BUDOWNICTWO
CZASOPISMO TECHNICZNE
TECHNICAL TRANSACTIONS
CIVIL ENGINEERING
WYDAWNICTWO POLITECHNIKI KRAKOWSKIEJ
2-B/2012
ZESZYT 3
ROK 109
ISSUE 3
YEAR 109

TOBIAS SCHÖNER*

A COMPARISON OF WUFI®PLUS WITH THE PHPP

PORÓWNANIE NARZĘDZIA WUFI®PLUS Z PAKIETEM PHPP

A b s t r a c t

The building sector is affected by the global rise of energy demand. Because of this, energy efficient techniques become more and more important. There is a possibility of relating the costs to energy efficiency, especially in new buildings. One of the most comprehensive approaches in this case is the Passive House concept. The distribution of these highly energy efficient buildings increased from the first demonstration houses in 1991 to around 3,500 housing units in 2004 [1]. The Passive House Planning Package (PHPP) is commonly used in design. Through the increasing distribution outside Central Europe, additional requirements, e.g. moisture protection or thermal comfort, are becoming more and more important. Transient building simulation could provide possible solutions. It is assumed that monthly energy fluxes are comparable.

Keywords: Passive House, WUFI®Plus, PHPP

S t r e s z c z e n i e

Globalne zwiększenie zapotrzebowania na energię wywiera wpływ na sektor budowlany. Z tego powodu coraz większego znaczenia nabierają technologie energooszczędne. Istnieje możliwość dostosowywania kosztów do potrzeb energooszczędności, szczególnie w nowych budynkach. Największe możliwości daje w tym przypadku koncepcja domu pasywnego. Liczba budynków o wysokiej wydajności energetycznej wzrosła od pierwszych domów pokazowych w 1991 r. do ok. 3500 jednostek mieszkalnych w roku 2004 [1]. W dziedzinie projektowania powszechnie wykorzystuje się planistyczny pakiet domu pasywnego (Passive House Planning Package – PHPP). W obliczu wzmożonego zainteresowania obserwowanego poza krajami Europy Środkowej coraz ważniejsze stają się dodatkowe wymagania, np. ochrona przed wilgocią lub komfort cieplny. Rozwiązań dostarczyć może przejściowa symulacja budowlana. Zakłada się porównywalność miesięcznych przepływów energii.

Słowa kluczowe: dom pasywny, WUFI®Plus, PHPP

* Eng. Tobias Schöner, Fraunhofer-Institute for Building Physics (IBP) Holzkirchen Branch, University of Applied Sciences, Rosenheim.

1. Introduction

A significant part of global energy consumption is caused by households. In Germany, the domestic consumption accounted for 27% of the total energy use [2].

Energy efficient building standards can help to reduce this consumption. In Germany, an existing building consumes 220 kWh/m^{2}year for heating only [1]. In comparison, a house built in 2002 requires only 70 kWh/m^{2}year for heating [1]. The certification criteria for a Passive House (PH) are much lower with 15 kWh/m^{2}year. This illustrates how the use of energy efficient technologies can significantly undercut the current state of standardization.

The Passive House concept was developed in the mid-1980s from a low-energy standard for new buildings in the Nordic countries [3]. The concept is based on the following principles: excellent thermal protection, the avoidance of thermal bridges, the air-tightness of a building envelope, heat-resistant glass and a controlled ventilation system [3]. Heating should be provided via the already necessary ventilation system. By building without a separate heating system and distribution investment, the costs will be reduced so the additional financial burden is limited.

