DESIGN SUPPORT TOOL FOR LOW-ENERGY DWELLINGS: IDENTIFYING EARLY DESIGN DEFAULT VALUES THROUGH A PARAMETRIC STUDY

Lieve Weytjens[1,2], Griet Verbeeck[1,2], and Liesbeth Staepels[1,2]
[1]Faculty of Architecture and Arts, Hasselt University, Diepenbeek, Belgium
[2]PHL University College, Diepenbeek, Belgium
Contact information: lieve.weytjens@phl.be; griet.verbeeck@phl.be

ABSTRACT

Architects are increasingly challenged to design low-energy buildings. Considering the importance of early decisions for the final building performance, early design support for architects is necessary. A research project has been established to develop a design tool, supporting architects in the decision-making process of low-energy single-family dwellings. This paper focuses on adapting the required data-input for the tool to the limited available input of early design phases, while providing valuable feedback. A parametric study is conducted, examining the impact of design parameters on the energy performance of dwellings and defining adequate default values. The validity of the default values is demonstrated in case studies.

INTRODUCTION

Since 2006 the European EPBD has been implemented in the Region of Flanders, Belgium through the EPB legislation. This legislation enforces an energy performance level (E-level) and insulation level (K-level). The EPB software, a steady-state monthly based one zone simulation program, allows architects to calculate compliance with these regulations and to evaluate the energy performance and summer comfort of their building designs. Although Flemish architects become increasingly familiar with this software, research has demonstrated that it is mainly used in detailed design phases to check code compliance. At that moment, major decisions with impact on energy performance are fixed. Also, considering the recast of the EPBD requiring all new buildings to be near-zero energy by 2021 (EPBD, 2010), early design support becomes very important.

In this regard, a design tool is under development, facilitating the integration of energy efficiency in early design phases (EDP) and supporting design decision-making for single-family houses in Flanders. This particular research focus is related to the typical Flemish context, which is dominated by small-scale residential buildings for private clients and prevailing small sized architectural firms.

The research explores the extent to which the detailed input of EPB can be reduced and adapted to the available information of EDP, while maintaining reliable results. Hence, one of the main issues relates to identifying adequate default values for unknown design parameters in EDP. This requires profound insight into the impact of the different parameters in the EPB-model.

In the past, the impact of architectural parameters on the energy performance has been internationally investigated for distinct energy performance indicators (e.g. Capozzoli et al., 2009; Depecker et al., 2001; Kim & Moon, 2009; Pessenlehner et al., 2003). However, the results of these studies cannot be simply transferred to the current design tool, since they are not specifically directed towards the Flemish E- and K-level, they are often conducted for other climate types, and/or they employ different calculation models. In this context, an extensive parametric study was conducted on the Flemish EPB-model, assessing the impact of various architectural parameters on the energy performance of dwellings. The results demonstrate key design parameters and provide information to match the required data-input of the design tool to EDP, through default values. The validity of the default values is studied in several case studies.

First, the paper provides a brief description of the EPB model, followed by the methodology and the results of the parametric study. After the discussion, the validity of the defaults through case studies is outlined and the main conclusions are documented.

EPB CALCULATION MODEL

The insulation level (K-level) is calculated based on the mean U-value of the building envelope and the compactness (i.e. ratio of heated volume and overall heat loss area). Currently, the maximum is set at K40, representing a mean U-value of 0.40W/m²K for a compactness of 1m.

