GSDR 2015 Brief

Passive Housing

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Related Sustainable Development Goals

Goal 07 Ensure access to affordable, reliable, sustainable and modern energy for all
Goal 09 Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
Goal 11 Make cities and human settlements inclusive, safe, resilient and sustainable
Goal 13 Take urgent action to combat climate change and its impacts

**The views and opinions expressed are the authors' and do not represent those of the Secretariat of the United Nations. Online publication or dissemination does not imply endorsement by the United Nations.* *Authors can be reached at daphne.vandam@wur.nl and mirle.vanhuet@wur.nl.*

Introduction

Worldwide, buildings consume around 40% of the total primary energy. In the EU, up to 36% of the total CO_2 emissions comes from buildings alone and in the Unites States, residential and commercial buildings consume up to 70% of the electricity and 39% of the total primary energy available.[1] Residential and commercial buildings are thus significant consumers of energy and are one of the major producers of GHGs globally. Along with the growing concerns regarding the level of greenhouse gases and the exhaustive use of finite energy resources, initiatives for clean and energy-efficient innovations for buildings are of major urgency for reaching world-wide targets set for sustainable energy use and increasing the quality of life. One of the solutions which can increase the energy efficiency of any country is buildings with a low energy demand, such as passive houses.

Passive housing (PH) is the implementation of certain technological innovations such as better insulation, air-tightness and heat recovery ventilation, which drastically lower the energy demand of a building. The concept and the technology is suitable for all climate types, however the specifics do need to match the climate in which it is implemented.[2],[3] Although PH officially has one definition set by the Passivhaus Institut, in reality there are many variations used by various actors, such as housing corporations, construction companies, policymakers and homeowners. However, the basic idea revolves around limiting energy demand for heating and/or cooling to a very low threshold value while maintaining excellent comfort throughout all seasons (appendix 2). Although PH has been successfully implemented nationwide in countries such as Austria, Belgium and Germany,[4] it seems that it is not yet, or only at a slow rate, adopted by other countries. Literature shows that there are many obstacles with regards to the diffusion and adoption of this new technology[5] and that innovation which requires adjustments to an existing system is in general quite complex.[6]

FOOD FOR THOUGHT

Buildings often last longer than 50 years and maintain their initial level of energy consumption once they are built, unless they are upgraded with for example better insulation, thicker windows). However, the building's energy efficiency can only reach a certain maximum level before the refurbishing costs exceed the value of the initial investment.[i]

Although there are many types of sustainable and energy-efficient improvements and innovations which are currently developed and researched, we chose passive technologies as it has been gaining interest in both the scientific world and the current housing market. We want to stress that this digest is not focused on promoting PH but on clarifying its present implementations challenges. There is a possibility that comparable innovations face similar challenges.

Scientific debate

Currently there are many actors striving and working towards a more sustainable development of the housing industry, partially in order to lower the environmental impact and to lower costs for both homeowners and those who construct them. From top-down, policies and regulations are implemented that set certain criteria, which support this trend. From bottom-up, there are individuals and organizations, which hope to set a new standard in the market for energy-efficient and sustainable constructions. The development of this trend can be amplified when both the top-down and bottom-up actors increase their cooperation.[7]

Passive housing is one of these developments in the energy-efficient housing industry. Whilst the technology behind PH is well founded and tested over the past twenty years with significant positive results worldwide[8], there are several challenges which if the technology is implemented, need to be taken into account and possible overcome. This science digest will analyze and discuss the motivation, knowledge and competencies needed to overcome these barriers. We make a distinction between the enterprises, end-users and energy-policy makers. This structural framework used for this analysis is based on Mlecnik's scheme, which is further explained in appendix 3.

End-Users

Knowledge and motivation; perceived pro's and con's

Organizations, such as iPHA[9], and researchers such as Mlecnik[10,11], and Schnieders and Hermelink[12], often mention and promote the fact that PH offers higher comfort in winter and summer, better health conditions, modern living, future value and a lower financial load with regards to energy costs as added values of passive housing. However, at the same time they stress that there is not a significant drive among the potential users of innovative housing technologies (such as used within a passive house) to look for, or purchase an energy-efficient house, which could be due to a knowledge gap.