2. The methodology

For the design of such a building, the PHPP from the Passive House Institute (PHI) is used [4]. The PHPP uses Excel© as its program base and calculates the annual heating demand by monthly heat balances. In this method, the internal and solar heat gains are subtracted from the heat losses. The required heating power in the PHPP is calculated by (1) from [4].

$$Q_H = (Q_T + Q_V) - (Q_S + Q_1) \cdot \eta \quad (1)$$

where:
Q_H – heating demand [kWh/a]
Q_T – transmission heat losses [kWh/a]
Q_V – ventilation heat losses [kWh/a]
Q_S – solar heat gains [kWh/a]
Q_I – internal heat gains [kWh/a]
η – utilization factor

The period under review in the PHPP depends on the monthly difference between the heat losses and the heat gains. If this difference is greater than 0.1 kWh, the month will be considered. This means that the period under observation can vary between the different cases.

For an estimation of the annual heating demand, the monthly method is adequate. It is assumedly validated before with a calibration simulation [4]. If there is monitoring as in [5], it is shown that the user's behaviour has a strong impact on the validity of the results. A stronger temporal discretisation than a monthly one could provide more realistic results by taking the user's behaviour into account. It can also improve the assessment of thermal comfort and mould growth prediction. For other climate zones than Northern and Central European ones, these effects can be important. A higher degree of discretisation could be reached by using transient building simulation software. Because of the considered seasonal heat storage effects, transient building simulation programs could provide more realistic results than monthly balanced methods.

For cases like this, the Fraunhofer-Institute for Building Physics (IBP) developed hygrothermal building simulation tool WUFI®Plus [6]. WUFI®Plus combines the hygrothermal component calculation with a building simulation [6]. The requirement for a direct comparison of these two programs is that the results in the monthly balanced method could be reproduced with WUFI®Plus.

To verify this, a small black box, as shown in Fig. 1, was calculated in both programs. In the first step, each of the four heat fluxes was considered in detail. In the next step, the annual heating demand is compared between the programs. For this comparison, the original PHPP calculation of the heating demand was replaced step by step by interim results from WUFI®Plus.

This approach was chosen to detect deviations between the two programs at an early stage. The individual factors under consideration were: the decimal places, the specific heat capacity of air, the heat flow calculation, and the calculation of the annual heating demand.

This means that in the first step the PHPP calculation was repeated with the input data from WUFI®Plus. The result of this calculation was set into relation to the original PHPP calculation and illustrates the influence of the input data.

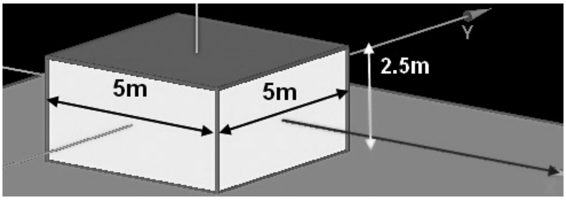

Fig. 1. Simulation black box

Rys. 1. Czarna skrzynka symulacyjna

2.1. The practical limit of error

For the following evaluation of the results, it is important to define an interval of acceptance of the deviations. For this work, the +/-0.1K criterion, based on [7], is used. It is assumed that temperatures can be recorded with a measurement accuracy of 0.1K [7]. This means a fluctuation of the heating degree hours by +/-0.876 kKh in the PHPP calculation for a whole year.

2.2. The climate

In order to create the same initial conditions for both calculations, it is necessary to adjust the climate in the two programs. The measured values were exported from the climate databases METEONORM. This approach makes it possible to have a look at arbitrary climates. It means that the basic data set is a hourly weather data set for WUFI®Plus which is reduced by monthly averaging/summing to provide a data set for the PHPP. For the following example, the climate of Hohenpeissenberg was chosen.

Furthermore, it should be noted that the calculation of solar radiation on vertically oriented surfaces is different for both programs. For an accurate comparison of WUFI®Plus with the PHPP, it is necessary to exclude seasonal heat storage effects in the components. By keeping a constant indoor temperature of 20°C, these effects can be reduced.

3. The comparison

In the following chapters, the individual heat flows will be directly compared between the two programs.

