a balanced energy recovery system.[3] However, considerations of sustainability suggest that progressive housing programs must address far more than energy use alone; therefore, Passive House must also be assessed based on the compromises and side effects inherent in its current form.

The Passive House design strategies and construction methods grew out of research beginning in the 1970s as a response to an energy crisis that resulted in a three-fold increase in the price of oil.[4] Centered on energy reduction, Dr. Wolfgang Feist's building design concepts grew steadily in popularity across Europe. The first Passive House was built in Darmstadt, Germany in 1991 by Dr. Feist and promised space-heating demands that were 90% less than a standard home. Since that time, over 25,000 passive houses have been built in Europe.[5]

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[1] Dovetail's report "What is PassivHaus?" is available at: http://www.dovetailinc.org/files/DovetailPassiveHouse1110sm.pdf

[2] The "Emerald" rating within the ICC 700 National Green Building Standard requires energy efficiencies that are 60% better than code (http://www.nahbgreen.org/NGBS/default.aspx). Passive House construction yields a 70-90% energy improvement.

[3] Katrin Klingenberg and Mike Kermagis, "Principles of Passive House Design, Parts I and II." 2009 http://www.solaripedia.com/13/50/principles_of_passive_house_design,_parts_i_and_ii.html

[4] Martin Holiday, "The History of Superinsulated Homes in North America." Oct. 10, 2010 http://www.greenbuildingadvisor.com/system/files/sites/default/files/History%20of%20Superinsulation%20-%20BC.pdf

[5] http://www.passivhaus.org.uk/standard.jsp?id=122

The PassivHaus Institute (PHI) was founded in Germany in 1996, and the techniques and products developed by Dr. Feist were used to form the Cost Efficient Passive Houses as European Union Standards (CEPHEUS) project in 2000. Despite this rapid European expansion, it wasn't until 2003 that the first home meeting Passive House standards was built in North America – the Smith House in Urbana, Illinois.[6] Subsequently, the Passive House Institute U.S. (PHIUS) was founded in 2007.

As noted in our previous report, PHI and PHIUS initially functioned as two parts of the same organization, but these groups have since separated. In 2011, as debates raged regarding standard units of measurement and basic heating and cooling assumptions and criteria, the organizations' differences came to a boiling point. As a result, PHIUS began modifying and selling its own version of the Passive House Planning Package (PHPP) within the U.S. Additionally, PHIUS began altering German Passive House training programs and associated examinations for use in the U.S. Claims by PHI of improper certification of PHIUS houses and consultants eventually turned the conflict into a separation of factions, resulting in two separate entities.

On August 17th, 2011, Dr. Feist of PHI sent a letter[7] to PHIUS declaring, "Recent actions by PHIUS have culminated both in breaches of contract and good faith," effectively severing its contracts with PHIUS. According to the website greenbuildingadvisor.com, this schism appears to have undercut the program within the U.S. by damaging its credibility and ease of use.[8] Nonetheless, in January of 2012, PHIUS joined the Home Energy Rating System (HERS) in an effort to add a higher level of quality assurance by including new blower-door tests and insulation inspections.[9] Both institutes use similar basic performance specifications necessary for certification. The criteria used for certification by PHIUS are listed below.

PHIUS Passive House Certification Criteria

1. The building must not leak more air than 0.6 times the house volume per hour (air infiltration and exfiltration is ≤ 0.6 air changes per hour at 50 Pascals of pressure)
2. Specific heating and cooling demand is ≤ 15 kWh per square meter (1.39 kWh/sf or 4,756 Btu/sf per year)
3. Total building primary energy consumption is ≤ 120 kWh per square meter (11.15 kWh/sf or 38,048 Btu/sf per year)
4. The ventilation system must operate at 75% efficiency or higher and have a low electric consumption of ≤0.45 Wh/m^3.