The EPB model concerns a simplified one zone steady-state calculation model, which makes necessary assumptions to standardize energy calculations of buildings allowing a comparison of the performance among different buildings in the context of regulations. The energy performance level or E-level stands for the ratio of the primary energy use for the building, calculated at standard climate conditions for Brussels on a monthly steady-state basis and standard occupants' behaviour, and the primary energy use of a reference building with the same heated volume and heat loss area. The current legal requirement (2013) is E70. The lower the E-level, the better the energy performance of the building. Calculation of the yearly primary energy use for residential buildings is described in detail in (EPB Besluit, 2010). It takes into account primary energy use for space heating and cooling, domestic hot water, auxiliary energy use for pumps and fans, and primary energy gains from solar collectors, photovoltaic and cogeneration systems. The primary energy use for space heating is primarily based on the EN-ISO13790 (2004) and is determined in several steps, but this paper only focuses on the net energy demand. The net energy demand for space heating ($Q_{heat,net}$) is calculated on a monthly, steady-state basis with a constant indoor temperature (18°C) and average values for monthly outdoor temperature and solar radiation, and is calculated as the balance between heat losses ($Q_{Loss,m}$) (ventilation[1] and transmission) and useful heat gains ($Q_{gain,m}$)(solar and internal gains) (Equation (1)). Internal gains are fixed in a standardized way, depending on the building volume.

$$Q_{heat,net,m} = Q_{Loss,m} - \eta_{util,m} \cdot Q_{gain,m} \qquad (1)$$

The utilization factor of heat gains ($\eta_{util,m}$) depends on the monthly ratio of gains and losses and the time constant of the building. Four construction types are distinguished for thermal capacity, i.e. ‘heavy’, ‘medium heavy’, ‘moderately heavy’ and ‘light’. Research demonstrates that the net heating demand calculated according to the EPB-model only deviates 4% compared to dynamic computations such as TRNSYS or ESP-r, at similar boundary conditions and assumptions (Van der Veken et al., 2004). Despite its simplified approach, this model is sufficiently accurate as basis for an energy design tool targeted at architects and EDP. Since January 1st 2012, a maximum net energy demand for heating of 70kWh/m².yr is imposed for new dwellings.

In addition to energy performance, the EPB-model allows assessing summer comfort by means of an overheating indicator (I_{overh}) (EPB Besluit, 2010). This is also monthly, steady-state based and considers the entire building as a single thermal zone. Hence, it provides a simplified indication of the expected summer comfort performance. The indicator is based on the yearly ‘gain surplus’ ($Q_{excess,year}$), being the sum of all monthly gain surpluses ($Q_{excess,m}$) (Equation (2)), and calculated by subtracting useful gains from total gain at a mean indoor temperature of 18°C (heating set-point) (Equation (3)). H_T and H_V (Equation 3) stand for the specific heat losses for transmission and ventilation respectively.

$$I_{overh} = Q_{excess,year} = \Sigma_{m=1}^{12} \; Q_{excess,m} \qquad (2)$$

$$Q_{excess,m} = ((1-\eta_{util,m})\cdot Q_{gain,m}/(H_T+H_V)) * 1000/3.6 \qquad (3)$$

To estimate the overheating risk, a lower (8000Kh) and upper threshold value (17500Kh) are imposed. Below the lower threshold the risk on summer overheating is expected to be negligible. Above the upper limit, overheating is highly probable and the designer is obliged to take design measures to reduce the risk. Between both values a fictitious cooling load is considered, taking into account the probability that active cooling will be installed afterwards. The net energy demand for cooling is then calculated as the multiplication of a probability factor (between 0 en 1) that active cooling will be installed and the gain surplus at an indoor temperature of 23°C (cooling set-point). If an active cooling system is initially planned, the full cooling load is considered.

METHODOLOGY

General

The study particularly focused on parameters related to building envelope and geometry, such as the level of thermal insulation (U-value), window-to-floor ratio (WFR), g-value (solar transmittance), orientation and air-tightness. Parameters related to building systems remained fixed during the entire study and will be investigated in future research. This way, the impact of architectural parameters regarding energy performance could be clearly derived.