3.1. Transmission

One of the biggest heat losses even in well-insulated buildings is the transmission heat loss through the surrounding opaque components. The heat flow is the product of the component surface (A), the heat transfer coefficient (α) and the difference between ambient (θ_a) and surface temperature (θ_s) [8], as you can see in (2).

$$q = A \cdot \alpha \cdot (\vartheta_a - \vartheta_s) \tag{2}$$

where:
q – heat flow density [W/m²]
A – component surface [m²]
α – heat transfer coefficient [W/m²K]
ϑ_a – *a*mbient temperature [°C]
ϑ_s – surface temperature [°C]

In Table 1, the transmission losses in WUFI®Plus are compared with the losses in the PHPP.

Table 1

Transmission losses in WUFI®Plus and PHPP

	WUFI®Plus [kWh/a]	PHPP [kWh/a]	deviation
exterior wall	573.2	573.3	-0.02%
bottom plate	235.4	235.7	-0.13%
flat roof	287.3	286.0	0.46%
total	1,096	1,095	0.08%

3.2. Ventilation

For Central Europe, the second largest heat flow is the heat loss through ventilation. In order to create the same conditions, the effective air change rate from the PHPP was also used in the WUFI®Plus simulation. The ventilation heat flow for both programs is shown for different air change rates in Fig. 2.

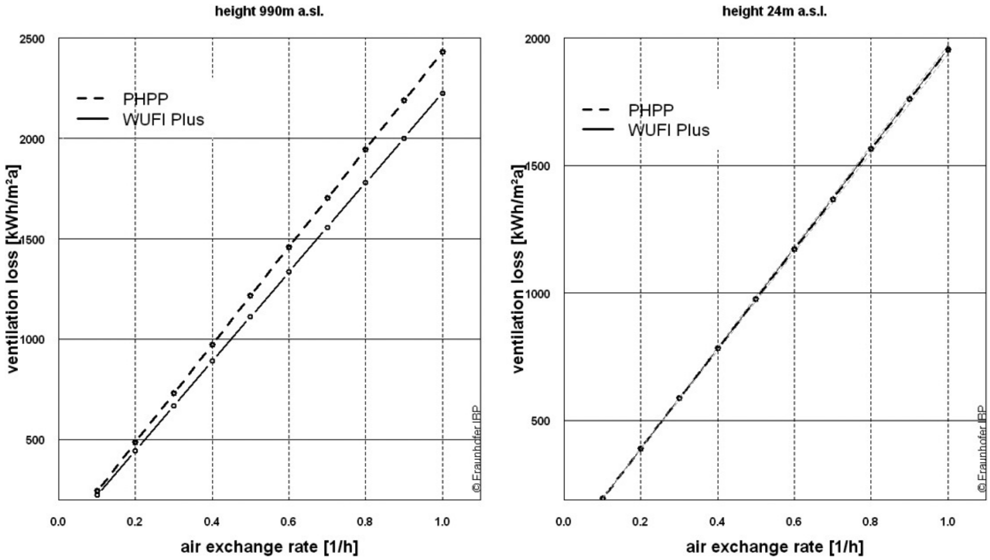

Fig. 2. Ventilation losses depending on air exchange rate and height above sea level

Rys. 2. Straty wentylacyjne zależne od wskaźnika zmiany powietrza i wysokości n.p.m.

The chosen weather data file for Hohenpeissenberg relates to a location 990 m above sea level. The WUFI®Plus findings for that location are 8% lower than the PHPP ones. In comparison, another case near sea level – in Bremen – was used. It is shown that both programs produce equal ventilation losses without height differences to sea level.

3.3. Solar gains (through windows)

In the case of solar heat gains, it is necessary to differentiate between gains from the absorption of the short wave radiation of opaque partitions and solar gains through windows. Solar gains through windows are considered in the following chapter.

In both programs, a horizontally oriented window was used with a solar heat gain coefficient (SHGC) of 0.7. Solar radiation on vertically oriented surfaces is different in both programs because of the applied calculation method.

If additional shading is taken into account, solar gains for both programs are shown in Fig. 3.

