Experiences from the first German EPBD implementations: - Field tests for residential and non-residential buildings - Certificates for well-known national and international buildings

H. Erhorn-Kluttig, H. Erhorn, K. Höttges, J. Kaiser
Fraunhofer Institute of Building Physics, Germany

ABSTRACT

In preparation of the implementation of the Energy Performance of Buildings Directive (EPBD) the responsible German Ministry has undertaken several actions including the development of a new energy performance calculation procedure for non-residential buildings (DIN V 18599) and two field tests for the certification of residential and non-residential buildings. This paper presents the main results of the evaluation of the field tests concerning the form and acceptance of the certificate, the necessary expertise of the issuers, the duration of the work, possible simplifications, etc.

The second half of the paper deals with experiences made at Fraunhofer Institute of Building Physics with issuing of national and international energy performance certificates for well-known buildings such as the Berlaymont building (Brussels), several German ministry buildings (Berlin), a high-performance office building in China (Shanghai) and two European schools (Brussels).

1. INTRODUCTION

The European Directive 2002/91/EC on the Energy Performance of Buildings (*EPBD*) (European Commission, 2002) demands that all member states of the EU include the following in their legislation on building by January 2006:

- a methodology for the calculation of the energy performance of buildings;
- the application of minimum requirements on the energy performance of new buildings, and of existing buildings that are subject to major renovation;
- energy certification of buildings
- regular inspection of boilers, air-conditioning systems and assessment of heating systems with boilers that are more than 15 years old.

In the case of Germany there was already a methodology for the calculation of the energy performance of buildings in use that satisfied the requirements for residential buildings. According to the *Energieeinsparverordnung* (Energy Saving Decree, German Government 2002/2004) the primary energy demand of buildings and installation systems for heating, ventilation and domestic hot water has to be determined with two German standards: DIN V 4108-6 and DIN V 4701-10 (DIN standard committee, 2000/2001). Also minimum requirements on the energy performance of new buildings and for major renovations at existing buildings have been applied since a long time, see Figure 1.

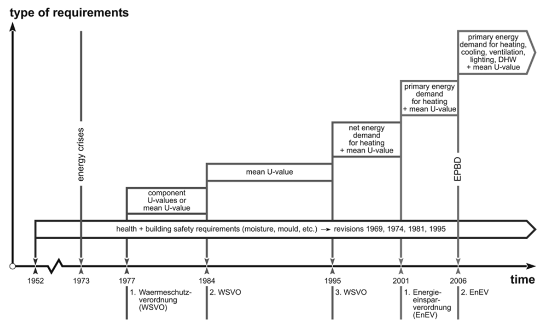


Figure 1. History of the minimum energy performance requirements in Germany.

However the energy performance assessment for non-residential buildings including the primary energy demand for heating, ventilation, domestic hot water plus for cooling and lighting was not possible with the existing calculation standards. Therefore the German government gave the mandate to the standard committee to develop a new calculation code which covers all the necessary energy parts, the new DIN V 18599 (DIN standard committee, 2005/2007).

Since also the issuing of energy performance certificates had not been realised in a big scale, especially not for the existing building stock, the Ministry of Transport, Buildings and Urban Affairs decided to initiate a field test for both, the residential buildings and the non-residential buildings.

2. FIELD TEST FOR RESIDENTIAL AND NON-RESIDENTIAL BUILDINGS

The German Energy Agency *dena* managed both field tests. The Fraunhofer Institute of Building Physics was a major contributor to the evaluation of the field tests.

2.1 Field test for residential buildings

In 2004 the first field test was started with the focus on residential buildings. Since the calculation method was already known since 2002 but has been used only for new buildings the attention was on the application of the method at existing buildings, on how the energy performance certificate should look like and if the procedure was accepted by different types of building owners. Additionally possible simplifications and default values for the input data of the calculation were tested.