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[6] Mike Kernagis, "Passive House Takes Root in the United States."
http://www.passivehouse.us/passiveHouse/Articles_files/HEM_Climate_kernagis.pdf

[7] http://www.passivehouse-international.org/index.php?group=1&level1_id=76&page_id=246&lang=de

[8] Richard Defendorf, "The PassivHaus Institut in Germany Disowns Its U.S. Satellite." Aug. 19, 2011
http://www.greenbuildingadvisor.com/blogs/dept/green-building-news/passivhaus-institut-germany-disowns-its-us-satellite

[9] Paula Melton, "Passive House U.S. Develops Separate North American Certification." Dec. 1, 2011
http://www.buildinggreen.com/auth/article.cfm/2011/11/29/Passive-House-U-S-Develops-Separate-North-American-Certification/

Early Problems Experienced with Passive House in the U.S. and Abroad

I. The Software

While Passive House's focused goals for energy conservation create simplicity, several large system issues continue to remain unaddressed within the program and its limited design options. Passive House design and certification relies on a proprietary software system produced by PHI. Dubbed 'Passive House Planning Package', or PHPP, the software models and calculates building energy loads through the entire design process ensuring that certification standards will be met before construction begins. PHIUS uses a slightly modified version of PHPP, which in the past has converted metric to imperial standards.[10]

It is not unusual for new programs or systems to encounter problems that reduce effectiveness or even create unintended consequences. An example from Passive House can be seen within the proprietary software design. The PHPP currently relies on square footage for energy use calculations[10] that, in some situations, can make it more difficult for small homes to meet the standard. For example, Box 1 shows an example of Passive House Energy Use Calculations for two different home sizes. To meet the Passive House standard, a project designer can either improve the energy efficiency of the home or increase the square footage to distribute the heating and cooling demand. In theory, this can create an incentive for larger homes. The overall impact is that the Passive House standards appear to encourage larger home sizes over small ones. To a certain extent, the effects of this calculation are mitigated by a requirement in the design software that external surface areas be equal to or less than the total volume of the house—a requirement that also translates into houses that tend to be boxy in design. On the following page, Box 2 shows an example of surface area to volume ratio calculations. In practice, most Passive Houses around the world tend to range in size from 800 to 1,500 square feet for a variety of reasons such as: cultural norms, environmental concerns, and economic limitations.

Box 1. Example of Passive House Energy Use Calculations

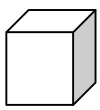
House A: 800 square feet in size
800sf x 1.39kWh/sf = maximum of 1,112 kWh of heating and cooling demand per year

House B: 1500 square feet in size
1500 sf x 1.39kWh/sf = maximum of 2,085kWh of heating and cooling demand per year

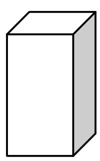
[10]In the interest of creating a worldwide, unified program, the 2012 version of the PHPP is communicated in metric terms, but includes a calculator to easily convert metric to imperial standards. http://www.passivehouse-international.org/index.php?page_id=188

Box 2. Example Ratios of Surface Area to Volume Calculations

Passive House requires minimizing the surface area to interior volume ratio, favoring an efficient shape to minimize energy losses. However, reliance on this ratio also favors larger homes because as the home grows larger, the ratio of surface area to volume becomes smaller. This relationship also favors boxy shapes (cubes). These relationships are illustrated below:

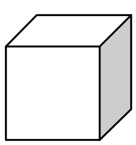


Cube with sides equaling 10 feet each:
Surface Area=600sf
Volume=1000cf
Ratio: 1:1.67



Rectangle with a height of 10 feet, width of 5 feet, and a length of 20 feet:
Surface Area=1100sf
Volume=1000cf
Ratio: 1.1:1

Though this change in shape maintains the same volume, the ratio of surface area to volume increased, making it less efficient. Since the surface area is now greater than the volume, it also no longer meets Passive House requirements.



Cube with sides equaling 20 feet each:
Surface Area=2400sf
Volume=8000cf
Ratio: 1:3.3

By doubling the dimensions of the cube, the ratio of surface area to volume is now nearly half of the smaller cube and complies with the Passive House requirement.

