

# QUALITY ASSURANCE FOR PASSIVE HOUSES

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## Abstract

For newly built houses national ambitions prescribe increasing levels of energy performances, even including achieving net zero energy or carbon neutral houses. This is in large contrast with the lack of quality in many building processes. The building regulations, processes and control will have to be reshaped to support these ambitions, taking into account a development of performance guarantees in the building sector. Passive houses have to reach a target energy demand for heating less than 15 kWh/m<sup>2</sup>a and a total primary energy demand less than 120 kWh/m<sup>2</sup>a. Quite some examples of houses (and other buildings) in various countries show that it is technically feasible to reach this performance. In most of these countries also some form of quality assurance and certificates for these houses exist. In this paper we describe the possible changes of building processes due to the introduction of the passive house concept, and the urgency of reliable quality assurance to adequately reaching the energy ambitions and to assure quality issues at the same time. We illustrate this with passive house certification schemes from some European countries. This leads to some conclusions about the role and content of passive house certificates in the coming years.

## 1. Introduction

Promoting energy efficiency is essential to achieve the Kyoto Protocol. The European building sector is responsible for about 40% of the total primary energy consumption. To reduce this share, the European Commission (EC) has introduced the Energy Performance of Buildings Directive, the EPBD (2002/91/EC). This framework has led to energy performance certificates for buildings, in many countries to be introduced in 2007-2009. The EC has also highlighted that future adaptations of the EPBD may be extended to include 'low energy or Passive Houses' as a requirement. For newly built houses the national building regulations prescribe increasing levels of energy performances. More and more countries, but also regions or municipalities, formulate ambitions for net zero energy or carbon neutral houses.

The EC has highlighted in its 'energy efficiency action plan' that future adaptations of the Energy Performance of Buildings Directive (EPBD) may be extended to include 'low energy or Passive Houses' as a requirement, setting a target date of 2015. For many countries the passive house level is seen as a long term political ambition level to reduce energy consumption in the building sector (Dyrbol et al., 2008). Many countries also have industry initiated target settings, supported by the government. E.g. in France the 'Grenelle de l'environnement' specified targets for sustainable construction. The 'Code for sustainable Homes' in the United Kingdom states that by 2016 new dwellings will need to be zero carbon and will have to achieve a similar level of fabric performance as passive houses. In the Netherlands, a strengthening of the energy performance level of buildings is proposed to nearly passive by 2015. In the Flanders Region specific passive house targets have been proposed by the transition arena 'sustainable living and building'. (Mlecnik et al., 2008)

Passive houses have to reach a target energy demand for heating less than 15 kilowatt hour per square meter net heated surface and per year (kWh/m<sup>2</sup>a) and a total primary energy demand less than 120 kWh/m<sup>2</sup>a (PEP, 2008). Some European countries and regions have introduced long term visions for the year 2015-2020 that include voluntary passive house certification or in certain circumstance a mandatory passive house standard. Often a verification of reaching the passive house standard is a condition for financial benefits.

Formulating ambitions and sharpening regulations is relatively easy to do. Technical solutions are currently available to realize the passive house standard in building projects. There is quite some evidence however that the mainstream of building processes do not lead to the pre-defined quality. Traditionally the municipal

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departments of building control in most countries had an important role in assuring that building plans and construction processes would lead to buildings that meet the minimum required quality levels. There is a tendency to put more emphasis on the responsibilities of owners and private parties to ensure quality. This means that the private parties will have to improve their working process and will have to learn to handle performance guarantees. Owners will require guarantees from the designers and building companies for the quality of their property. Certification and accreditation of parties, processes and products will become more important for building processes in general.

For the realization of high energy performance standards, a reliable quality assurance system will be very important. In most countries that have some experiences with passive houses some form of performance guarantee and associated quality assurance scheme exists. It is crucially important to study these examples.

This paper continues in section 2 with an elaboration on the trends in regulations and building control that stress the importance of certification. Section 3 will explain of the impact of the passive house concept on the building process. In section 4 examples of passive house certification in some European regions are presented. In section 5 finally we draw conclusions.

## **2. The need for quality assurance**

Besides the conditions described in the previous section, the poor performances of the building industry in the mainstream building projects in combination with a withdrawing government from building regulations and actual building control is perhaps the most important reason to develop reliable certification schemes, especially for passive houses.