More than 1000 buildings received an energy performance certificates based on both calculated energy demand and measured consumption. Additionally the issuers were asked to give tips for improving the energy performance of the building and to assess those in terms of reduced final and primary energy demand. The evaluation was based on the analysis of a database which was filled in by the issuers of the certificates, on interviews and questionnaires and on the results of workshops which discussed the experiences made during the field test. The database gave information on the building, the building owner, the issuer of the certificate, the software tool used for the calculation, the type of heating and ventilation system in the building, the age of the building and the installation systems, the results of the calculation (mean U-value, net heating energy demand, final energy demand for heating, ventilation and domestic hot water, primary energy demand, saved energy according to the energy saving tips, CO_2 emissions) and the measured energy consumption. A choice of calculations was analysed in detail in order to find out if the permissible simplifications do not deviate too much from the more detailed calculations.

The telephone interviews and questionnaires gave additional answers to questions such as the outlook of the energy performance certificate, the practicability of the process, the acceptance of the building owners and the time and money needed for issuing the certificates.

Figure 2 presents the two possible layouts for the energy performance certificates in the field test for residential buildings. Type A (left) is a classification into grades A to I, type B (right) is a so-called open scale (*Bandtacho*).

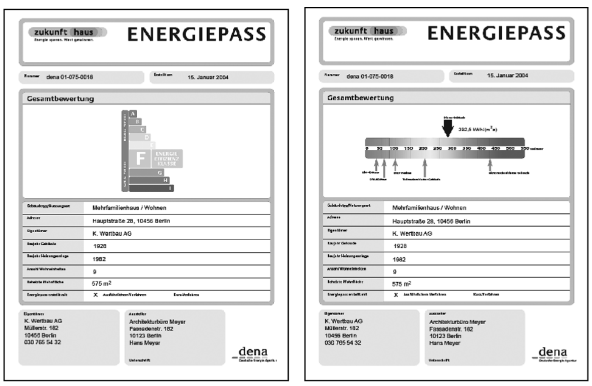


Figure 2. Two types of energy performance certificate layouts were possible in the field test for non-residential buildings.

The main results of the evaluation can be summarised as follows:

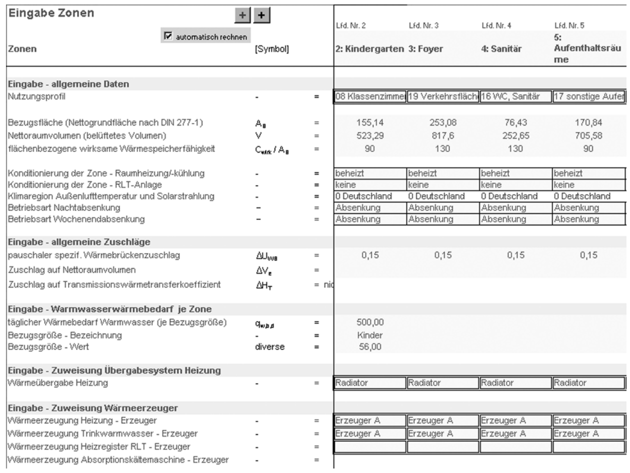
- the average primary energy demand for single-family houses was 305 kWh/m²a and for multi-family houses 206 kWh/m²a.
- most of the single family buildings had to be classified in class I (> 400 kWh/m²a primary energy demand) or in classes E and F (200 to 300 kWh/m²a). The multi-family houses were quite evenly distributed between class A and F (< 80 kWh/m²a up to 300 kWh/m²a).
- there is a clear link between the building age and the energy efficiency of the building.
- the consumption data often showed deficiencies, missing data, unclear or wrong units, implausible values, etc.
- the measured energy consumption and the calculated energy demand was partly significantly different. In 55 % of the buildings was the energy demand higher than the consumption. In 22 % of the buildings was the demand and the consumption within a range of +-20 kWh/m²a and in 23 % of the buildings was the energy demand lower than the consumption. The deviation is smaller in case of the multi-family houses.
- the main reason for the building owner to pay for the energy performance (*EP*) certificate was the desire to know about the energy status of the building.
- the issuers are very satisfied, the private building owners satisfied to very satisfied with the process of the energy certification. The housing associations however were more critical concerning the necessary time and the given explanations.
- part of the certificates were made in the frame of an energy consulting (financed by the Ministry of Economy and Technology). The other certificates cost between 200 and 500 €. This was for the very most of the building owners appropriate. More than 500 € was said to be too high.
- the certificate itself was rated as very good and reputable by the private building owners, a bit more critical by the housing associations, but still clearly positive.
- there was a free choice for the issuer between the label types (classes vs. open scale). 55 % of the buildings received EP certificates with classes, 45 % with the scale. However when asked, the building owners, independent if private owner or housing association, preferred the open scale.
- the terms such as primary energy, final energy etc. are satisfactorily explained for the building owners. There were additional information for experts included as well.
- the renovation tips were understandable yet mostly not new and not detailed enough. 15 % of the tips have been realised already. 40 % of the private owners said that the certificate either caused the renovation or made them realise the renovation earlier. The housing association voted by 50 % that the certificate did not influence the decision on the building renovation.