> **FOOD FOR THOUGHT**
> *"Although insulation proves to be handy material when it comes to energy efficiency, it is warned that one "can save a lot more energy by installing 2 inches of foam under 7 houses than by installing 14 inches of foam under one house."* [ii]

End-users or homeowners can perceive two financial barriers, which are in the way of the adoption of passive technologies as it stifles the growth of demand. The first is the perception that there is a low return of investment or that it is entirely impossible to reach a complete return of investments. Literature and experts are divided with regards to the costs.[13]-[14] Most interviewed experts mentioned that material costs are lowering and that large-scale implementation significantly decreases any possible additional costs when compared to the current standard. For those wishing to construct their own house, passive housing or any of its related technologies might indeed require a higher investment as the financial benefits gained with large scale implementation do not apply here. However, incentives could be created in order to overcome the financial barriers faced by end-users, such as subsidies or other appraisal systems.

> **FOOD FOR THOUGHT**
> The low financial load due to a lower energy demand is a positive benefit for low income households, e.g. in social building projects.

The second financial barrier is the phenomenon of discounting which is "*the process of determining the present value of a payment or a stream of payments that is to be received in the future*".[15] It means that end-users perceive their future return of investment to be of lower value in the present and that the amount of time in between investment and receiving returns determines this perceived value. Pilot projects overcome this barrier as these projects demonstrate passive housing in real-life, which makes the innovation tangible.[16]-[17] The aim of these trial projects is to create awareness and interest among actors; not only end-users but also housing corporations, construction companies and policy stakeholders such as municipalities. PH can also become more attractive when financial incentives are created. Municipalities might be able to get subsidies from national government when implementing energy-efficient buildings, which lowers their financial threshold.

In addition to the financial barriers, most end-users currently do not have a fully informed understanding of the innovation and might perceive it as 'difficult'. The innovative technologies used in passive houses decrease the intensity of heating and cooling needed in comparison to what has been the standard for many years. This might create a certain caution, which can drive end-users to choose for the 'safe' and already known method. Rogers' model (appendix 4) shows that the perceived advantages need to be present in order for innovation diffusion to succeed.

In order to visualize the actual advantage of PH, 'warm rent' (total cost of ownership) could be obligatory when presenting when buying/selling a house, since it visualizes the financial benefits of PH[18]. Additionally, peer-to-peer knowledge exchange networks for owner-occupiers, architects and contractors or multi-player enterprise networks can be trustworthy players who can provide neutral information about the financial opportunities and the use of passive housing.[19] But also municipalities can be perceived as neutral and could support the market by for example providing a list of each passive technology with their initial investment and their future return.

Competencies

One of the main barriers that end-users face in implementing energy saving technologies in their homes, public buildings or company buildings is that they need training in order to benefit from it; for example, what is the effect of an open window on the air temperature and quality inside the building. Experts are essential in this learning process as they transfer the competencies to the end-users.[20,21] While experts are quite easy to organize in Europe as it is currently mostly implemented in this region, this might pose a bigger obstacle in other parts of the world.

> **FOOD FOR THOUGHT**
>
> *"Especially construction industries in developing countries tend to be most commonly reactive; attempting to comply with existing regulations rather than seek benchmarks and market differentiation through environmental gains".* [iii]

Enterprises

Commitment

Enterprises such as housing corporations or construction companies mainly have a profit-driven business plan and therefore the motivation to change their strategy will be linked to their perception of the profitability of the technology. [22] Although the potential of passive technologies has been proven, there are still uncertainties regarding the costs needed to implement them.

However, the experimentation phase is nearing its end. The costs are lowering due to a larger production scale of the materials needed and the growth of expertise in this field. Feasibility and cost-efficiency, and therefore motivation for enterprises to implement PH technologies largely rely on the scale of the implementation.[23] The largest gains can be won in the construction and renovation of large scale building projects, especially apartment buildings which on average need less construction materials, construction time and space per accommodation compared to a single house. Purchase of the required materials, which are often not yet mass-produced will therefore be cheaper as they are being bought in bulk.[24]

