Passive House at the crossroads: The past and the present of a voluntary standard that managed to brifge the energy efficiency gap

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Abstract

Improving energy efficiency in dwellings is generally seen as the low-hanging fruit of climate change mitigation. In particular decreased heat loss through better insulation is suggested as one of the most cost-effective means to achieve the ambitious national and international goals of climate gas reduction. However, the literature shows that a profitable technological solution is not sufficient to reach the energy goals. Aspects such as a lack of information, unobserved costs, and heterogeneity among users can compromise the success of technical innovation. Still, there are successful concepts that drive the technological development in the construction sector. The Passive House is an example for such innovations that manage to bridge the energy efficiency gap. This paper addresses the Passive House concept and standard as a success story of technological innovation. With Bruno Latour's Science in Action (1987) as a starting point, we describe the conditions under which the standard was created, the role of the network built around the Passive House Institute, and the consequences of exporting the standard. We identify success factors that have supported the diffusion of the Passive House standard and concept and discuss its possible development in the current situation which is characterized by its wide-spread adoption.

Introduction

Reducing buildings' energy consumption is generally seen as the low-hanging fruit of climate change mitigation (IPCC 2007). In particular decreased heat loss through better insulation is suggested as one of the most cost-effective means to achieve the ambitious national and international goals of climate gas reduction (McKinsey and Company, 2009). However, that the large potential of these measures is still promoted today should suggest caution: the benefits of better insulation have existed and have been well understood for years (e.g., Perlman and Warren, 1977) but have apparently not lived up to their potential. The list of factors that are able to explain this classic case of an energy efficiency paradox is long, including the lack of information and private information costs, principal/agent slippage, unobserved costs, and heterogeneity among users (Jaffe and Stavins, 1994); sociocultural and psychological factors (Wilk and Wilhite, 1985); and the strategic postponing of costly investments (van Soest and Bulte, 2001).

Although all of these factors explaining the lack of energy efficiency investments apply to the case of buildings and building insulation, there is a counterexample of a building type that goes far beyond the usual measures to avoid heat loss: due to an innovative recombination of existing energy efficiency measures and the development of building elements, the Passive House concept allows a comfortable indoor temperature even without an active heating or cooling (hence the name "passive"). In practice, most Passive Houses have an active heating but still with radically reduced energy demand. At the end of 2010, there were approximately 27,600 certified Passive Houses in Europe, and it is estimated that there will be approximately 65,000 such houses by the end of 2012 (www.pass-net.net). The increase in the number of projects has been exponential since the first Passive House was built in Darmstadt, Germany, in 1991. Reducing the heating needs of buildings by a factor of 10, the Passive House requirements are considered by many experts today as a precondition to the "nearly zero energy building" that, according to the EU directive on the energy performance of buildings (EPBD), must be implemented by all new buildings by the end of 2020 in the EU Member States.

This is a remarkable success story, given that the diffusion of the concept was initially mainly and is still mostly driven by enthusiastic individuals. The success is not only measurable in the number of dwellings built in accordance with the voluntary Passive House standard, but also in the attention that the Passive House enjoys in Europe and beyond.

In this paper, we describe how this voluntary standard could become so widespread. To identify the critical success factors in this history, we have analyzed insider accounts, observed a major Passive House conference and studied relevant documents. However, before we reconstruct the history from these sources, we will present a brief overview of what is known from the literature about barriers to otherwise rational energy efficiency measures. This overview will then guide us in the interpretation of success factors in the Passive House story.

Factors explaining the energy efficiency paradox

Explanations for the lack of seemingly rational investments in energy efficiency measures such as improved insulation each refers to its own general theory of human agency.

In this context, economic frameworks dominate. They introduce additional factors that influence the relationship between actors (potential investors) and their actions (investment energy efficiency) and thus help to make the outcome predictable. These “barriers” have been categorized along several axes, for instance, as being institutional, market related and behavioral (Weber, 1997). Jaffe and Stavins (1994) describe market failures such as the lack of information, principal/agent slippage (investments made by those who are not paying the energy bills, e.g., “landlords versus tenants”; see Phillips, 2012), and existing subsidies keeping energy prices artificially low. That these factors are described as “failures” implies that they should be corrected to create a perfect market. However, even if information about energy efficiency savings were perfectly transparent, investors could withdraw the profits directly and if there were no distortion through subsidies, according to Jaffe and Stavins (1994), non-market failures would still interfere. The authors mention private information costs (an individual’s effort to learn new things) and heterogeneity among potential adopters (affecting the desirability of technological adoption, e.g., climatic variation). As a final non-market-related factor, they describe uncertainty about future energy prices. This point was generalized by van Soest and Bulte (2001), who demonstrated that the strategic postponement of costly and irreversible investments may be rational, given the problem that technological progress does not follow easily predictable linear paths (see also Sørensen et al., 2000).