- the question regarding the change in the market value of the building was answered positively by the private owners and negatively by the housing associations.
- the EPBD is welcomed by 60 % of the private owners, but only by 40 % of the housing associations.
- the EP certificate was not forwarded to the tenants. As reason were given: no interest at the tenants, certificate too complicated, fear of questions and necessary efforts, fear of demands for renovation, difference between calculated demand and measured consumption.
- the issuers were mostly civil engineers (38 %) and architects (28 %). The remaining 34 % are craftsmen with a further education as building energy consultants.
- the proposed prices of 150 € (single family house) and 250 € (multi-family house) was regarded as not cost-covering. The issuer proposed 250 to 600 € for single-family houses and 350 to 1000 € for multi-family houses. However they expect a better cost-covering when issuing additional EP certificates.
- the comparison between the simplified and the detailed calculation method showed some serious differences in the results, which led to the following recommendations for the ministry:
- simplifications shall not lead to better results. If areas or components are not considered this has to be balanced by supplements at the losses.
- the supplements shall be made at the respective energy balance parts (transmission, ventilation, solar gains), not at the net heating energy demand.
- if components are not calculated due to the simplifications, then they are often not considered in the renovation tips as well.
- detailed recommendations for the possible simplifications have been made.
- the default U-values based on the building age in the guideline have to be improved and completed.

2.2 Field test for non-residential buildings

The German field test for the non-residential buildings was started in 2005. Here the focus was on the application of the new developed calculation standard DIN V 18599. The standard is based on an holistic approach that includes the interference between building and systems. In order to cover all energy demands (heating, cooling, ventilation, hot water and lighting) the new standard has become a comprehensive tool that can be used for the assessment of nearly all possible installation systems. It is based on the division of the building into usage zones.

In contrast to the residential test there was yet no commercial calculation software available for the use of the issuers. The reason is that the standard was only ready shortly before. Therefore the Fraunhofer Institute of Building Physics developed an excel-based calculation tool (Höttges, Weiss, Erhorn, 2005) that was used by all issuers.