Another challenge related to the reliance on floor area calculations is that it causes PHPP to dismiss heating and cooling as a three dimensional process.[11] For example, raising ceiling height in a design will not change the calculation based on the same floor area. This ignores how heating and cooling systems actually work. Basing a ventilation rate on the floor area of an unknown volume creates potential for an uneven standard and significant variation in heating and cooling effectiveness within any given building envelope. A building may or may not meet the standard based on potentially unnoticed losses of energy with the PHPP software. Taking time to integrate volume considerations during the design process would significantly aid in refining the overall Passive House design system.

Perhaps the most significant challenge regarding the use of Passive House in the U.S. is that it is still largely based on German standards and has yet to be fully converted to apply to the North American situation. The software has begun recognizing differences associated with climate and location, but cultural considerations need to be taken into greater account.[12] For example, many American households utilize basements as livable space, while most German homes do not. Within the current PHPP only 60% of a house's basement area is entered into calculations.[11]

II. Affordability and Style

A problem often associated with green building in general and Passive House in particular is affordability. This worry is not unfounded as specific Passive House components can require significant additional upfront expense. These items include added insulation, triple-pane windows, and specialized mechanical air-

[11] John Straube, "BSI-025: The Passive House (PassivHaus) Standard—A comparison to other cold climate low-energy houses." Sept. 7, 2009 http://www.buildingscience.com/documents/insights/bsi-025-the-passivhaus-passive-house-standard

[12] Paula Melton, "Passive House U.S. Introduces PHIUS+ Certification." Nov. 7, 2011 http://archrecord.construction.com/news/2011/11/Passive-House.asp

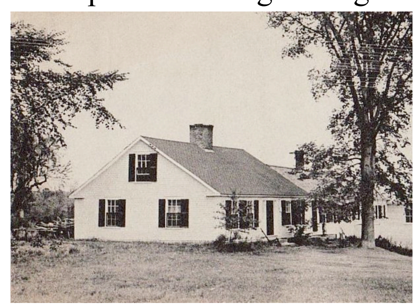
exchange elements. However, potential offsets are realized in energy bills that tend to be one tenth to one-quarter that of a conventional house.[13] PHIUS further maintains that the initial investment is only approximately 4-10% more than a regular energy code-compliant 2x4 constructed house of the same square footage.[14] As proof, the Smith House cost $94/sq. ft., which is comparable to the average home construction cost in Illinois.[15]

Passive homes are also often criticized for their style and design. High profile Passive Houses tend to be a modern design, which does not appeal to all. To some extent the variability of designs is limited due to the square footage parameters and the basic reality that the best way to reduce heat loss is to build a "cube." A boxy design maximizes the system's potential and helps a project meet Passive House criteria. Passive House guidelines are also strict regarding placement of a house on its site, which can further limit the design. However, it should also be noted that the 1-1 ½ story Cape Cod cottage design (Figure 1, far right) is basically a modified cube and one of the most popular house designs in the U.S.

Figure 1. Modern Passive Houses (left and center images) and the popular Cape Cod Cottage Design


Source: Concretenetwork.com


Source: Inhabit.com


Source: http://en.wikipedia.org

III. Health and User Control

While Passive House guidelines have proven worthy as an energy reduction technique, questions are frequently raised over Passive House's contradictory use of sealed building envelopes. Standard building practices utilize "breathable" building envelopes for indoor air quality benefits. Investigative reports have begun looking beyond energy conservation to understand the impacts of tight building envelopes on indoor air quality.