Networking & Collaboration

Research and development in low energy and sustainable building design "*seems to be carried out very much in isolation between different countries*".[25] However, organizations such as the Passivhaus Institut, the International Passive House Association, New York Passive House, Passive House Revolution and the Passiefhuis-platform are some of the change agents who promote PH either nationally or worldwide. Additionally, the PASS-net project was successful in connecting several PH organizations with each other[26]. Some organizations are actively involved in research and the construction of trial projects which are currently seen as one of the main promotion tools in the market for convincing not only homeowners but especially construction companies and housing corporations which implement large scale projects.[27]

The level of knowledge sharing and collaboration between not only companies and sectors but also countries with regards to PH and other sustainable and energy-efficient housing technologies is currently not entirely clear and more research should be conducted in order to explore the extent of the passive technology market and the possibilities of its collaboration network. Some literature mentioned that the housing industry is quite conservative[28], [29] and when there is no demand, there are unlikely to be incentives to broaden their network and collaboration scope. However, the moment that demand for sustainable technologies is created by end-users, collaboration between enterprises in the housing sector will highly likely automatically follow due to the need for new knowledge and materials.

Policy makers

Motivation

Although the PassivHaus Institut[30] argues that passive houses and the individual technologies can be implemented anywhere, others argue that the standard was developed for the mild winters of Central Europe and does not consider the harsh circumstances of for example Canada as those houses might need thicker insulation to fulfill the standard which decreases usable floor space.[31] However, it is said that passive houses can provide a stable indoor temperature for many days even after the heating source is long gone. This proves to be a large benefit for those living in extreme cold climates and under threat of heavy storms that might be able to damage power lines and thus cut of power supplies.[32]

Knowledge

Policy makers can provide a system of appraisal in order to stimulate the diffusion of passive housing. The system could entail performance appraisals (taxation and subsidies), but also non-financial incentives to increase motivation for passive housing. According to Mlecnik (2013) "*this system should be compatible with market incentives and regional grant schemes, administrative control of tax relief and other energy-related issues*".[33] However, it is difficult to indicate the right combination of policy instruments, since this will vary for different countries and regions. National and local governments should investigate what combination of instruments is best for their local situations. This investigation will be an important subject of future research.[34]

Labels & certification

Confusion and complexity regarding labels and certification is not only visible with passive housing but other sustainable and energy efficient constructions as well. There is an abundance of different (sustainability) labels, which often seem more attractive than they actually are. It is thus important to make a clear-cut and understandable distinction between these so-called 'green' labels. Energy policy makers can contribute in this complex sphere of labels by promoting certain promising labels and demoting/leaving out those who do not contribute (sufficiently) to the process towards passive housing. Multiple level certifications can stimulate house owners and the building industry to invest in sustainable buildings as perceived value is created with these labels.

FOOD FOR THOUGHT

When combining PH with other energy saving and renewable energy technologies such as solar panels, a passive house can easily be converted to a (nearly) zero-energy building. The possibility to further lower energy costs and to lower the impact on the environment makes the PH technology even more attractive for sustainable development.[iv] The PH standard also has been successfully applied with innovative construction methods such as earthquake resistant technologies.[v]

In order for labels to become truly effective, the criteria and definitions should be clarified and institutionalized by policymakers, especially on a regional and national level.[35] By getting end-users enthusiastic for labels, e.g. by appraising houses in their value, a competition for having the 'most passive house' can emerge. In this sense, passive housing will become more attractive.

Goals & targets

As certified passive houses and houses with passive technologies drastically lower energy demand, there is also a relation with SDG 7. However, the largest gain can be won by supporting the sustainable development of cities, human settlements (SDG 11) and also industries which relates to both SDG 9, 11 and eventually 13 as housing GHG emissions takes up a large chunk of the worldwide total.

Additionally, passive housing can support low-income households as low energy demanding houses decrease the household's financial burden.

- A platform focused on international sustainable building could provide a solid basis for exchange between the market and policy and would stimulate worldwide implementation of sustainable and energy-efficient housing techniques such as those used in passive houses. Even though the PH promoters and other companies making use of the technique practice in a bottom-up approach in the market, top-down involvement is necessary in order to successfully institutionalize the innovation as was the case in Germany, Austria and Belgium. The involvement of policy further enhanced the national development of PH as actors were impelled to educate themselves in the required technique and skills, which were necessary in order to comply with certain sustainable and energy-efficient regulations. In short, policy involvement and decisions are necessary in order to successfully implement this innovation.