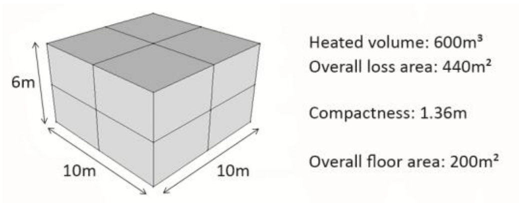

Figure 1 Reference dwelling

A simplified detached model was used for the analysis (figure 1)[2]. Different variants were generated exploring the impact of design parameters on K- and E-level, net heating and cooling demand, and overheating indicator. All performance metrics were calculated using the EPB-model. Following simplifications and invariable parameters were assumed:

- A condensing natural gas boiler for space heating and domestic hot water is used
- A natural ventilation system, with ventilation grids in the window, is used
- No active cooling is installed

[1] Ventilation losses depend on hygienic ventilation and in/ex-filtration, and the presence of a heat recovery unit. The ventilation rate for hygienic ventilation is fixed in the EPB model and depends on the volume of the building and the quality of the ventilation system.

[2] This choice is related to the specific Flemish residential context, which is dominated by detached dwellings.

Parameter ranges and combinations

The parametric study was conducted in two steps to limit the number of parameter combinations. In a first step, the impact of air-tightness and other parameters was examined, while the orientation remained fixed, resulting in 9600 simulations (table 1). In a second step, the impact of orientation and other parameters was studied for a fixed air-tightness, resulting in 315000 combinations (table 2).

In EPB, air-tightness is defined by the v50-value, i.e. the infiltration rate at 50Pa (m^3/h) per m^2 envelope area. The default value in EPB is $12m^3/h.m^2$, but this can be altered in its real value, if a blower door test is conducted. The values adopted in the first step vary between EPB-default and $1m^3/h.m^2$ (~passive house).

Table 1:
Parameters and ranges step 1

PARAMETER	RANGES	UNIT
U_{roof}	0.3-0.2-0.15-0.1	W/m²K
U_{wall}	0.4-0.3-0.2-0.15-0.1	W/m²K
U_{floor}	0.4-0.3-0.2-0.15-0.1	W/m²K
$U_{windowframe}/U_{glazing}$	2.4/1.1-1.8/1.1/-0.8/0.6	W/m²K
WFR	10-20-30-40	%
Air-tightness (v50)	12-6-3-1	m³/hm²
Construction type	Medium heavy Lightweight	-

In the second step, air-tightness is fixed at the EPB-default. The U-value for opaque elements ranges between legal maximum for 2011 (0.3W/m²K for roofs and 0.4W/m²K for walls and floors) and passive house standard (0.1W/m²K), see table 1 & 2.

Table 2:
Parameters and ranges step 2

PARAMETER	RANGES	UNIT
U_{roof}	0.3-0.2-0.15-0.1	W/m²K
U_{wall}	0.4-0.3-0.2-0.15-0.1	W/m²K
U_{floor}	0.4-0.3-0.2-0.15-0.1	W/m²K
$U_{windowframe}/U_{glazing}$	2.4/1.1-1.8/1.1/-0.8/0.6	W/m²K
WFR	10-15-20-25-30-35-40	%
Orientation	Rotation steps:30°	°
Glazing distribution	Uniform - Main orientation	
Solar shading	See table 3	-
Construction type	Medium heavy Lightweight	-

In step 2, more variants for the WFR are considered and two configurations for the distribution of glazing area are applied, being a uniformly distributed WFR over the four façades (25% each) and a distribution with 55% of total glazing area on a main orientation and 15% on the other façades. A similar approach was used in (Pessenlehner et al., 2003). The building is rotated in steps of 30°. In step 1, orientation is fixed and the WFR is uniformly distributed towards north, east, south and west.

Table 3:Solar shading variants in step 2

g-value glass	Overall g-value ($g_{g+c,\perp}$)
0.6	No solar shading
0.6	0.27
0.6	0.1
0.4	No solar shading
0.4	0.07

Solar shading (outdoor moveable screens) is also considered in step 2 (table 3). Two g-values for glazing are used, 0.6 and 0.4 (solar reflective glass). Based on the g-value for glass and the overall g-value (glass and solar shading), EPB calculates a resulting g-value taking into account a utilization factor. In step 1, the g-value for glazing is fixed at 0.6.