One such investigation, Evert Hasselaar's 2008 report, "Health Risk Associated with Passive Houses: An Exploration,"[16] provides an in depth examination of Indoor Environmental Quality (IEQ). Promotional materials for Passive House report positive results for IEQ, but typically focus

[13] Hans De Keulenaer, "Are Passive Houses Expensive? (Comparing to Traditional House and Low-energy House)." Dec. 16, 2006 http://www.leonardo-energy.org/are-passive-houses-expensive-comparing-traditional-house-and-low-energy-house

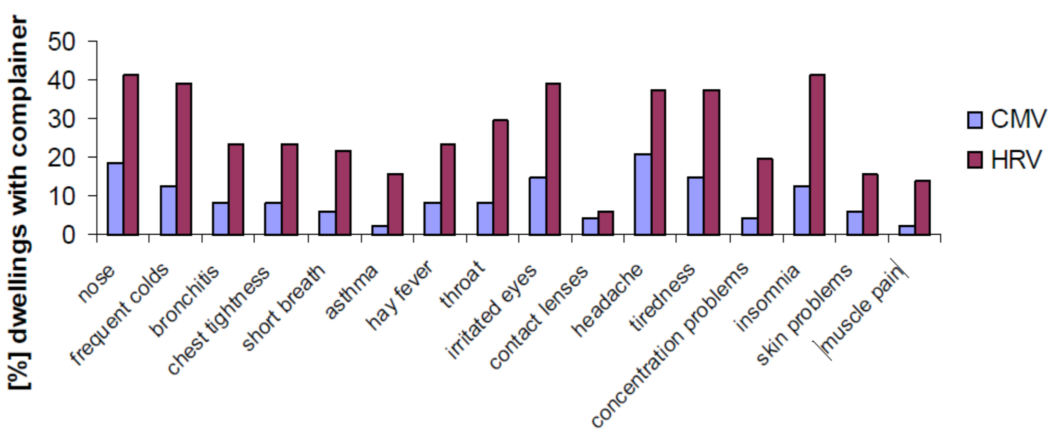
[14] Passive House Frequently Asked Questions. 2011 http://www.passivehouse.us/passiveHouse/FAQ.html

[15] Wotzak, Rob, "First U.S. Passive House Shows Energy Efficiency can be Affordable."March 2, 2009 http://www.greenbuildingadvisor.com/homes/first-us-passive-house-shows-energy-efficiency-can-be-affordable

on room temperature, relative humidity, and CO_2 levels. Hasselaar's paper examined two Danish Passive Houses and reported that the sealed building envelopes can result in a low airflow rate, which creates an uneven distribution of heat (a complaint also often heard amongst conventional home owners). Furthermore, tight building envelopes were found to seal out exterior noises, but also trap interior noises. The "acoustically insulated envelope" made indoor noises more noticeable, especially fans and ventilation systems, resulting in occupants setting unsafe low flow rates in attempts to reduce the sound.

Ventilation systems in homes, including Passive Houses, are generally designed for given situations. However, according to Hasselaar,[16] Passive House designs may lack excess capacity and flexibility in use because of the objectives of meeting certification standards and minimizing energy use. Failure to design for excess capacity could be a major issue and subsequent overloading of the system could impact health, safety, and integrity of the building structure. For example, a low load ventilation system could have trouble quickly reducing excesses of CO_2, heat, humidity or other air quality impacts associated with additional home occupants or guests, cooking activities, showering, additional large appliances, or anything else that might alter the system for which the home was designed. Providing for little or no excess capacity in Passive House design can result in insufficient airflow to compensate for these activities. Building VOC's, cleaning products, pests, pesticides, pets, fragrances, and secondhand smoke can all accumulate in any home, but with inconsistent removal by low flow systems such problems may increase, resulting in significantly adverse occupant impacts. Figure 2 illustrates the rate of common occupant health complaints from conventional and passive houses.