The chart clearly shows that WUFI®Plus calculates solar gains in a linear way. The PHPP graph shows a partially defined function. If the calculation period is the same in both programs, the graphs are equal. The graph “floating heating period” refers to the period under review. For this graph, the period under observation was the whole year. During the year, the solar gains were only considered if there was heating demand at the same time. This simulation case focused on alternative ways of calculating solar gains. This proceeding is only possible in WUFI®Plus and not assignable to the PHPP calculation.

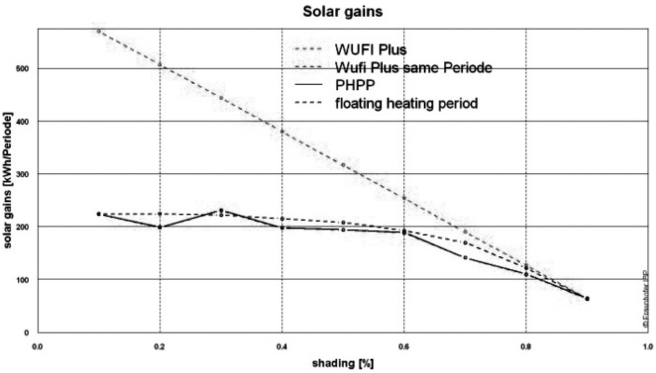

Fig. 3. Solar gains depending on the shading percentage

Rys. 3. Zyski energii słonecznej zależne od stopnia zacienienia

3.4. Internal gains

The second part of heat gains include s internal gains. For example, internal heat gains are people or electrical equipment located within the building envelope.

The internal gains are calculated as the product of heating days, the internal heat load and the treated floor area [4]. If the borderline conditions are the same, the findings should be in good accordance, too. If the period under observation is equal in both programs, the results are also suitable.

3.5. Annual heating demand

As shown in equation (1), the annual heating demand in the PHPP is the difference between the heat losses and the heat gains. The utilization factor in (1) reflects how well the occurrence of the solar gains matches the occurrence of heating demand. For the cases considered so far, this factor was around 1. A variation between the programs on the basis of this factor is not expected for these cases.

All the calculated heat flows lead to the calculation of the annual heating demand. Therefore, the main focus is now on the evaluation of the annual heating demand. The computation was done as described in Chapter 2. The findings are shown in Table 2.

Table 2

Annual heating demand

<table>
<tr><th>PHPP origin</th><th>Decimal places</th><th>Heat capacity</th><th>Heat Flow</th><th>Heating Power</th><th colspan="2">Reliance based on column 3</th></tr>
<tr><td rowspan="2">658.7</td><td rowspan="2">658.3</td><td rowspan="2">640.5</td><td rowspan="2">637.4</td><td rowspan="2">637.0</td><td>+ 0.1K</td><td>648.7</td></tr>
<tr><td>- 0.1K</td><td>623.4</td></tr>
</table>

From the left to the right, the influence of decimal places, the specific heat capacity of air, heat flow calculation and heating demand calculation is presented.

4. Discussion

In Section 3.1, it became clear that transmission heat flows in WUFI®Plus and in the PHPP are comparable under the assumption of simplified borderline conditions. For all the components, the differences between the two programs are well within the reliance interval. The remaining differences are due to rounding errors. These results are only possible because of the largely excluded heat storage effects. If these issues are included, the component heat flows are no longer comparable between both programs.

On the other hand, the ventilation loss in Chapter 3.2 indicates a clear difference between both programs. It depends on the altitude of the weather station from which delivers the data. The PHPP uses a constant value for the specific heat capacity of air but WUFI®Plus calculates it individually depending on the height above sea level. As Fig. 2 shows for the case near sea level, both programs agree very well. For subsequent comparison, this means that the programs provide identical results only for climates which are close to sea level. For all other locations, the specific heat capacity must be adjusted manually.