In both steps, two construction types are simulated, a medium heavy construction corresponding to a typical Flemish dwelling with cavity walls and a lightweight corresponding to a wood frame structure.

RESULTS PARAMETRIC STUDY

Step 1: Impact of air-tightness

Figure 2 shows the impact of air-tightness on E-level, for the medium heavy construction. The Y-axis represents the cumulative percentage of all cases with a particular v50-value that reach a specific E-level.

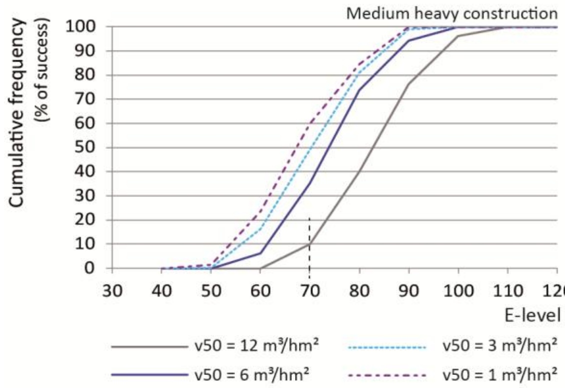

Figure 2 Impact of air-tightness on E-level

The data reveal a strong relation between E-level and air-tightness. The E-level decreases with better air-tightness. The decrease is larger when adapting air-tightness from 12 to $6m^3/h.m^2$ than from 3 to $1m^3/h.m^2$. Hence, the impact decreases with lower v50-values. The large impact on E-level is mainly related to the impact of air-tightness on net heating demand. The impact on net cooling demand was limited, which is related to the EPB-method[3]. Further, the data in figure 2 show that for this reference dwelling and considered installations and architectural parameters, E-levels below the current legal requirement E70 are hardly achievable without

[3] For cooling calculations, EPB assumes a v50-value of $0m^3/h.m^2$ at the default for heating ($12m^3/hm^2$), but a v50-value equal to that of heating if a blower door test is conducted.

improved air-tightness. Tendencies were similar for the lightweight construction, but the E-level is slightly higher due to higher cooling and heating demand. Since tendencies for the impact of other parameters on E-level (such as WFR or mean U-value) remained similar for different levels of air-tightness, their impact is only discussed in step 2.

Step 2: Impact of architectural parameters

This section outlines the results of the second step, with a fixed air-tightness (v50=12m³/h.m²). Unless stated differently, the figures in this section represent the results for the medium heavy construction and a g-value for glass of 0.6 without solar shading.

Impact of U-value and WFR:

Figure 3 demonstrates the impact of mean U-value in relation to WFR on E-level. For all WFRs, the E-level significantly decreases with decreasing mean U-value. This is related to the large impact of the mean U-value on net heating demand. The mean U-value also affects the net cooling demand, which increases with lower mean U-values. This explains the fact that the slope in the curves is flattened out, particularly for higher WFRs.

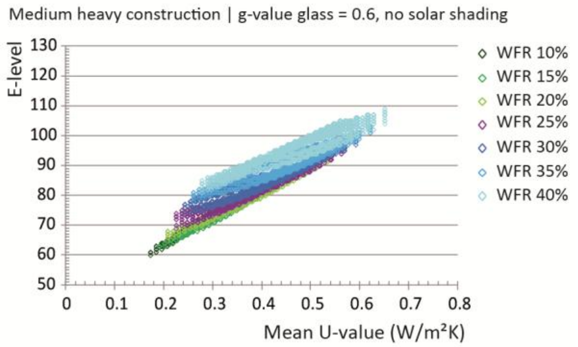

Figure 3 Impact of mean U-value and window to floor ratio (WFR) on E-level

Figure 3 also shows that the E-level increases with higher WFRs. Consequently, it is more difficult to achieve good energy performance levels in case high WFRs are applied without solar shading (as discussed in figure 7) and/or for high mean U-values. Trends were similar for the lightweight construction.