### **2.1 Failures in the Dutch building industry**

The cost of failures in the Dutch building industry amounts to more than 10% of turnover (USP marketing consult, 2007). Total investment costs (including maintenance) in homes were € 46 billion in 2005, which means annual wastage of € 4.6 billion in this part of the building industry. Vereniging Eigen Huis, a consumer organization for homeowners, carries out final inspections on many new homes. In 2005 it was reported that construction companies are gradually improving their standards. The average number of deficiencies in more than 1,400 homes examined at new build housing areas was 17.5 per home. However, some homes had as many as 71 deficiencies. There are also many problems with aspects of building physics, as revealed in a study of 78 housing projects by the VROM Inspectorate (Kuindersma et al., 2007). The researchers observed acute health risks, reduced living comfort and, above all, poor energy performance. New homes must comply with the EPC (Energy Performance Coefficient), an important policy instrument for achieving CO<sub>2</sub> reduction targets. The study showed that 25% of the EPC calculations that were part of the building permit were not correct. The performance of the built homes was studied too, and it was unsatisfactory in 47% of homes! In order to comply with EPC regulations, a system whereby heat is recovered from the ventilation system (balanced ventilation) is often installed. In the past few years, this system has been installed in approximately 400,000 Dutch homes. Problems with the system in the Vathorst area of Amersfoort have featured regularly in the news (Duijm et al., 2007). An analysis of the problems has shown that they are not necessarily due to the ventilation system itself, but that poor quality management throughout the construction chain can lead to an accumulation of faults.

We suspect that the Dutch situation is not unique. At a meeting of the European Consortium of Building Control in Riga in 2008, representatives from many countries reported on problems in the individual countries. Although the problems are very diverse, it is apparent that in many countries there is a discussion about the organization of building control in the context of quality problems.

There are major challenges in terms of realizing and maintaining the physical performance of homes. Requirements will become much more stringent than is currently the case, particularly with regard to energy conservation, the indoor environment and integral environmental quality. Quality management and, above all, quality assurance are becoming more and more important. In the future, responsibility for these aspects will be increasingly transferred to parties in the building sector.

### **2.2 Developments in building regulations and building control**

Building regulations are the subject of an ongoing debate between, on the one hand, those in favor of deregulation and reducing the administrative burden and, on the other hand, new quality demands that require government intervention. Currently in the Netherlands, both sides of this debate appear to be gaining in importance. Deregulation, as well as high targets for energy conservation, structural safety and reliable government, are high on the politicians' agenda. The desire for deregulation is leading to the opinion that greater emphasis should be placed on the responsibility of property owners, which could lead to less government intervention. However, the existing forms of quality control for private actors in the Dutch building industry seem to be of quite a low standard. Accidents occur and physical quality does not appear to be sufficiently important. As the CO<sub>2</sub> and energy targets increase, stronger regulations and accurate building control become a priority.

When the Dutch building regulations were made more uniform in 1992, the changes were not reflected in the processes for assessing building plans or carrying out inspections of construction work. As early as 1996, evaluation research by the OTB Research Institute (Meijer et al., 1995) showed that the introduction of the deadline for issuing a permit represented a shift of focus away from assessment and inspection by municipalities towards the monitoring of administrative and legal procedures. In the past ten years, it has become increasingly clear that the quantity and quality of assessments carried out by many municipal authorities leave something to be desired (VROM Inspectorate, 2007).

In this context we should remember that the client and the parties who engage for the design and construction stages have primary responsibility for complying with regulations. When a building permit is granted, this suggests that the plan has been shown to comply with all the regulations. But this is not the case. In practice, a permit is granted because, during the checking process, the plan was not found to deviate from the regulations.