A common motive in critiques of economic approaches to the energy efficiency paradox is that they hide or at least do not account for their own normative foundations (Weber, 1997). As early as 1985, Wilk and Wilhite described the rationality of not investing in home insulation that is revealed if competing normative goals that are particularly abundant only in domestic settings are taken seriously (see, e.g., Aune, 2007). Extending this perspective, Shove (1998) reminded us that the individuals involved in (not) making energy-efficient choices are creative social agents embedded in a broad variety of technical, social and cultural contexts that have to be accounted for if these (non) investments are studied.

In this paper, we assume that taken together, the economic, technical, social and cultural explanations for non-investments in energy efficiency all contribute to a better understanding of why people do not invest in energy efficiency. However, instead of trying to integrate these explanations into one all-encompassing system (as proposed by Chai and Yeo, 2012), we follow actors who have overcome most of these barriers and describe how they have dealt with them. As we will show in our description of the Passive House concept and standard, this is a story of a vigorous fight against consequences of market failures, information, technological and economic uncertainty, and competing norms. We will argue further that in the current situation, in which the diffusion of Passive Houses reaches new quantitative dimensions, one of the challenges described in the literature, the heterogeneity among adopters will become crucial.

Method

This paper is the result of a structural analysis of in-depth interviews with key actors in the Passive House scene, participant observation at the 15th International Passive House Conference in 2011, and document analysis. This multi-method approach helped us to follow the key actors in various situations: being challenged to talk about their work and about Passive Houses generally, communicating with colleagues and promoting the technological solutions developed by industry partners, and presenting the concept through the World Wide Web to mobilise possible actors and convince possible customers. Moving between these situations, the actors adapt the language and the arguments to the listener. In all cases, they are promoting the Passive House as a robust concept, although the way they communicate the message is malleable.

The four in-depth interviews took place in Germany in June and July 2011 and lasted between 1.5 and 3 hours. The interviewees were key actors in the Passive House scene, and their answers offered a competent yet partial evaluation of the development of the concept. Two of the interviewees, a physicist (DB) and an architect (DA), were employed by the Passive House Institute (PHI), whereas the other two are involved in product development (DC) and in the design of Passive Houses and renovations of old buildings to Passive House standard (DD). The last two interviewees have been involved in Passive House projects from an early stage and have been active in developing new products, respectively new architectural solutions over the years.

The 4-day 15th International Conference held in Innsbruck, Austria, in 2011, offered a sample of how the Passive House concept and standard are communicated publicly. The thematic sessions of the conference were accompanied by exhibitions of certified components, poster sessions, and visits to Passive House projects. The social events allowed participants to meet and discuss the topic, strengthening the links between actors. The newcomers were presented to the audience, and their projects were publicly encouraged. The participation at the event offered the opportunity to follow the participants as actors in the network and to observe how they communicate and interact. The visits to Passive House projects in the region of Vorarlberg allowed the architects to present their work as a success story and to talk about challenges and solutions when implementing the concept in practice. The conference proceedings, the website of the PHI, relevant links to web sites, and the booklets made available by various actors are the documents that completed the picture of the Passive House development. These documents reflect the shared opinions, the research, the intentions and the targets of the actors and offer an official image of the Passive House as seen by its developers.

In this paper, we trace the most relevant moments of the Passive House concept by following the actors who have been involved in its development and who continue to support it. This is not to say that the concept did not have its critics and that these adversaries did not influence its diffusion. The exclusive focus on insider records can be seen as a limitation of the paper. However, our intention is to understand how key actors retrospectively see the development of the Passive House concept and standard and how they argue for the ways chosen at each crossroad. The specific controversies surrounding the Passive House concept are interesting in their own right and will be discussed in a separate paper. We are not taking sides but adding a third voice by proposing a theoretical perspective that contributes to an explanation to the success of this concept—in addition to and despite its intrinsic qualities or faults. Therefore, we use the methodological relativism (i.e., the deliberate use of relativism as a heuristic tool), as developed in anthropology and science studies, which is agnostic toward the value of is discussed—neither challenging nor supporting it. This does not mean that we are not committed to the truth of our account; if mistakes or omissions are present in the interviews, presentations and documents on which we base this study, these also form an important part of the analysis and are reported here.