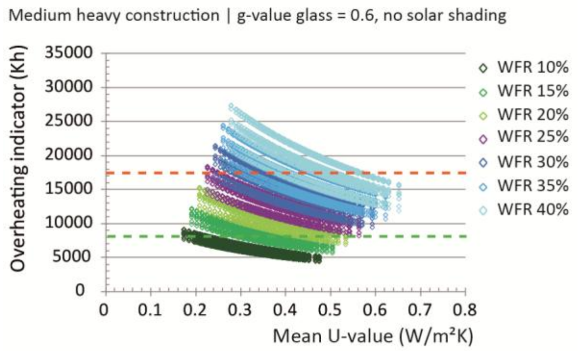

Figure 4 Impact of mean U-value and WFR on overheating indicator

Figure 4 shows the impact of mean U-value and WFR on the risk of overheating. The green dotted line represents the lower threshold (8000Kh) and the red dotted line the upper (17500Kh). The overheating indicator clearly increases with lower mean U-values for each WFR. The impact is stronger at larger glazing areas (steeper curves). The figure further reveals a significant impact of WFR. Also, the spread on the results (at equal mean U-value) is larger for high WFRs, which is due to the higher impact of orientation as a result of increased solar gains.

Since the impact of the U-values of distinctive construction components is related to the relative area of the particular component in the whole building, the impact of the mean U-value of the opaque components was assessed. There was a clear relationship between opaque U-value and E-level, as displayed in figure 5. A more detailed analysis revealed that the impact of Uopaque on E-level decreases with higher WFRs, due to decreasing opaque area and increasing solar gains.

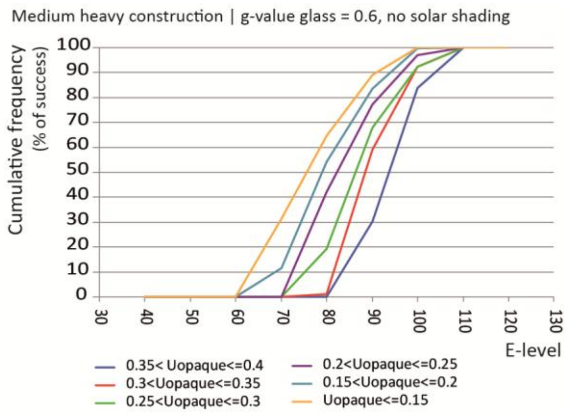

Figure 5 Impact of mean opaque U-value on E-level

The data further indicated a linear relationship between net heating demand and Uopaque, explaining the large impact on E-level. There was also a clear impact of Uopaque on net cooling demand and on overheating indicator. They both increase with decreasing Uopaque, and the impact increases with higher WFRs.

The impact of different U-values for windows was limited on both K- and E-level. The difference was mainly visible between a ‘regular’ window and a ‘passive house’ window, and increased with higher WFRs. Similar findings appeared for net heating and cooling demand and the overheating indicator. Overall, tendencies for the U-value appeared to be similar for the lightweight construction.

Impact of orientation:

Figure 6 reveals the impact of orientation on E-level for 25% (in yellow) and 40% WFR (in grey) with the main façade configuration for glazing area distribution. The data for both WFRs are displaced from each other for clarification purposes, but apply to the same main orientation indicated in the X-axis (i.e. façade with largest glazing percentage). For each orientation, the spread on the results of the WFR is caused by the mean U-value (lowest E-level corresponds to lowest mean U-value), being the only variable at a constant orientation. The overall difference in E-level due to the impact of orientation at equal mean U-value is rather small (up to 5 E-points for 25% WFR at lowest mean U-value). The impact of orientation on overheating indicator was also limited, but more pronounced and increased at higher WFRs. There was a large difference between north and south, but the difference for steps of 30° or even 60° was limited. This also applies to the E-level, suggesting that orientation can be rounded off to main orientations (north, north-west, north-east, etc.) for evaluation in early design. The impact of orientation on net heating demand was limited. Regarding net cooling demand, the impact was limited for intermediate steps, but more pronounced than for heating demand. It must be noted that the results for overheating and cooling are calculated using the steady-state EPB-approach and are thus only indicative.