- New innovations and technologies need the combination of top-down (niche creation and policy incentives) and bottom-up (market innovations) approaches which amplify and support each other, thus stimulating the demand which in turn increases the adoption rate. PH promotion by policy makers (top-down) should include the creation of incentives for buyers, such as labels, appraisals and non-financial incentives in such a way that it stimulates users by creating the feeling of being left out when they not comply. Policy should additionally support neutral information and educational programs about passive technologies preferably in co-operation with market actors such as PH organizations, housing corporations and construction companies.

- Thus, the barriers hindering the implementation of energy-efficient housing technologies should be overcome and the development of an integrated master plan focused on the further development of quality-assurance systems and enterprise collaboration towards systemic innovation is needed. [36] Transition management is key. Important to keep in mind is long term development of this plan; not only must niche creation be supported (short term), but concrete decisions must be made which change the existing system in order for the new innovation to find its place in the socio-economical regime.

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Appendix 1: Research methodology

The research for this Science Digest has been conducted through literature study and expert interviews. The relevance of passive housing as an emerging issue within the scientific world is shown by the large increase of publications on the topic in recent years. The scientific database Scopus shows the growing number of publications over the years when inserting the keyword 'passive house'. One can see that most of the literature on these topics has been published within the last few years, which shows the growing and current interest in the topic of passive housing.

The topic of this Science Digest is based on personal background and personal interest. The content of this Science Digest is informed by extensive literature research and exploratory interviews with experts on the topic of passive housing. Experts were selected on the basis of their knowledge and involvement with the topic in question. Their expertise was identified by the relevance of their publications. Using these criteria, four scientists were identified as "experts" and "validators":

Ir. Gerhard Bayer: Senior expert at the Austrian Society for Environment and Technology (ÖGUT) and Project Coordinator PASS-NET (Establishment of a Co-operation Network of Passive House Promoters). Telephone interview took place on Wednesday 19th of November 2014 at 16:00.

Sarah Mekjian: International Communications at International Passive House Association (iPHA), part of Passivhaus Institut (Passive House Institute). Interview (via Go To Meeting) took place on Monday 24th of November 2014 at 11:00.

Dr. ir. arch. Erwin Mlecnik: Scientific Researcher at Delft University of Technology. Senior expert R&D at Passiefhuis-Platform. Corresponding author of a highly cited scientific article regarding passive housing used for this Digest. Email correspondence took place in November and December 2014.

Dr. Jurgen Schnieders: Scientist at Passivhaus Institut (Passive House Institute). Corresponding author of a highly cited scientific article regarding passive housing used for this Digest. Communication tool: Skype interview took place on Wednesday 19th of November 2014, 10:30.

All comments provided by the experts and project coaches have been carefully taken into consideration. However, due to time and space constraints, not all of the suggestions put forward could be incorporated into the final version of the Science Digest.