The path to the Passive House concept and standard

The idea of a very low-energy house was not formed in a vacuum. At the time the Passive House concept was developed and tested, other low-energy dwelling projects had been realized. The interest in energy efficiency and in sustainable development had already reached the political arena,2 and the extension of the broader political agenda to the construction sector was an implicit consequence (Ornetzeder and Rohracher, 2009: 1535). The foundation for an innovative technical solution for the construction sector was present. However, the interviewees describe the beginnings of the development of the concept as an adventurous time, with clear ideas and a few enthusiastic supporters.

The Passive House from concept to standard

According to the interviewees, one beginning of the Passive House concept was the visit of the Swedish Professor Bo Adamson in China. In the southern part of the Yangtze River, because of scarce resources and a relatively mild climate, people are not permitted to heat their homes. However, in winter, the region can become uncomfortably cold (DB). In summer, however, the high temperatures would require active cooling to achieve a comfortable environment. Adamson was employed by the Chinese government to develop solutions that would enhance thermal comfort in these houses without using fuel. He called the resulting concept of houses that did not require heating "Passive Houses" (passipedia.passiv.de). Considering that the results could be applied further, his idea was "to transfer this principle to Europe using technical means (passipedia.passiv.de, historical review)." When he returned to Europe, Adamson met the German physicist Wolfgang Feist, and together they developed the Passive House concept and standard.

That travels are a source for knowledge transfer is a truism. At least as important as the travel itself was the creation of a centre of calculation (i.e. the place where the knowledge is stored, encoded and developed, see Latour, 1987) represented by the working platform built by Bo Adamson and Wolfgang Feist. The knowledge brought to the center was combined with knowledge about European building traditions and the adaptation to local conditions and with existing projects of low-energy houses in Europe and the United States (passipedia.passiv.de).

A period of calculations followed, during which the information that was brought to the center was combined and developed further. The aim was to create an even more energy-efficient dwelling that combined the architectural means with the existing technology. According to our interviewees, the first calculations demonstrated that the compactness of the building was relevant for energy savings but also that the existing components were not in line with the requirements of the new concept. The Passive House standard was the result of these first calculations transforming the concept into a standardized set of requirements. The interviewees repeatedly underlined the importance of the accurateness of the calculations at the beginning. Any failure or mistake could have compromised the concept. When the calculations were completed, the Passive House concept was stabilized as the Passive House standard. The standardization of the concept allowed it to multiply and to take various shapes, while still respecting the basic principles. The Passive House became through the process of standardization an "immutable mobile". By that Bruno Latour (1987) describes knowledge-objects that are able to "act at a distance on unfamiliar events, places and people" (Latour, 1987: 223). They become mobile, stable and combinable (Latour, 1987: 223), being able to move and recombine without distortion. The five basic principles of the Passive House standard are simple: thermal insulation, Passive House windows, ventilation with heat recovery, airtightness, and a thermal-bridge-free design (passipedia.de). The thermal comfort in dwellings built in compliance with the Passive House standard "is achieved to a maximum extent through passive measures" (passipedia.passiv.de). the standard allows for 10 W/m2 specific More specifically, annual heating load, while the total energy for space heating, domestic hot water and household appliances may not exceed 120 kWh/m2 a (CEPHEUS).

This simplicity is the consequence of a learning process made possible by a conceptual back and forth between centre (represented by the working platform created by Feist and Adamson) and periphery (the buildings where Passive House principles were implemented). In line with Bruno Latour's (1987) description of scientific knowledge production, these basic principles were the abstract result of combination and re-combination of the information that reached the center. The coding process that results in the Passive House (similar to the coding of the shapes of the land masses to form a map in Latour's example) allows construction materials, technological devices, thicknesses of walls and roofs, and U values of the components to become specifications of the standard.

From the beginning, it was clear that the developed standard should have a performance-based character. The aim was to reduce energy consumption in dwellings, and the specific technical solutions that led to the target were left open. The essence of Passive House is encoded in the principles that remain at the foundation of the concept, but the performance of the dwelling is clearly coded in performance requirements.