We will now return to the continuing call by politicians for greater deregulation and easing of the administrative burden. In 1997 we contributed to the building-regulations project as part of the MDW (Market Forces, Deregulation & Legislative Quality) programme of the Ministry of Economic Affairs. The purpose of our research was to formulate deregulation proposals on the basis of examples from other European countries (Visscher, 1997). Notably, in those countries, many private-sector parties are involved in assessment and inspection. We have studied (Visscher, 2000) how the responsibility for these tasks could be transferred to the private sector in the Netherlands too, primarily through the certification instrument. The Ministry of Housing, Spatial Planning and the Environment (VROM) also took up this idea. Since the end of the 1990s, it has been developing a process certificate for assessing building plans against the requirements of the Building Decree. The assessment guideline, BRL 5019, which sets out the requirements for this form of certification, was completed some time ago. More than twenty organizations took part in trial projects, and the first four organizations almost reached the certification stage. The Certified Building-Plan Test was intended to serve as a voluntary equivalent alternative to assessment by the municipal authority.

The current cabinet is aiming to reduce the administrative burden by 25%. Again, the field of building regulation is seen to have a great deal of potential in this regard. The Ministry of Economic Affairs and the Ministry of VROM appointed the Construction Sector Fundamental Review Committee (Commissie Fundamentele Verkenning Bouw) chaired by Sybilla Dekker, the former Minister for VROM, to draw up proposals for the far-reaching simplification of building regulations. The committee recommended the abolition of preventive assessment of building plans by local authorities. The client should be responsible for complying with the regulations and should also ensure that sufficient checks are in place. It can engage a certified body to do this, but there may be alternatives. The role of the municipal authorities will shift towards that of process auditing, i.e. supervising the checks. The question is then: how this can be operationalised?

In many countries there are problems with a lack of compliance with building regulations, and this often serves as a stimulus for reviewing and improving the system of building control. The considerable pressure to deregulate in the Netherlands has parallels in other countries. There is a clear trend towards increasing the role of private parties. In many countries, the role of local authorities in carrying out assessments and implementation inspections has virtually disappeared.

Therefore it is interesting to study innovative ways in which quality is guaranteed by private parties. The certification of passive houses is a field that requires building actors to transform the usual building process into a performance based approach and to learn by doing. In the next section we illustrate how the building process can be impacted when the client requires a passive house.

### **3. Innovative building process for passive houses**

Building passive houses is still no daily practice for many designers, building contractors and installers. Due to the lack of experience of designers and contractors to build to the much more demanding requirements of the passive house, there is potentially a high risk of the house claiming to be a passive house having higher energy demand than predicted by the passive house standard. Therefore it is advisable that, when a consumer wants to purchase a passive house, some form of quality assurance is provided. This can start with a contractual agreement of a building team to deliver a passive house according to the previously described specific measurable criteria. Certification of the project or product will offer more certainty for the consumer. Alternatively, or in addition, requiring experience guarantees of the architect, the building contractor and the installer may help to make sure that the consumer involves self-educated parties and finally gets the energy efficient and comfortable house which he/she had in mind. Performance based contracting is being initiated for passive houses and low energy buildings and these experimental processes provide first insights in shifts from means contracting to performance contracting. For the commissioning of passive house buildings the preferred award procedures are the performance-based bidding procedures; open or restricted calls for tenders, the design contest, the negotiated procedure with or without publication and the competitive dialogue.

An essential element in the performance assurance is the calculation of energy performance, usually already in a first design phase, either using EPBD related software or specific passive house software. The so called PHPP software, developed by the German Passivhaus Institut Darmstadt (2008) was specifically designed to design and certify passive houses and has the advantage that its consistency has been verified on hundreds of passive houses. For passive houses, verification, minimum at the final design stage, is required according to PHPP, and later, a practical performance test on site to check the air tightness of the building envelope. This has implications on the whole building process, as illustrated in Figure 1.

In most cases the building designer does not have the knowledge of the PHPP tools. A passive house energy consultant is usually assigned to the project. The energy consultant will provide passive house design advice, PHPP calculations and recommendation for products and technologies specification. The PHPP calculation is based on a large number of building and installation characteristics. Key elements for information gathering are thermal and solar characteristics of building components and factors influencing heating and primary energy demand and indoor climate requirements. PHPP also checks minimum ventilation requirements, dimensioning of heat production and the risk of overheating.