Eingabe Zonen			Lfd. Nr. 2	Lfd. Nr. 3	Lfd. Nr. 4	Lfd. Nr. 5
automatisch rechnen						
Zonen	[Symbol]		2: Kindergarten	3: Foyer	4: Sanitär	5: Aufenthaltsräume
Eingabe - allgemeine Daten						
Nutzungsprofil	-	=	08 Klassenzimme	19 Verkehrsfläch	16 WC, Sanitär	17 sonstige Aufer
Bezugsfläche (Nettogrundfläche nach DIN 277-1)	A_B	=	155,14	253,08	76,43	170,84
Nettoraumvolumen (belüftetes Volumen)	V	=	523,29	817,6	252,65	705,58
flächenbezogene wirksame Wärmespeicherfähigkeit	C_{wirk} / A_B	=	90	130	130	90
Konditionierung der Zone - Raumheizung/-kühlung	-	=	beheizt	beheizt	beheizt	beheizt
Konditionierung der Zone - RLT-Anlage	-	=	keine	keine	keine	keine
Klimaregion Außenlufttemperatur und Solarstrahlung	-	=	0 Deutschland	0 Deutschland	0 Deutschland	0 Deutschland
Betriebsart Nachtabsenkung	–	=	Absenkung	Absenkung	Absenkung	Absenkung
Betriebsart Wochenendabsenkung	–	=	Absenkung	Absenkung	Absenkung	Absenkung
Eingabe - allgemeine Zuschläge						
pauschaler spezif. Wärmebrückenzuschlag	ΔU_{WB}	=	0,15	0,15	0,15	0,15
Zuschlag auf Nettoraumvolumen	ΔV_e	=				
Zuschlag auf Transmissionswärmetransferkoeffizient	ΔH_T	= nic				
Eingabe - Warmwasserwärmebedarf je Zone						
täglicher Wärmebedarf Warmwasser (je Bezugsgröße)	$q_{w,b,d}$	=	500,00			
Bezugsgröße - Bezeichnung	-	=	Kinder			
Bezugsgröße - Wert	diverse	=	56,00			
Eingabe - Zuweisung Übergabesystem Heizung						
Wärmeübergabe Heizung	-	=	Radiator	Radiator	Radiator	Radiator
Eingabe - Zuweisung Wärmeerzeuger						
Wärmeerzeugung Heizung - Erzeuger	-	=	Erzeuger A	Erzeuger A	Erzeuger A	Erzeuger A
Wärmeerzeugung Trinkwarmwasser - Erzeuger	-	=	Erzeuger A	Erzeuger A	Erzeuger A	Erzeuger A
Wärmeerzeugung Heizregister RLT - Erzeuger	-	=				
Wärmeerzeugung Absorptionskältemaschine - Erzeuger	-	=				

Figure 3. Screenshot of the Excel tool used by all issuers in the field test for non-residential buildings.

In between the two field studies, the German Building Ministry made decisions on the layout of the now seven-page energy performance certificate, one of them being to use the open scale instead of the classes. The ministry also provided three guidelines for the calculation of the energy performance, the normalisation of the measured data and the building inspection. The calculated primary demand and mean U-value and the measured energy consumption has to be opposed to building type specific comparison values. A reference building is used for the DIN V 18599 calculation and an average of various buildings for the measured data. The questions that had to be analysed covered the four parts: technical bases (standard DIN V 18599), data acquisition, EP certificate, market acceptance. The test was run at 39 buildings with different usage (public and private office buildings, town halls, libraries, museums, schools, research buildings, hotels, youth centres, sports halls, event buildings, community centres, hospitals and nursery homes and a fire department). All but three were categorised as existing buildings, the others were built 2004 or later. The main results of the evaluation are as follows:

Analysis of the EP certificates and calculations:

- the calculated primary energy demand was between 72,2 and 1100,5 kWh/m²a with about 2/3 of the buildings between 100 and 300 kWh/m²a. Compared to the requirements according the new energy decree EnEV (*Energieeinsparverordnung,* Ministry of Transport, Buildings and Urban Affairs, 2005/2007) had 55 % of the buildings a lower demand than allowed and about 1/3 a higher demand than allowed. The remaining buildings had EP values very close to the requirements. Compared to the residential study there was more compliance