From the drawing of the first Passive House plans, a critical role was played by a calculation tool. This Passive House Planning Package (PHPP) aims to cover all possible calculable details of a dwelling.3 An advantage of this evaluation tool is that "it has been specifically created as a design and certification tool for Passive Houses and that it regularly incorporates new research results in its calculation procedures" (Mlecnik et al., 2010: 4598). In addition to the technical means, the tool also covers aspects related to funding and to specific details when building a Passive House (the Passive House construction manual) and includes an example project calculated in the PHPP (passipedia.passiv.de).

Busch (2011) calls standardization "a form of trust (though likely not the only one) well suited for a world consisting largely of strangers acting in the marketplace" (Busch, 2011: 215). To fulfill this role, the processes leading to certification have to appear trustworthy. It is important that the PHPP be promoted as scientifically superior: "The behaviour of buildings can be predicted very accurately using a simulation that is based on the fundamental laws of physics" (passipedia.de). Similarly, our informants focused extensively on the claim that the Passive House is based on physics and not on politics driven by lobby groups. As a consequence the Passive House is described as reliable (DA), and performance variations between identical dwellings in use are supposed to be smaller in the case of Passive Houses than in "normal" dwellings (DD).

The interviewees claim that the PHPP offers a more accurate statement regarding the energy efficiency of a building and that the national calculation tool prescribed by the official German building regulation (EnEV, DB) can be used "creatively" (DD), thus, it can offer different results because of the possibility to choose how to perform the measurements. The accurateness (or rigidity) of the Passive House calculation tool is presented by the interviewees as able to reduce the hazard of the results and can easily be used as policy tool if the target is to anticipate the outcomes. The interviewees claim that this accuracy can be achieved because the concept of the Passive House was not new: it has always existed. The pioneers who developed the concept "found" it in the laws of physics. As a consequence, proponents of the Passive House standard maintain that the concept is stable and reliable because it is based on scientific knowledge: "The Passive House concept has not been invented/made up, but rather discovered" (passipedia.de).

Thus, the interviewees and the web site of the PHI support the idea that the optimal solution to reduce energy consumption in all buildings exists "out there", "in nature", waiting to be found. Our sources claim that based on travels and calculations, they have discovered this one best solution that can be reduced to a set of simple principles because it is found in the fundamental laws of physics. In relation to key barriers against energy efficiency investments, this strong reference to scientific principles above all is relevant because of its ability to create certainty. Who would deny that the fundamental laws of physics will prevail in the end? The resulting standard reduces uncertainty as long as the trust in the standardization process to be able to remain true to the laws of physics is intact. At the same time, we observe that the standard eases information transfer ("five simple principles"), which was further supported by creating a "standardized package" (Fujimura, 1992) consisting mainly of the PHPP calculation tool that incorporates calculatory knowledge.

Pilot buildings and enthusiasm for the concept

In general terms the introduction of the concepts "immutable mobile" and "centre of calculation" (Latour, 1987) changed the focus of research from theories and ideas as a monopoly of intellectual elites to the way in which knowledge is produced and disseminated (Stöckelova, 2012). The accurateness of a scientific result does not automatically lead the tested idea to success: the way this idea is formulated, circulates, has the ability to mobilize actors and to fight enemies, the way in which this idea prevails and wins recognition over other ideas, are as important as scientific acknowledgment. In this sense, after the first calculations proved the viability of the concept, the long and important work of enrolling allies had only just begun.

As early as 1991, the first Passive House was built in Darmstadt, Germany. This project is today celebrated as the beginning of the Passive House movement. Indeed, this first dwelling can be considered a milestone in the development of the Passive House. However, as was shown in the previous chapter, the history of the concept and the standard actually began several years prior, when the idea of a very low-energy dwelling was born and the first calculations were performed. The first Passive House building was the proof of the idea. It visualized the existence and the viability of the concept, thus transforming the idea into reality.

From the first travels and calculations until the first project was realized, new actors had to be mobilized. The creation of the standard alone did not guarantee the success of the concept. However, the development of the standard was a precondition to the success of the concept.

The individual solutions that were developed to make the Passive House concept reality marked not necessarily a revolutionary departure from existing solutions. Combined into an integrated concept, however, they were a step towards the kind of integrated innovation that usually lacks in the building sector (Taylor and Levitt, 2004).