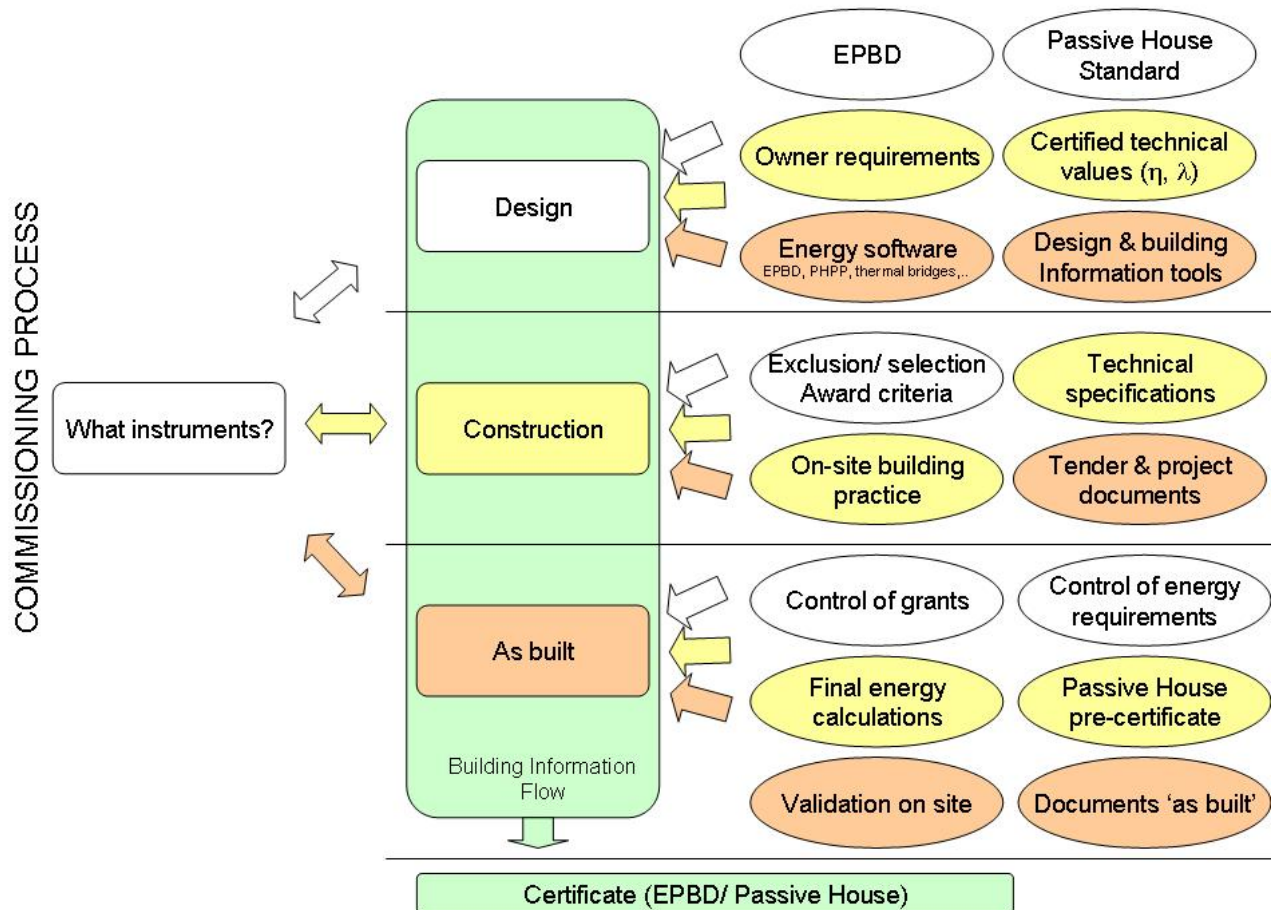


Figure 1 Situation of EPBD and the passive house in the commissioning process of buildings.

In the building permit stage, EPBD requirements in most countries require to report a specific official energy performance, i.e. a building energy rating (sometimes combined with an indoor climate rating). E.g. in Belgium, a specific EPB software has to be used to produce E levels and advisory reports for buildings requiring a building permit. These are produced by an accredited EPB reporter who is registered in a regional database of assessors. Many of these reporters are not very familiar with the details of the passive house concept.