The trend of the PHPP graph in Fig. 3 shows some special effects, e.g. if the shading rises from 20% to 30%, the solar gains increase, too. This effect is due to the longer period used for the assessment of heating demand. It means that, with increased shading, heating is required for a longer period of time. For this longer period, the solar gains are assessed. Therefore, the strange result is an increased solar gain by more intensive shading. With the simulation variation “floating heating period”, it was possible to smooth this peaks. Apart from that, both tools agree well.

When it comes to the internal gains, the expectation is that if the borderline conditions are the same, the heat flows are also in good accordance. If the calculation period is the same, the heat flow matches an average deviation of 0.01%.

In the closing part, this paper concentrates on the calculation of heating demand. The findings are summarized in Table 2. The allowed number of the decimal spaces of the input data is different in WUFI®Plus and the PHPP. Table 2 proves that this fact has a weak impact on the result. The strongest effect is due to the fact that one tool takes height depending on specific heat capacity changes of the air into account, whereas the other does not. In this case, the deviation is clearly outside the reliance of the original PHPP calculation.

It should be noted that for cases with solar gains through vertically oriented components, additional deviations – due to the different calculation of solar radiation – are expected.

For the final simulations, the adjusted ventilation loss calculated with WUFI®Plus was used for the PHPP computation. In Table 2, it can be seen that for cases with exchanged heat flow and annual heating demand, the practical limit of error is not exceeded.

5. Conclusions

The previous chapters show that it is possible to compare the building simulation with WUFI®Plus with the monthly balance based method of the PHPP. This was conducted on a simplified model in a step-by-step approach. For this "black box", both individual heat flows and heating demand can be replicated with high accuracy. In addition to the meticulous matching of the component data, it is necessary to use the same climatic data as the base for both tools. In order to make the results generally acceptable, the calculation of specific heat capacity and global radiation on vertically oriented surfaces has to be equal. Comparisons of thermal bridge effects, solar absorption, the HVAC systems and overheating in summer were not included in this assessment.

The next step must be the assignment of the findings from the black box to a real building. Further differences, due to transient heat storage effects and hygrothermal effects, need to be assessed.

It is expected that apart from a simplified black box model, transient simulation software like WUFI®Plus is able to provide a much more comprehensive insight for complex buildings. An integral analysis of measures to increase energy performance considering comfort as well as the aspects of moisture-related damages is only possible with the use of a hygrothermal whole building simulation.

This comparison was part of a Master's Thesis at the University of Applied Sciences in Rosenheim, Germany. The author thanks his supervisors: Prof. Dr. Elmar Junker, Prof. Dr. Harald Krause and M. Eng. Florian Antretter for supporting this work.

References

[1] Schnieders J., Hermelink A., *CEPHEUS results: measurments and occupants satisfaction provide evidence for Passive House being an option for sustainable building*, Energy Policy, 2004.

[2] Bayer W., *Energie auf einen Blick*, Statistisches Bundesamt Wiesbaden, 2009.

[3] Feist W., *15 jähriges Jubiläum für das Passivhaus Darmstadt-Kranichstein*, PHI Darmstadt, 2006.

[4] Feist W. et.al., *PHPP Handbook*, PHI Darmstadt, 2007.

[5] Søren P. et.al., *Messtechnische Untersuchung und Auswertung Klimaneutrale Passivhaussiiedlung Hannover-Kronsberg*, Stadtwerke Hannover, 2001.

[6] Andreas H., *Raumklima-Simulation-Methoden*, Validierung, Anwendung, Zeitschrift für Wärme-Kälte-Schall und Brandschutz, 2006.

[7] Feist W., *Passivhäuser in Mitteleuropa*, Dissertation Universität Kassel, 1992.

[8] Hartwig K., *Verfahren zur ein- und zweidimensionalen Berechnung des gekoppelten Wärme- und Feuchtetransports in Bauteilen mit einfachen Kennwerten*, Dissertation Universität Stuttgart, 1994.