According to our interviewees, the difficulties at the beginning and the lack of trust of other experts transformed the step between performing calculations and the first Passive House built into a real adventure. Only a limited number of enthusiasts believed in the concept. As an interviewee said:

> There were so many voices from everywhere. From the architects: 'The windows are ugly'; from the construction industry: 'This is not traditional. The house will collapse because it is based on insulation. How can you do that? This will not work'; from the manufacturers: 'The components they needed are too expensive'; from clients, 'I want to open the windows. I do not want to live in a house where I cannot open the windows'. But you can open the windows. (DA)

The pilot project proved that the standard can be applied with the expected results, and after the construction it served as feedback for possible improvement. This back and forth between the standard in paper form and its material solution was used over the years to improve both the calculation tool and the technical solutions and components.

The first pilot project was also the first exposure of the new concept to the consumers. As DD said, "There should be a house for the public to have hands on to show people what is going on". The theoretical background could convince the experts, while the dwelling was the "exhibition piece" that took the form of a home/dwelling.

The interviewees presented the beginning of the development of the Passive House as a time of exploration, when the pioneers accepted the challenge to transform a "scientific finding" into reality. Two of the interviewees who were part of the development in its earliest phase confirmed that they were excited by the new concept and more than willing to participate.

The first supporters of the Passive House were enthusiasts. In this context, the demonstration project played an important role, as one interviewee said:

> I looked with wide open eyes at the first Passive House project in Darmstadt. I was very impressed by it, and since then I feel very connected with this mindset. (DD)

The interviewee had joined because he had "the same philosophy" and the Passive House provided a good scientific background for his work. It was "the most reasonable" concept. Then, he met like-minded people at the conferences and open days, and he enjoyed these meetings (DD). Similarly, another interviewee said:

At the beginning there was a very enthusiastic architect, Folkmer Rasch, and his partner, Petra Grenz. They worked together with the manufacturers; they pushed them. They said, 'We want this window; we are not buying this ugly window', and they also got a good price. They were negotiating with them and said,

> 'Well, you cannot put all the costs of the development of something new into this project now; this does not work. There is a market, and you are the first ones on the market.' They were very good. And they built the first pilot projects. (DA)

As can be observed, the actors involved in the development of the Passive House concept engaged from the beginning in the promotion of the concept. They mobilized and involved possible developers by showing them the advantages (being the first on the market) and, at the same time, by imposing their conditions attractive components).

In the beginning, the networks built around the researchers, developers, architects, consulting engineers and component makers were based on personal contact. The circle was closed, and the participants knew and trusted one another. They were "like-minded", and so there was a reduced danger of conflicts and misunderstandings. The people involved called university colleagues and asked them to join (DB). The relationship was based on trust. The participants built around the Passive House an identity, and they shared this identity. People and things (e.g., pilot buildings) created a stable network. An interviewee spoke about a ventilation system with heat recovery as "the world champion" (DC). This implies that the ventilation system is seen as a result of a training process. Similar to people, the technological devices engage in a competition. Due to their qualities, these objects act as promotion agents.

The Darmstadt project was followed by a series of other pilot projects. From residential buildings, the interest moved to nonresidential constructions in which the financial calculations prevailed over the emotional element. Being a "physicotechnical concept, the Passive House does not appeal to people who approach the topics emotionally" (DD).

One of the most discussed issues is the architectural qualities of Passive Houses because the main principles of energy efficiency limit architectural freedom to a certain degree. The pilot projects in Germany and elsewhere also had as their stated mission to involve architects who developed attractive design. Architectural qualities were expected to give these buildings an identity and make them more attractive to the public (DD).

Especially early implementations of Passive Houses in Austria were successful in this respect. In the state of Vorarlberg where

the first dwelling was built as early as 1996, the dwellings built to Passive House standard adopted the local architecture dominated by timber houses (Dangel, 2010). The technological concept matched the architectural ideals of the "Vorarlberg School of Architecture" that had developed since the 1960s and was grounded in the traditional regional architecture. This symbiosis between an established architecture school and the innovative standard turned out to be of decisive importance for the widespread diffusion of the Passive House (Dangel, 2010).