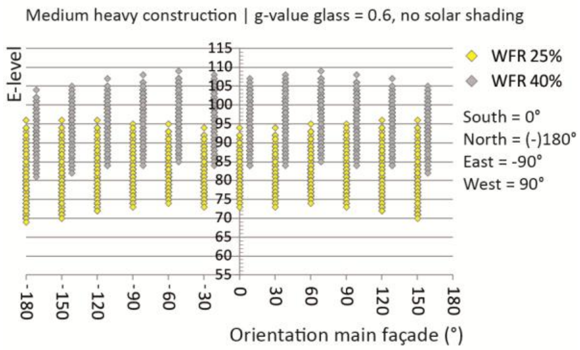

Figure 6 Impact of orientation on E-level

Impact of WFR and solar shading:

The impact of WFR and solar shading on E-level is shown in figure7, for the medium heavy construction. The left graph concerns a g-value for glazing of 0.6 without solar shading. In the middle and right graph solar shading is applied for this glazing type, with an overall g-value for glazing and solar shading ($g_{g+C,\perp}$) of 0.27 and 0.1 respectively. Along the Y-axis, the cumulative percentage is distributed. The data without solar shading (left) show a strong relationship between E-level and WFR. The E-level clearly decreases with lower WFRs, mainly due to reduced cooling demands. The net heating demand appeared to be less dependent on WFR especially for the passive house window, for which increased solar gains largely compensated higher transmission losses at higher WFRs. Nonetheless, the heating demand has an impact on the relation between E-level and WFR for the regular window types (decreasing heating demand with lower WFRs). The impact of WFR on E-level decreases with lower g-values (middle and right graphs of figure 7). Applying movable solar shading results in much lower E-levels at high WFRs, due to reduced cooling demand. The heating demand remains similar to the variants without solar shading, since moveable solar shading has no influence on it in EPB. In general, the results demonstrate the possibility to apply large WFRs while achieving similar E-levels as for lower. There was a large impact of solar shading on overheating.

Impact of thermal mass:

Thermal mass (medium heavy vs. lightweight) had a strong impact on E-level. The E-level increased for the lightweight construction and the impact of WFR also increased. This is related to an increase in both heating and cooling demand. The difference between the medium heavy and lightweight construction was more profound at higher WFRS. The spread on E-level was larger for the lightweight construction. The impact of thermal mass was more pronounced for net cooling than for heating demand. In general, tendencies for the lightweight construction were similar to the medium heavy, but the impact of different parameters was more pronounced.

DETERMINATION OF DEFAULT VALUES

In general, the results demonstrate the importance of architectural design decisions in achieving low-energy dwellings. The design of the façades (window area and solar shading), combined with other parameters (air-tightness, U-value, thermal mass) provide large opportunities to optimize a design regarding energy performance. This is shown by the entire spread on E-level, ranging from E46 (v50=1, medium heavy construction) to E123 (v50=12, lightweight construction), that is realized only by means of architectural parameters.