between the calculated value and the required value.
- the average energy balance parts at the final energy was: heating 175 kWh/m²a, hot water 25 kWh/m²a, lighting 21 kWh/m²a, ventilation 11 kWh/m²a and cooling 8 kWh/m²a. When using the primary energy demand as criteria: heating 164 kWh/m²a, hot water 30 kWh/m²a, lighting 57 kWh/m²a, ventilation 29 kWh/m²a and cooling 21 kWh/m²a. The reason for the differences are of course the primary energy factors used in Germany and the different fuel types used in the buildings.
- the issuers have chosen to use between 3 and 12 zones, with 8 zones being the average. Here a better guideline is necessary since regular offices should be applicable with about 5 zones.
- the measured heating energy consumptions were between 39,6 and 364,5 kWh/m²a. The comparison value based on many buildings of the same type was for 1/3 of the buildings lower, for 1/3 higher and for 1/3 at about the same dimension. The mean deviation was less than 10 %.
- the comparison between the calculated final energy demand for heating and the measured heating consumption showed an in average 20 % higher value of the calculated demand. The differences were partly higher than 100 kWh/m²a and were to both sides.
- the calculated primary energy reduction due to the renovation tips was between 4,4 and 74 % with the average being 35 %.
- the scale for the primary energy demand of the buildings running from green to red was quite evenly distributed. The scale for the measured heating energy consumption was concentrated in the yellow area, whereas the scale for the measured electricity consumption showed 14 buildings in the red area. However there was an accordance of 40 % of the buildings at the colour of the scales concerning demand and consumption. A stricter definition of the scale range was recommended.
Analysis of the questionnaires for the issuers:
- 50 % of the issuers welcomed the detailed calculation method, the other half proposed simplifications especially for existing buildings.
- an appendix to the standard with fixed system configurations and additional user profiles was suggested.
- all but one issuer have used the simplifications out of the building inspection guideline and ¾ of them judged them as practicable.
- the analysis of the consumption data (different metres, different time phases) proved to be difficult for 44 % of the issuers. The comparison values for the measured consumption have to be extended and partly improved.
- the excel tool was assessed to be very helpful, however 60 % of the issuers plan to change to commercial tools when available.
- the necessary time for the different parts of work was in average as follows:
- intake interview: 4,9 hours
- building inspection (measured consumption): 6 hours
- building inspection (calculated demand): 44,5 hours
- calculation for measured consumption (normalisation): 15,7 hours
- calculation of primary energy demand (DIN V 18599): 63,8 hours
- handover of EP certificate and explanations to the building owner: 4,7 hours
- the issuers expect an average of 25 % reduction of their efforts, when issuing additional certificates.
The building owners were also interviewed and based on the results of all analyses several recommendations for the further development of the process were made.

3. CERTIFICATES FOR WELL-KNOWN NATIONAL AND INTERNATIONAL BUILDINGS

The Fraunhofer Institute of Building Physics issued various national and international EP certificates. The following list gives an overview on the buildings concerned:
- Berlaymont building, Brussels (head office of the European Commission), 2005
- two office buildings for a insurance company in Munich, 2005
- community centre of the protestant church in Stuttgart-Sonnenberg, 2005
- townhall in Essen, 2005
- Financial Ministry of Rheinland-Pfalz, Mainz, 2005
- an office building and a multi-functional building owned by a construction company in Eschweiler and Erfurt 2005/2006
- Federal Ministry of the Environment, Nature Conservation and Nuclear Safety in Berlin, 2006, (two buildings)
- 2 European schools in Brussels, 2006
- Pujang office building in Shanghai, China, 2006
- Federal Ministry of Transport, Buildings and Urban Affairs in Berlin, 2006
- a school in Karlsruhe and the townhall in Möckmühl for an energy industry company, 2007
- the Fraunhofer Gesellschaft head quarter in Munich *„Fraunhofer-Haus"*, 2007

End of 2004 Fraunhofer-IBP was first to apply the German standard DIN V 18599 at a real building. As German representative in the European project for issuing energy performance certificates for the Berlaymont Building in Brussels, first experiences with the building data input, the calculation and the production of an EP certificate in comparison with other countries have been made. Besides Germany only 5 nations were at that time ready to use the new standards and tools for the EPBD implementation. The idea of the project was not to check for conformity of the different certificates and calculation methods, but to show that at that time already some countries were ready. Additionally they wanted to present how an EP certificate can look like. The certificates were handed over at a press event and are now presented inside the building. The European Commission has written a summary report on the project (European Commission, 2005). In all EP certificates the building was assessed at least as comparable to a new building of the same type, see Figure 4.