Figure 2: Percentage of Health Problems Reported in Conventional vs. Passive Homes



CMV = *conventional (exhaust) ventilation with natural inlet functions*
HRV = *heat recovery balanced floor mechanical ventilation (typical of passive houses)*
Source: Hasselaar (2008)[16]

[16] Evert Hasselaar, "Health Risk Associated with Passive Houses: An Exploration." Aug. 17, 2008. http://repository.tudelft.nl/view/ir/uuid%3A88fd72b2-f7ab-45ea-a403-ce367801cf3f/

Passive Houses are often very technical buildings that require strict maintenance. Thus, user maintenance and use of building systems in a Passive House can be contradictory to a homeowner's expectation of "hands off" functionality. The ventilation system requires stringent maintenance of filters and ducts to prevent pressure and flow rate changes. Human tendency is to overcompensate in the desire to "normalize" their environment. For example, when home occupants are too hot or too cold, they will adjust the thermostat significantly rather than just a few degrees in order to get the desired change as quickly as possible. This presents a problem in Passive Houses since they are not designed to handle rapid temperature and humidity changes. In response, homeowners may over-adjust the Passive House system by opening windows or significantly changing flow rates, effectively breaking the building envelope's seal, resulting in the HVAC system working even harder to adjust.

The points raised above advocate towards a more user-friendly system. While people can learn to live according to housing system regulations, lifestyles are rarely as static as the PHPP and Passive House flow rates dictate. More flexibility should be accounted for in the PHPP and design standards in order to accommodate for a greater range of expected occupant behaviors.

IV. Climate and Building Codes

Because it was originally developed for Germany's moderate climate, designers have long been skeptical of Passive House's application in more extreme climates. For example, in colder climates, there is the risk of freezing the heat recovery ventilation unit. Attempting to counteract this by defrosting the unit through heating or cyclic use reduces heat recovery efficiency.[17] Moisture control is another factor to be considered when defrosting the unit because it could lead to bacteria and mold growth, which would then be circulated through the home. In addition, homes operated in colder climates have been unable to meet the 15 kWh per square meter heating demands necessary for certification.

However, these setbacks have not discouraged PHIUS from continuing to research and develop new methods of design for a variety of U.S. climate zones. Their efforts show that additional insulation is likely necessary in cold climates (e.g., Minnesota). In regions with hot climates, cooling demands must be considered, and de-humidification is also an issue to be addressed.[13]

There are other ways that PHIUS is working to reduce the environmental impacts associated with Passive House design requirements. Until recently, many Passive Homes utilized spray polystyrene foam (SPF) insulation due to its ability to air seal even the most difficult areas. However, the process of making polystyrene foam uses large amounts of energy and emits vast quantities of CO_2. These impacts during manufacturing effectively cancel out some of the assumed benefits of Passive

[17] Jyri Nieminen, "Passive House for a Cold Climate." http://web.byv.kth.se/bphys/copenhagen/pdf/171-1.pdf

House design. In January 2012, PHIUS issued a statement declaring that projects using SPF would no longer be given Passive House certification.[18]

Another challenge facing Passive House is building codes. As described in the recent Dovetail report "Building Codes: Barriers to Green Innovation,"[19] U.S. building codes are frequently in conflict with green building designs and standards. Europe has built over 25,000 passive-certified homes in numerous areas largely because of the success with integrating PassivHaus standards into mandatory building codes. In the U.S., however, various voluntary standards for green building have not yet been widely incorporated into building codes.[20] Therefore, the number of certified Passive Homes in the U.S. remains low, and they are frequently constructed outside of jurisdictions with strict building codes.

Other Green Programs to Learn From

The Passive House initiative has inspired others to pursue improvements in energy and environmental performance. The "Active House" and "Living Building Challenge" provide examples of green building efforts that are expanding on the lessons learned through Passive House.

Active House

The aptly named Active House program has emulated many of Passive House's best qualities. While initially formed as a response to Passive House failures, it retains the spirit and successful elements that Passive House has tested. For instance, High R Value (HRV) walls and a concern for energy usage are commonplace within both programs. The major difference with Active House is that its core principles include attention to concerns about environment, indoor climate, and energy conservation.[21]

The creation of the Active House concept is an attempt to address sustainability more directly within the building standard itself. Passive House is marketed as a house that will be less harmful to the environment in its operation. Active House attempts to go further, pushing for a house that gives back more than it takes. Also, whereas the Passive House system needs occupants to fit within the constraints of the minimal ventilation and heating system, the Active House model does not assume or require a significant change of lifestyle.