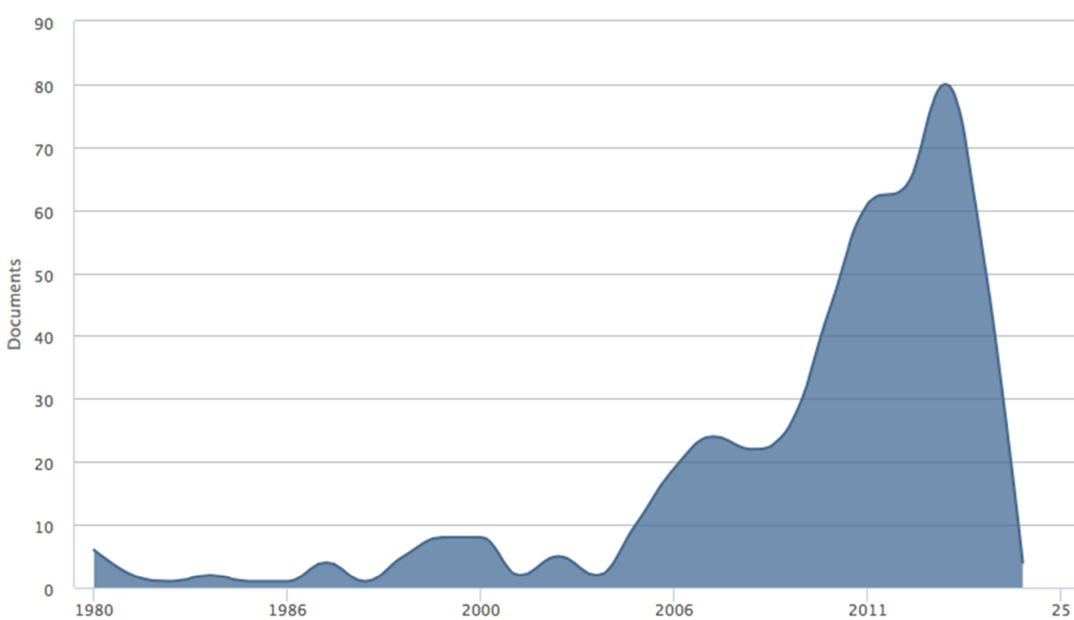


Figure 1. Number of publications on 'passive house' throughout the years

Appendix 2: PH definition as given by Passivhaus Institut and iPHA

Additionally, due to its broad appliance and frequent appearance in literature, and its short formulation, we would also like to mention the definition given by Schnieders[EM3] and Hermelink (2006). According to these authors, a passive house is "a building which assure(s) a comfortable indoor climate in summer and in winter without needing a conventional heat distribution system[EM4] " (p.152). With regards to energy use, the organizations Passivhaus Institute (2014) and Passivhaus Bauban [EM5] (2014) state that "a passive house should not use more than 15kWh per square meter per year, not including warm water, electricity and so on".

For a building to be considered a Passive House, it must meet the following criteria:

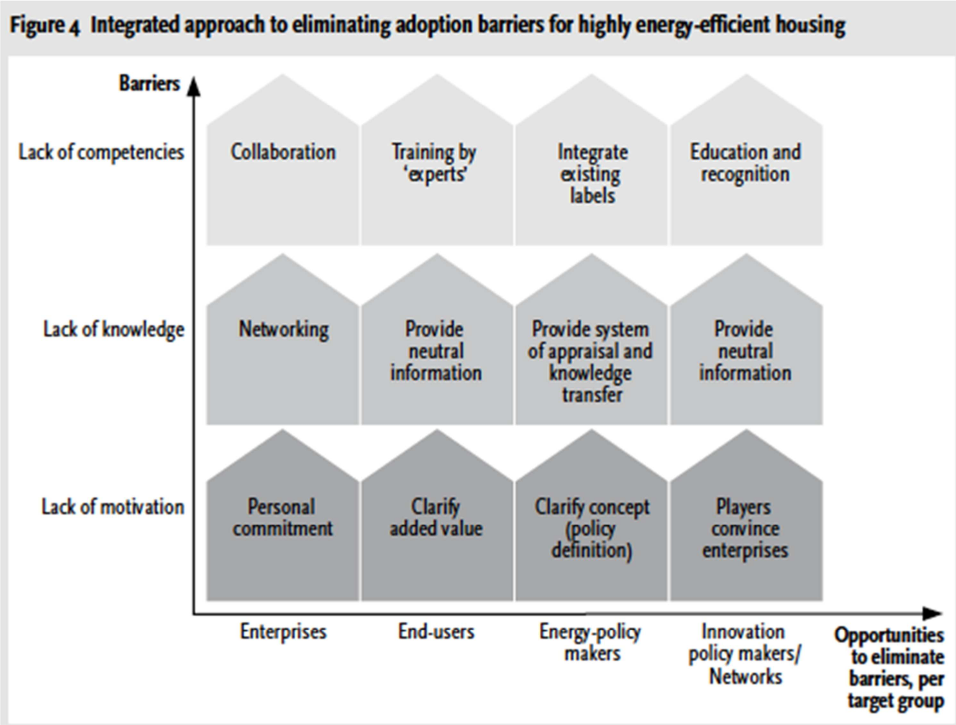
1. The Space Heating Energy Demand is not to exceed 15 kWh per square meter of net living space (treated floor area) per year or 10 W per square meter peak demand. In climates where active cooling is needed, the Space Cooling Energy Demand requirement roughly matches the heat demand requirements above, with a slight additional allowance for dehumidification.
2. The Primary Energy Demand, the total energy to be used for all domestic applications (heating, hot water and domestic electricity) must not exceed 120 kWh per square meter of treated floor area per year.
3. In terms of Airtightness, a maximum of 0.6 air changes per hour at 50 Pascals pressure (ACH50), as verified with an onsite pressure test (in both pressurized and depressurized states).
4. Thermal comfort must be met for all living areas during winter as well as in summer, with not more than 10 % of the hours in a given year over 25 °C.