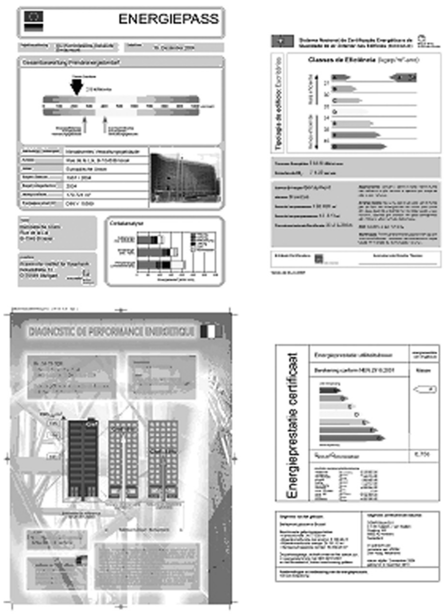


Figure 4. EP certificates for the Berlaymont building from Germany, Portugal, France and the Netherlands.

The next big step was the issuing of an EP certificate for the first community centre with a church in Europe in 2005. The project included a detailed inspection of the building, the certificates for both calculated demand and measured consumption and an energy and cost-related assessment of possible renovation measures. In 2006 the church decided to realise some of the measures eg. a wood pellet burner. The calculated primary energy savings because of the renovation are 180 kWh/m²a, see Figure 5.

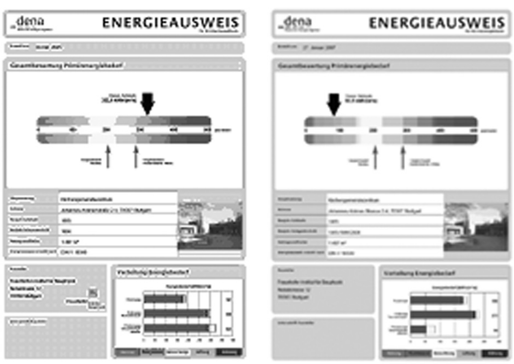


Figure 5. EP certificate for the community centre in Stuttgart before and after the renovation measures.

In 2006 Fraunhofer-IBP was asked to issue EP certificates for three international buildings. For the event at the announcement of the EU Action Plan for Energy Efficiency the Commission chose the German certificate as the most detailed one to be applied at two European schools in Brussels. Since the method is internationally applicable the German Building Minister Tiefensee handed over an EP certificate for a high performance office building in Shanghai during his China visit, see Figure 6.

Figure 6. Press event with EU Commissioner Piebalgs at the hand-over of the EP certificate for the schools in Brussels (left) and EP certificate for the office building in Shanghai (right).

REFERENCES

European Commission (2002). *Directive 2002/91/EC*. www.buildingsplatform.org

German Government (2002/2004/2005/2007). *Energieeinsparverordnung (EnEV)*. www.beuth.de

DIN standard committee (2000/2001/2005/2007). *DIN V 4108-6, DIN V 4701-10, DIN V 18599*.www.beuth.de

Höttges, K., Weiss, N., Erhorn, H. (2005). *Excel-Berechnungsblatt zur DIN V 18599*. www.ibp.fhg.de/wt

European Commission (2005). *Energy Certification of Berlaymont. Summary Report on Project Results*. www.ibp.fhg.de/wt/berichte/2004/final_report.pdf