Early proponents of the Passive House standard presented themselves as being part of something important, even revolutionary. Although the concept was framed as a simple matter of the fundamental laws of physics, actually realising the concept generated a great deal of enthusiasm. The proof that the abstract principle could be manifested physically added to the credibility that was initially based on the reference to scientific laws and a simple but consistent standard.

Creating a centre and controlling the margins

With pilot buildings, measurement and calculation tools, and committed individuals, the concept of the Passive House gained ground, but it was also in danger of losing its focus that would allow for a coordinated development.

In 1996, the Passive House Institute (PHI) was founded by Dr. Wolfgang Feist. This independent research institute allowed the concentration of all activities of the interdisciplinary team on the new concept. Additionally, its independence from other institutions conferred on the institute an image of impartiality and objectivity—that created trust among customers. The interviewees unanimously described the creation of the PHI as an important step in the development of the concept. According to them, Wolfgang Feist understood that "the concept is not going to develop by itself" (DA). The network had to be enlarged by involving new topics and new actors in the process. The extension occurred on the conceptual level as well: From the beginning, the Institute promoted cost effectiveness (not considered in the first demonstrations) in addition to the energy efficiency of buildings and component development. With time, new aspects completed the development, such as the aesthetics of the buildings and aspects related to their marketing.

The control of the PHI over the Passive House actors was ultimately maintained through certification, not only for the buildings and the building components but for people as well. The Institute organized courses by which one could become a "Certified Passive House Designer" "to show to the public that there is an extra knowledge available to this person, that he or she has extra experience with Passive Houses", as one interviewee (DB) described it. These certifications are not necessarily performed by the Institute itself. There are now approximately 15 partners that are connected to the PHI through a collaboration contract and annual meetings.

If the beginning of the Passive House development was dominated by enthusiasts, the next phases involved more strategic networking while close contact and trust remained valued aspects. Platforms were created in which these experts could meet and talk. In these activities, the PHI was presented by the interviewees as an independent and impartial institution that guaranteed the quality of the products, performance, and experts. Through the certifications, the PHI had gained the reputation of an impartial third party that guaranteed the clients the quality of each service.

In addition to guarantees for the certified people and products, certifications clearly were also a way of excluding actors from the Passive House market (Busch, 2011, calls this "standardized differentiation"). Non-certified products could not enter the Passive House market, whereas the certified products would also have an advantage outside this market.4 One of the interviewees stated that certain companies decided to certify some of their products because they could not sell them otherwise. Their products did not have the quality proof of an impartial authority (DB).

The PHI accompanies the actors of the network during the entire process of product development. The interviewees said that they do "consulting with architects and building companies to get a good overall design of the building" (DA) and that they collaborate with component makers to ensure cost effectiveness and good design (DB).

As "recipes of reality" (Busch, 2011), standards are able to order "people and things so as to produce outcomes desired by someone. As such, they are part of the technical, political, social, economic, and ethical infrastructure that constitutes human societies." (Busch, 2011: 13) Because of the elements that connect the center (i.e., the PHI) and a growing number of peripheral sites (e.g., Passive Houses), the standard increased the power of the center that controlled the Passive House development. Thus, the actors in the center had a "strategic position" because "they design networks that are tied together in a few obligatory passage points" (Latour, 1987: 245). The standardization of a concept and the procedure of certification helped companies to sell their products and to make the PHI a necessary point of passage in the acceptance of a component as suitable for Passive Houses.

With the creation of the PHI and its certification scheme, a technological niche was created that quickly developed into a commercial niche (Schot and Geels, 2008). Resting on its power to define what is inside and what is outside the market, entry into this niche was artificially restricted by the gatekeepers at the PHI. The basis for this power depended on the Institute's ability to reduce uncertainty and to provide information. Moreover, the niche was held together on the inside through the PHI's training. Finally, principal/agent problems were reduced by ensuring that as many links in the chain as possible would have the same information and the necessary amount of motivation.

Quo vadis Passive House?

Spreading the word

Today, a high priority is given by the PHI to the presentation of the Passive House standard to prospective members and customers. This presentation is accomplished through the organization of "open days", conferences and workshops. Moreover, product developers organize courses in which experts can learn "extra knowledge", and open laboratory doors where customers and experts can view and experience the new technological devices and the Passive Houses built with different material, architectural and technological solutions.