Passive House buildings are planned, optimized and verified with the Passive House Planning Package (PHPP). All of the above criteria are achieved through intelligent design and implementation of the 5 Passive House principles: thermal bridge free design, superior windows, ventilation with heat recovery, quality insulation and airtight construction.

The following basic principles apply for the construction of Passive Houses:

1. Thermal insulation: All opaque building components of the exterior envelope of the house must be very well-insulated. For most cool-temperate climates, this means a heat transfer coefficient (U-value) of 0.15 W/(m²K) at the most, i.e. a maximum of 0.15 watts per degree of temperature difference and per square meter of exterior surface are lost.
2. Passive House windows: The window frames must be well insulated and fitted with low-e glazing filled with argon or krypton to prevent heat transfer. For most cool-temperate climates, this means a U-value of 0.80 W/(m²K) or less, with g-values around 50% (g-value= total solar transmittance, proportion of the solar energy available for the room).
3. Ventilation heat recovery: Efficient heat recovery ventilation is key, allowing for a good indoor air quality and saving energy. In Passive House, at least 75% of the heat from the exhaust air is transferred to the fresh air again by means of a heat exchanger.
4. Airtightness of the building: Uncontrolled leakage through gaps must be smaller than 0.6 of the total house volume per hour during a pressure test at 50 Pascal (both pressurized and depressurized).
5. Absence of thermal bridges: All edges, corners, connections and penetrations must be planned and executed with great care, so that thermal bridges can be avoided. Thermal bridges, which cannot be avoided, must be minimized as far as possible.

Appendix 3: Mlecnik's approach for eliminating adoption barriers



Appendix 4: Rogers' framework (2003)

Rogers' framework has five variables which determining the rate of adoption. Those are the perceived attributes of innovations, the type of innovation-decision, communication channels, nature of the social system and the extent of change agents' promotion efforts. With adoption is meant the full use of an innovation as the best course of action available (Rogers, 2003).

Perceived Attributes of Innovations (p. 15-16, Rogers 2003):

1. Relative Advantage: the degree to which an innovation is perceived as being better than the idea it supersedes
2. Compatibility: the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters
3. Complexity: the degree to which an innovation is perceived as relatively difficult to understand and use
4. Trialability: the degree to which an innovation may be experimented with
5. Observability: the degree to which the results of an innovation are visible to others

Rogers (2003) makes a distinction between three types of innovation-decisions. First is the optional decision, where the innovation is an option for individuals and independent from decisions made by others. Second is the collective decision, through which the decision is made by consensus within a group. Third is the authoritative decision, where few individuals with power decide for others. According to Rogers (2003), a communication channel is the way by which a message gets from the sender to the recipient. Different methods can be used to send a certain message about an innovation. For PH this be e.g. pilot projects, international platforms, educational programs for construction companies. The senders are often the Change Agents: feel the needs of the client and recommend innovation that could help fulfill the needs (p.228).

Rogers' definition of the social system: a set of interrelated units engaged in joint problem solving to accomplish a common goal (p. 23). Within different countries there are different cultures and therefore different norms, values, ways of communication. The differences in nature of the social system between the three areas are therefore important to analyze for PH, to see what characteristics contribute to the adoption and diffusion of innovation.

Limitations:

We stress that diffusion is difficult to measure as the exact causes of adoption are complex and hard to quantify. This theory is thus in no way a step-by-step guideline to successful innovation; the complexity of human interaction and the multitude of aspects on which decisions are made needs to be taken into account. Additionally, the model does not measure the necessity of an innovation.

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