When a passive house is built, the building owner or the certificate provider (architect, contractor) usually commissions an air tightness test (undertaken by an independent testing company). The building should achieve required air-tightness level as for the passive house standard. This test is usually performed when the building is wind and weather proof, and repeated on delivery of the building. Thermographic imaging is recommended in combination with the air tightness test, for indicating areas where thermal bridging or air leakage is occurring.

When building a passive house the required on-site practices and know-how to achieve high air-tightness, proper installation of insulation, windows, heat-recovery ventilation system, etc. are much more rigorous than typical on-site EPB related construction practices. Lack of equipment and know-how is sometimes perceived as a bottleneck. Therefore some countries are involved in developing specialized training for passive house contractors and project managers. Some education initiatives are associated with specific master degrees.

One can note that one the level of product and system energy performance additional certificates can be introduced. E.g. for passive house building systems and specific passive house technologies like triple glazing, high efficiency windows and doors, high efficiency heat recovery systems, and so on, specific certificates are provided in Germany by a list of experts. These certificates specify comfort (e.g. also acoustical quality) and energy related parameters of the product or system and thus complement information from more standard types of certificates.

When tests and final calculations are completed, the building owner can apply to an independent party, for a passive house project certificate. Many countries and regions have a range of financial stimuli for energy efficient investments in buildings, e.g. subsidies, tax reductions, attractive loans, etc. Typically for passive houses, a number of conditions have to be met to receive the benefits. In some cases a 'passive house certificate' by an independent expert is required to obtain the benefits. Certification usually means that these conditions have to be verified by a non-involved independent expert. The expert issues a verification based on standardized quality assurance procedures to a demanding party, usually the architect or the contractor, in some cases the owner. The receiving party perceives this 'certificate' as a guarantee of conformity. Note

that, if the client or inhabitant receives the certificate indirectly from the architect or contractor, the client's perception could include that a certain energy or environmental performance is guaranteed.

It should be noted that the use of the passive house concept usually also has implications after delivery of the building. E.g. many home owners are not familiar with the types of technologies and controls commonly used in passive houses. Special care needs to be taken by the contractor to ensure that the services provided are correctly specified, installed and commissioned and that the occupier is provided sufficient information to ensure correct operation and occupant satisfaction.

## **4. Passive house certification in some European regions**

### **4.1 Germany**

In Germany the passive house standard has seen a broad introduction in the mid nineties. Nowadays more than 6000 passive houses exist in Germany, also non residential buildings and renovations. In some cities like Frankfurt, Leipzig, Kreis Lippe, the passive house standard is required for the construction of buildings that belong to the municipality. Main economic driver for the construction of passive houses in Germany is the provision of a beneficial loan for the construction of low energy and passive houses by the German state bank KfW.

A certification system for passive houses and passive house suitable components was introduced in Germany in 1997 by the Passive House Institute Darmstadt. The certificate 'quality proofed passive house' confirms the 'as built' design of a building in accordance with the Passive House Planning Package. This so called PHPP software, issued by Passivhaus Institut Darmstadt (2008) is basically an excel software tool used for verification of the passive house standard. The limit values for passive houses according to PHPP are validated. It is assessed if the values for total energy demand, total primary energy and air tightness fulfil the passive house requirements (Elswijk et al. 2008, Beedel et al., 2007). PHPP was developed independently from German building legislation. The advantage is that calculation procedures and boundary conditions are not influenced by political considerations and special interests of stakeholders and fast integration of new research results is possible. These qualities are the reason that PHPP is a highly-estimated tool in Germany. Furthermore the official German building energy performance calculation procedure is included within PHPP to avoid extra work for planners. However, existing German norms (e.g. DIN EN 12831 for heat load calculations) are currently perceived as a barrier for certification. The Passive House Institute Darmstadt and selected partners now also provide certificates to companies for passive house technologies (glazing, frames, heat recovery systems, building systems, etc.). Certification of products facilitates finding and comparison regarding energetic qualities. In future the Passive House Institute also plans to certify building actors. A certificate for, and a listing of, passive house planners will make it easy to find a planner with substantiated knowledge regarding passive houses.