There is even a Passive House village, called "Sonnenplatz Großschönau", in Austria that offers the possibility for anybody to experience living in a Passive House. The offer intends to introduce the concept of a new way of living to the public and to dissipate the inhibitions that might accompany such a decision. It is the difference between hearing about it and trying it, as the village described itself:

The most pleasant and best way of learning about the advantages of Passive-House living is to try one out. After all, visiting a show home on a traditional housing development and flicking through the brochures is one thing, but getting to know and generating a feeling for a house is something quite different (www.probewohnen.at).

This is also the general message for both experts and laypeople: the concept is simple, it is based on physics (so it cannot fail), and it offers the full package of advantages, from low energy bills to comfort and architectural quality—a combination of objective and strict calculations before the product leaves the laboratory and the emotional factor in the promotion phase:

The clients should not feel the Passive House as a technical pressure, but the topic has to be presented as sexy, exciting, comfortable, great architecture possible, these aspects are important. (DD)

Through the years, the promoters of Passive Houses have learned to improve their message. As an interviewee stated, most clients "would not come and say, 'Well, I want to have a Passive House'. This is what we had to learn—the hard way" (DB). Systematic surveys that were conducted among early customers indicated that the energy efficiency and the Passive House label might appeal to experts but were of less importance to clients (CEPHEUS). A consequence was the inclusion of non-technical aspects but also the principle that prospective clients should be given the sense that they are voluntarily participating in the implementation of a new form of home.

This focus on spreading the word and recruiting new volunteers continues the strategies that have been employed successfully since the beginnings of the Passive House movement. In Austria, the concept gained credibility quickly and was implemented with success in many regions. The region of Vorarlberg claims to have the highest number of Passive Houses per person. The lack of language barriers (DB and DA), the trust in German technology (DC) and the openness of Austrian architects, engineers and physicists toward new concepts (DB) appear to be the most relevant favourable conditions for acceptance.

Additionally, in the state of Vorarlberg, public authorities promoted Passive Houses actively through various strategies, supporting it financially or transforming it into legal requirement. Moreover, a number of intermediary organisations (e.g. IG Passivhaus, consultancy organisations, research programmes such as "building of tomorrow") acted as key actors in the planning process, in the promotion of Passive Houses and certifications, and in the knowledge transfer (Ornetzeder and Rohracher, 2009). The mutual trust of actors and the more than average interest of all participants for energy efficiency in Vorarlberg represent a unique example of success. The cooperation of all actors in the network, from architects and craftspeople (also a traditional cooperation in the region that precedes the Passive House) to open-minded clients and supportive local government played a decisive role on the implementation of Passive Houses (Dangel, 2010).

After the first successful projects in Germany and Austria, other European countries opened the doors to the new concept.

Spreading the standard

Today, the concept has extended beyond the Central European borders and has gained ground all over the world. However, the implementation of Passive Houses in different climate zones is accompanied by several problems. Whereas some countries have decided to implement the standard as given, other countries have imported the name and the basic principles but revised the calculation method, i.e., they imported the concept but not the standard.5 Norway, for instance, has adapted the Passive House concept but has developed a specific Norwegian standard (NS 3700 for residential and NS 3701 for non-residential buildings) that resulted from three years of controversial discussions of the requirements for energy supply, single-family homes (which are common in Norway), and to what extent climate change mitigation should be included. Reusing the calculation methods that are well established in Norway (e.g., NS 3031) while retaining the cornerstones of the original (e.g., annual heating demand 15 kWh/ m2), this standard changed primarily the values and methods used in the calculation certification, thereby breaking the link to the PHI that had existed, among other links, through the PHPP calculation tool.

Researchers involved in the development of the Norwegian standard argued that Norwegian conditions would incur excessive additional cost and thereby "hinder the market penetration of Passive Houses in Norway" (Dokka and Andresen, 2006: 227). The interviewees from the PHI opposed this view, expecting the newcomers to apply the standard as given. The simple definition and the clear basic principles should allow the export of the concept without distortion—after all, physics is the same regardless of the location. The standard prescribes the performance of the dwelling but leaves open the choice of solutions. The solution for countries with other climates and traditions should be a timeconsuming development of components within the given standard (DA and DB). The interviewees conceded that these components do not yet exist, but they also said that it is only natural that the development of such components would take time (DA). The interviewees would rather allow countries that implement the Passive House concept several years of development and "learning" than to insist on the immediate implementation of the concept in a modified or adapted form. As has been shown, this is opposed to the Norwegian (and e.g., Swedish) approach, in which the concept is adapted to provide "better consistency with existing values, past experiences and needs of potential adopters" (Mlecnik et al., 2010: 4597).