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[18] Paula Melton, "Passive House Group Bans Certain Spray-Foam Insulation." Jan. 1, 2012 http://www.buildinggreen.com/auth/article.cfm/2011/12/27/Passive-House-Group-Bans-Certain-Spray-Foam-Insulation/

[19] Dovetail Report "Building Codes: Barriers to Green Innovation": http://dovetailinc.org/reportsview/2011/responsible-consumption/pjennifer-garmanp/building-codes-barriers-green-innovation

[20] This may gradually change as the International Green Construction Code (IgCC) is more widely adopted. For more information, see the Dovetail report "The International Green Construction Code": http://www.dovetailinc.org/files/DovetailIGCC0512.pdf

[21] For more information on Active House, visit http://activehouse.info/

Started by the Brussels-based group Active House Alliance, Active House envisions a home that produces more energy than it consumes. Projects are evaluated on the basis of interactions between energy consumption, indoor climate conditions and impacts on the environment. Active House emphasizes the use of renewable energy, CO_2 neutrality, indoor environments full of sunlight and fresh air, and positive environmental impacts throughout the lifespan of the building.

As summarized in Figure 3 below, Active House projects are divided into four categories based on the type of occupant and size of the project:

Figure 3: Active House Categories

CATEGORY	EXPLANATION
1.	Suitable in case of a high level of expectation. Is recommended e.g. for spaces occupied by very sensitive and fragile persons with special requirements (sick people, very young children, the elderly etc.).
2.	Suitable in case of an above-average level of expectation. Should be used as standard level for new dwellings and larger renovations.
3.	Suitable in case of a moderate level of expectation. Could be used as a reference for more limited renovations or as a reference value when measuring in well performing existing buildings.
4.	Suitable in case of a limited level of expectation. May be used as reference level when measuring in older existing buildings.

Source: http://activehouse.info/

The annual energy demand specifications for an Active House include those for space heating, water heating, ventilation, air conditioning, technical installations and electricity for lighting. Active House classifications also include specifications for the amount of renewable energy that must be used at a given site.

Active House Renewable Energy Specifications:

1: ≤ 30 kWh/m2, 100% of energy is produced on-site
2: ≤ 50 kWh/m2, more than 50% of energy is produced on-site
3: ≤ 80 kWh/m2, more than 25% of energy is produced on-site
4: ≤ 120 kWh/m2 (modernization only), less than 25% of energy is produced on-site

Only a few Active House prototypes exist, and these can be found in a number of countries, including Denmark, Portugal, Austria, Norway, the UK, Italy, Netherlands, and Russia. The world's first Active House was built in Lystrup, Denmark in 2009 (Figure 4). Since the design was an experiment and therefore considered a commercial product, the nearly £500,000 bill ($790,000

USD) should not be looked at too critically. When used more widely, Active Houses built in Denmark are projected to cost no more than a typical 3-bedroom home.[22] According to the designer's calculations, after about 30 years' time the excess electricity flowing from the house into Denmark's grid will have cancelled out the energy costs of building it.

Figure 4. World's First Active House: Lystrup, Denmark – 2009

Source: http://www.guardian.co.uk/environment/2009/may/21/active-house-denmark-zero-carbon

In addition to Active Homes being built across Europe, ground was recently broken for the first Active House in North America. In May 2012, the project 'Active House USA' began in Webster Groves, Missouri (Figure 5). The 3-bedroom, $450,000 home was designed by Jeff Day & Associates, along with builder Hibbs Homes and developer Verdatek Solutions. As a prototype of Active Homes in North America, the costs for future projects are expected to be lower. A rendering of the home can be seen below (Figure 5).