### **4.2 Belgium, Flanders Region**

In Belgium the passive house standard was introduced in 2002 by the non profit organization Passiefhuis-Platform. First project certificates were delivered in 2005, based on verification of calculations, using translation and climate adaptation of the German PHPP software as a basis. Special grants for passive house are given on a regional level and these are different in the Flemish, Walloon and Brussels Region. The cities of Turnhout, Bilzen and Mechelen also provide extra grants for passive houses. A federal tax reduction is offered for passive houses and a lowering of real estate tax is foreseen (Mlecnik, 2008). For most buildings requiring a building permit, official EPBD requirements are set for the energy performance and indoor climate at the same time. These requirements are different in the Flemish, Walloon and Brussels Region. In the Flemish Region the standard is called EPB and the reporting of is undertaken by trained reporters using required EPB software. In the Brussels and Walloon Region similar energy performance laws are under construction. The EPB software will serve as a basis for the production of building energy certificates. Problems arising with the use of this software for the evaluation of passive houses have been reported to the Flemish Energy Agency. A good coupling of the passive house concept with the EPB is still to be obtained and requires a substantial research effort. PHPP is used by passive house specialists and currently not accepted as an EPB calculation. Both calculations have to be performed. Certification based on PHPP calculation is currently performed by Passiefhuis-Platform vzw in the Flanders Region (alternatively by Plate-forme Maison Passive asbl) on a voluntary basis. The PHPP software serves as a basis. Federal tax reduction for passive houses refers to the necessity of demonstrating a passive house quality assurance form, provided by independent experts. The quality assurance form is currently granted based on verification of PHPP calculations and results of a building pressurization test to determine air tightness. In future, the quality assurance procedure will be extended to include summer comfort and air quality.

### **4.3 Austria**

In Austria the passive house standard is highly popular. In connection to the national policy the Programme of the Austrian Government for the period between 2007-2010 is to be cited, where the Austrian government mentions and defines the passive house standard for the first time. The Austrian pioneer federal state is Vorarlberg, where the federal government constituted at the beginning of 2007, that for new buildings of public housing associations passive house standard is obligatory. In 2008 the city of Wels signed a declaration to build all future municipal buildings in the passive house standard. In Austria nine different housing grant schemes exist, so verification can be different in different regions. The certification of passive houses in Austria basically happens by means of the Passive House Planning Package and/or the Austrian methodology according the guideline no. 6 of the Austrian Institute of Construction (ÖIB), when it comes to

housing grants. Since 2005 the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management supports the dissemination and implementation of minimum criteria concerning the energy performance and the ecological quality of new built residential buildings within its klima:aktiv haus program. Within the klima:aktiv haus programme criteria for so-called klima:aktiv passive houses were defined. They must be heat –bridges-free and airtight, their heat energy demand and their total primary energy demand must be verified by the PHPP, they must be equipped with energy efficient ventilation systems with heat recovery and water saving fittings. Further they must not be built of HFCH or PVC containing building materials and they must fulfill requirements concerning summer suitability. Some differences occur between the Austrian OIB methodology and PHPP, especially concerning surface definition. Very optimistic default values for internal heat gains and shading of the OIB methodology have been criticized, while PHPP shows good validation.

#### **4.4 Italy, South Tyrol**

In Northern Italy (South Tyrol) the certification programme KlimaHaus/CasaClima was introduced in 2002, before the European EPBD. First the certification was a voluntary measure. Due to the success of the first years and the new availability of specialized planners and craftsmen, since September 2004, the regional government requires a maximum space heating requirement of 70 kWh/m<sup>2</sup>.a for new buildings and the Klimahaus CasaClima certification can be used as documentation. The scheme will further be the implementation of the EPBD for the autonomous province of South Tyrol (Schmitt et al., 2007).

The core of the certification programme is the classification of better performance of buildings according to their space heating requirement. Klimahaus CasaClima now classifies buildings according to their annual space heat requirement in Gold:  $\leq 10$  kWh/m<sup>2</sup>a; A  $\leq 30$  kWh/m<sup>2</sup>a; B  $\leq 50$  kWh/m<sup>2</sup>a. All of them are considered as low energy buildings. Passive houses are considered to be in the KlimaHaus Gold category. The calculation code is less detailed, so that this criterion does not correspond exactly to the requisites for a passive house according to Passive House Institute Darmstadt. The certification programme is based on control of calculations. The 'Department for air and noise' of the Province conducts examinations on site and if indicated blower door test, both free of charge within the province. To underline the fact that not only energetic aspects are crucial for sustainable development, the option of having a building certified as 'CasaClima+' was established. This applies to those buildings where ecological aspects such as ecological construction materials and renewable energy sources for heating are used. (Schmitt et al., 2007)