The consequence of these conditions is that the PHI loses at least partially the control of the development of the Passive House standard: it cannot unconditionally and directly "act at distance" (Latour, 1987: 228) in countries such as Norway. In these situations, the certification is performed by new actors under new premises, relieving the PHI of its responsibility but also of its ability to control and learn through direct feedback. The implications weaken the position of the PHI as an actor in Norway. Another way of describing this development is that in the moment when the concept is exported and a new standard is adapted, a new center of calculation is created. In our case, the private research institution SINTEF is one of the central Norwegian institutions that have the competence to certify the products, the dwellings and the actors involved, and to train professionals and develop the concept—possibly in another direction from the PHI (Müller, 2012). However, the communication with the original centre of calculation and control is not completely broken. A large Norwegian delegation was present at the conference in Innsbruck, proving that the connections between the two centres remain strong. Thus, the communication still exists, but the border is only conditionally permeable, indicating that the PHI is no longer an obligatory point of passage.

Conclusion: Success factors

Our analysis of the Passive House development as told by its protagonists demonstrates that the success of the concept and the standard was not made possible through enforcement by (supra) national regulation or through the backing of powerful commercial actors. Rather, success was achieved through a combination of a fervent belief in the scientific basis of the fundamental principles of the standard, a rigid certification scheme (which involves a required certification tool), demonstration through good examples (from pilot buildings to the Passive House village), the creation of a protected market niche, extensive training activities and an increasingly professional marketing of the concept, standard, components and technologies. These success factors have created synergies that enabled the Passive House concept and standard to overcome the barriers to energy efficiency that are reported in the literature. More specifically, we have observed that

- the scientific foundation that remained at the core of the transformation of the concept into a performance-based standard has reduced uncertainty and instilled trust,
- the unambiguous simplicity of the standard has facilitated information transfer,
- a tool required for certification has further contributed to the reduction of uncertainty and created a standardized package that is easily employed,
- demonstrations through pilot buildings mobilized early supporters and acted as convincing proof for the viability of the concept and standard,
- a devoted community of like-minded proponents was formed that shared the same norms and values,
- a protected market niche was created through the certification scheme,
- strict quality assurance in training experts reduced principal/ agent problems, and finally,
- lessons learned throughout the history led to a professionaliza tion of the propagation of the concept and standard.

Currently, two factors – the climatic variation and the competing normative goals – are likely to gain prominence. Both are related to the fact that the heterogeneity of adopters has been growing rapidly over the course of the last few years. As described above, the history of Passive Houses over 20 years has occurred primarily in Germany and Austria. These two countries have a common language and a similar climate and technical infrastructure. Moreover, early adopters of the concept were likely to be interested in prioritizing energy saving to a more than average extent. In the current situation, the Norwegian case, among others, illustrates that for the rapid implementation of the concept, much is to be gained from modifying and thereby multifying the standard and weakening the connection to the original centre of calculations, the PHI. The Austrian case of the state of Vorarlberg is instructive in this respect: Unique cultural and social conditions that predate the Passive House have created an extraordinarily fertile ground for a creative development of the concept and standard. Cultural norms and values as described by Wilk and Wilhite (1985) vary geographically and have already influenced established calculation standards and associated methods. However, above all, climatic variations create barriers that are able to slow the diffusion of the standard.

Given the success of the Passive House to this point, a possible future scenario may be that such construction becomes a matter of course. This option is described by one informant as follows: "In the beginning I was a crackpot or a visionary, then I was a visionary who was in great demand, and today, Wolfgang [Feist] and many others, we are normality […]" (DD). The transformation from vision to normality changes the character of the certification from a tool of change to a tool of solidifying the status quo. The informant continues: "Today, audiences get excited when someone talks about plus-energy buildings" (DD). Indeed, we now observe the emergence of competing concepts and standards all over the world. Their different names, methods and philosophies inspire ambitious environmental goals. However, these concepts and standards may also produce confusion among otherwise willing adopters. In this situation, the tension between rigid control and flexible adaptability becomes the central moment defining the future of highly effective energy efficiency concepts and standards in the building sector.

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