Figure 5. Active House USA

Source: www.activehouseusa.com

[22] Andrew Purcell, "Zero Carbon Eco Home is Lightyears Ahead." May 2009 http://www.guardian.co.uk/environment/2009/may/21/active-house-denmark-zero-carbon

Living Building Challenge

The Cascadia Green Building Council initially launched the Living Building Challenge (LBC) in 2006 to act as a new standard and to serve as a new philosophy for green building. It also represents a step beyond the Passive House approach. The program's general operating method follows what it describes as the Flower Metaphor.

Living Building Challenge – Flower Metaphor:
"A home (like a flower) is rooted in place yet:

- Harvests all energy and water
- Is adapted to climate and site
- Operates pollution-free
- Is comprised of integrated systems
- Is beautiful (beauty is a necessity because it makes people care enough to preserve/conserve/serve the greater good)"[23]

Key elements of the LBC include rewarding early adopters, performance-based requirements, site-specific considerations and a focus on energy usage in initial design and planning (Box 3).

The LBC also doubles as its own advocacy tool since many steps in completing certification require writing letters to various companies regarding the program and how the company's products will be utilized. The LBC states that a phased approach may be the most effective form of green building. This approach means separating the project into manageable parts or priorities that can be accomplished over time rather than trying to do everything at once. Although the popularity of green building is growing, cost remains a significant factor when deciding whether or not to build green. By taking a phased approach, costs may become more manageable, while also serving to promote more green building in the future.

Box 3. Key Elements of the Living Building Challenge:

- Rewards early adopters,
- Based on actual rather than modeled or anticipated performance,
- Site specific (implementing different codes based on location), and
- Focuses on energy usage before completion, including construction, materials, and transportation. [23]

Currently, the LBC operates in the U.S., Canada, Ireland, Australia, and Mexico. In North America, there are over 100 projects pursuing Living Building Challenge certification. Projects may either submit for full certification or certification may be broken down into parts (due to the focus on a phased approach). There are three parts to becoming certified which are referred to as the three 'petals': Water, Energy, and Materials. Once a project is fully certified, it is said to have achieved "Living" status. In May of 2009, two projects were fully certified as having reached "Living" status.

[23] For more information on the Living Building Challenge, visit http://www.livingbuildingchallenge.org

The first, the Tyson Living Learning Center in Eureka, Missouri acts as an outdoor laboratory for students at Washington University, and the second, the Omega Center for Sustainable Living, in Rhinebeck, NY is a wastewater filtration facility that doubles as a teaching tool for the Omega campus.[24]

Figure 6. Tyson Living Learning Center - Eureka, MO - Figure 7. Omega Center - Rhinebeck, NY

Source: https://ilbi.org/lbc/certified

Conclusion

Since 1991, PassivHaus has met with great success across Europe, leading to the construction of over 25,000 passive homes. However, the concept of passive building standards has yet to take significant hold in the U.S. due to a number of factors, including the challenges of adapting the standard to North American climate and cultural differences.

In order to push Passive House further, it is valuable to look at other green building programs, including Active House and the Living Building Challenge that offer opportunities for significant improvements in energy efficiency and other environmental impact indicators associated with buildings.

[24] The listing of LBC certified project case studies is available online at: http://living-future.org/node/132

Resources

Previous Dovetail Reports:

"What is PassivHaus?"
http://www.dovetailinc.org/files/DovetailPassiveHouse1110sm.pdf

"The International Green Construction Code"
http://www.dovetailinc.org/files/DovetailIGCC0512.pdf

"Building Codes: Barriers to Green Innovation":
http://dovetailinc.org/files/DovetailBuildingCode1011.pdf

Related Organizations:

PassivHaus Institute (PHI)
http://passiv.de/en/

Passive House Institute U.S. (PHIUS)
http://www.passivehouse.us/passiveHouse/PHIUSHome.html

Active House
http://activehouse.info/

Living Building Challenge
https://ilbi.org/

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