#### **4.5 France**

The passive house concept was introduced in France in 2005 by different associations (La Maison Passive France, Minergie France, Plate-forme Maison Passive,...) and has received considerable attention in current legislation development. In France the Réglementation Thermique 2005 defines the limits for primary energy demand for heating, cooling and production of hot water. Several labels are currently being used to improve energy performance. The French label Effinergie (2008), the Swiss standard Minergie (2008) and the German passive house standard are used and they all define criteria concerning passive construction. The label 'Bâtiment Basse Consommation' (BBC)-Effinergie, developed by the society Effinergie, has been accepted as the official promotion label for low energy buildings ('bâtiment basse consommation énergétique BBC 2005', decided 8 May 2007, published 15 May 2007). It is given to buildings consuming a limited amount of primary energy, taking into account the demand for heating, sanitary hot water, auxiliary systems for hot water and ventilation (pumps), lighting and cooling. The value can vary from 50 to 70 kWh/m<sup>2</sup>a according to the climatic region (square meter gross floor area). Effinergie buildings also have to respect certain air tightness values, different for individual and collective housing.

Certification is done by four official certification institutes, specialized in different subsectors and recognized by the state. Certification includes technical verification of the project before construction, on site control, detection of errors and delivery of the label. Effinergie buildings can get specific loans. For passive houses also the Swiss Minergie-P and Minergie-ECO-P standards are used. Minergie-P fixes higher performance considering comfort, profitability and aesthetics. Energy consumption for heating, hot water, ventilation and cooling is limited to 30 kWh/m<sup>2</sup>a (square meter gross floor area). Passive house certification is issued by the association Minergie Switzerland or Minergie France and additionally includes advice to the architect and the client and a thermal check. For certification according to the German definition, the association La Maison Passive France is recognized by Passivhaus Institut Darmstadt.

#### **4.6 Emerging certifications**

There are many European countries that have no certified dwellings which meet the passive house standard or that have certified dwellings with a certification provided by another country. E.g. the first passive house in Ireland was certified by Passivhaus Institut Darmstadt. Most European countries have a number of designs at the planning or construction stage. Many architects, clients, insurers, manufacturers, regulators and specifiers state that third party certification and testing can be an accepted way of demonstrating conformance with standards and other requirements.

Also in the Netherlands, the passive house concept is more and more accepted as solid and feasible approach to achieve comfortable low energy buildings. There are no certified passive house projects in the Netherlands. A significant number of project initiatives, of up to 250 – 500 new passive houses is known to date, about 50 percent also in renovation. The association Passiefbouwen.nl is planning to issue a Passive House certification procedure for passive house buildings. The initial stage is to certify the completed project, based on project documentation, a PHPP calculation, and on site blower door test results and infrared images. In future stages also other steps in passive house development process could be certified. It is



anticipated that qualified independent assessors could fulfill the role, whereas the association Passiefbouwen.nl keeps oversight and supervises the process, and issues the certificates, called Passiefbouwenkeur. However, the association involved is no accredited certification institute and choice of certification experts is currently not transparent. Investigations take place to position Passiefbouwenkeur, either independent, or in relation to existing or future certificates for buildings. The proposed quality control process is expected to include new procedures, also for quality control during construction. The Dutch calculation method EPN (Energy Performance Standard, part of the Building Decree) is required to get building permit. Two calculations must be undertaken for a passive house project. A PHPP calculation does not replace an EPN calculation, even though a passive house stays well within the energy requirements currently required. (Beedel et al. 2007)

As a result of the project PEP (2008), many countries with emerging passive house development follow certification subject to the same requirements as in Germany, with some regional adaptations. E.g. in the UK the air tightness requirement is set less severe due to the milder climate. Some countries like the UK and Belgium tend to include confirmation of correct commissioning of the mechanical ventilation unit in future certification initiatives. Some countries also want to include other aspects of sustainable construction at the same time. E.g. in the UK consideration is currently being given to requiring the use of paints with less volatile organic compounds (VOC) for good indoor air quality. The passive house concept is also recognized as one route for achieving higher levels of codes for Sustainable Homes and building regulations. In many countries discrepancies exist between PHPP and EPBD calculations. (Mlecnik et al. 2008)

## 5. Conclusions

Quality assurance of passive houses, and associated technologies, has its origin in the verification and prediction of a restricted energy demand. Passive house project certification is not focused on issues like stability, safety, or more general environmental performance. Guaranteeing an energy performance is a new issue in building processes, requiring a shift in general thinking from means contracting to performance contracting. The urgency of the energy issue requires a swift implementation of (energy) performance contracting in the construction sector. In this paper passive house certification is regarded as an innovation in building processes to provide better building quality in general. Related to the introduction of passive house certification schemes the issue was raised how such initiatives can also upgrade knowledge in the construction sector.

Different European countries show a different embedding phase and related market penetration of passive houses and quality assurance of passive houses. Some countries like the UK, Ireland and the Netherlands are still starting up initiatives, while others like Germany, Austria, Switzerland, Belgium, France, and so on, provide a framework for grants and/or tax reductions and associated quality control procedures. In Western Europe the passive house standard is still a voluntary standard, while regions in Central Europe are already developing initiatives to include the passive house standard as a legal instrument and/or obligation for new constructions. Existing voluntary certification initiatives are different in different countries. Some harmonization between the different national initiatives might be interesting. Especially countries with no certification can already duplicate the most successful initiatives. Early adaptor countries have developed financial aid for passive houses, as well as a performance oriented quality approach for the design and construction process of passive houses. Control of quality of the design process, the construction process and the post construction inspection and testing of passive houses is considered as an essential feature, before stimulating the dissemination of information considering best practice demonstration projects.

Since the implementation of the European Directive 2002/91/EC and since the introduction of project related energy performance requirements and e.g. the passive house concept, problems about guaranteeing (energy) performances and information flow among building partners and quality control have become more significant. The EPBD and the passive house certification are being used to improve product and process modeling in commissioning for existing and new buildings as they are accompanied by a process of certification. EPBD calculation procedures are in many countries still not adapted to specific passive house technologies. This means that in many countries for passive house projects both PHPP and EPBD calculations have to be performed. The cost of an extra certification next to the legal energy performance certificate is considered to be a bottleneck.

As part of the process of demonstrating compliance with required energy performance, assessment of the energy performance of design of new dwellings is becoming mandatory in many countries and regions. For most buildings with a building permit, requirements are set for the energy performance as a consequence of the implementation of the EPBD, but also aspects of indoor climate and ecological criteria are sometimes introduced at the same time. It is generally perceived that a good energy requirement does not necessarily bring thermal comfort and good indoor air. Especially summer comfort can be a critical issue to be included in passive house certification as well as the proper working of balanced ventilation systems. In many cases the existing structures for energy performance evaluation, developed in the framework of the EPBD, are not sufficient to guarantee the quality and definition of the passive house.

PHPP software is mostly used as a basis for certification of passive houses. Its main advantage compared to other design and evaluation tools is that it has been specifically created as a design and certification tool for passive houses and that it regularly takes up new research results in its calculation procedures. Certification of passive houses usually also includes an air tightness test. In some cases, also the functioning of technical

systems and its effect on indoor climate is directly, or indirectly through evaluation by PHPP, considered. Some countries express the need to include, besides the PHPP calculations, comfort criteria (e.g. Belgium) or health criteria (e.g. UK, Austria). A differentiation in standard including low energy definitions, like in the Klimahaus CasaClima programme, can contribute to success of widespread certification.

In most advanced countries educational programmes for specific target groups were introduced, accompanying the introduction of certification systems. Experiences in Germany, Austria, Switzerland, Belgium and Italy illustrate that quality assurance of passive houses is necessarily related to the provision of passive house education initiatives. New fields like non-residential buildings and renovations require for the further development of more specific quality assurance procedures. It is not clear if the strict passive house definition can or should be maintained, especially since it is sometimes difficult to achieve for small houses or renovations. Also, PHPP calculation procedures in themselves are often not sufficient to evaluate the design of, for example, technical systems in office and school buildings.

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