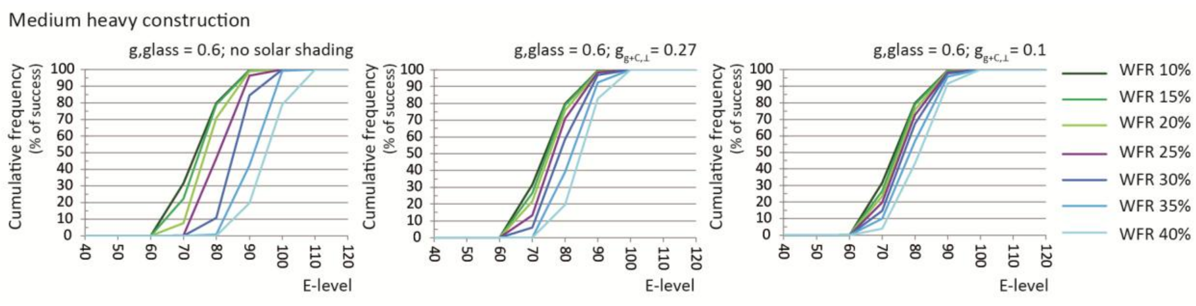

Figure 7 Impact of WFR and solar shading on E-level

The compactness remained fixed, which might have an additional impact if varied. Characteristics of building systems were also fixed.

However, different parameters with a strong impact on the energy performance level, such as U-values and air-tightness, are rarely known in the early design phase (EDP). Therefore, based on the impact results, default values were derived to adapt the required data-input of EPB to the data available in the early design phase (EDP). The absolute values of the default values itself were largely based on representative values from practice and not only from the actual impact of the parametric study. Because of the large range of possible values and their large impact, the default values were subdivided according to an ambition level of the project.

Four categories of dwellings were defined, namely "standard", "standard+", "low-energy" and "passive house". The term "standard" reflects the legal requirement, which was E80 and K45 at time of study. "Standard +" situates between "standard" and "low-energy". To define "low-energy", the economic optimum was applied, corresponding to a K-level K30 and an E-level E60 (Verbeeck, 2007). Hence, a dwelling is considered to be "low-energy" if both requirements are fulfilled. "Passive house" follows the requirements to obtain a certificate. Table 4 outlines the default values according to the categories.

Air-tightness

Air-tightness showed a strong impact on E-level and net heating demand. Large differences occurred between v50=12 and 6m³/h.m², but the impact from 6 to 3m³/h.m² and from 3 to 1m³/h.m² was limited. Therefore, the default is set at 3m³/h.m², if attention is paid to air-tightness and a blower door test will be conducted, for standard(+) and low-energy dwellings. This value also closely approximates the average measured value for newly built houses in Flanders (3.59m³/h.m²) (VEA, 2011). If no attention is paid to air-tightness, the EPB-default is used. For passive houses, the default value is set at 1m³/hm².

U-values

The mean opaque U-value also appeared to have a strong impact. Therefore, a range (a minimum and maximum value) on the opaque U-value is used per ambition level (table 4). The impact of the U-value for windows was mainly visible between a passive house window and a regular window. Hence, two defaults are adopted depending on the ambition level.

Other parameters

The construction type (medium heavy vs. lightweight) had a clear impact on E-level, but is usually known in the early design phase (Weytjens et al., 2009). Hence, this parameter does not require a default value, but it was important to examine if impact trends for other parameters were similar for different construction types.

The data further revealed a strong impact of WFR, but a rough percentage of transparent area is usually known early. Orientation is also usually more or less known early (Weytjens, et al., 2009), but the data suggest that it is sufficient to know the main orientations (north, north-east, east, etc.). Solar shading significantly influenced the results. This parameter is important regarding the 'design freedom' of architects, allowing large WFRs while achieving good energy performance and summer comfort. Two possible default options are provided if indicated that solar shading is used (table 4).

Finally, a significant reduction of required data-input is realized by the default values. However, they are based on the study of a single reference dwelling. Hence, validity tests are important testing their usability for dwellings with a different compactness. Therefore the accuracy of the default values was investigated in twelve case studies of existing dwellings.

CASE STUDIES

Methodology

Main objective was to analyze the extent to which the default values provide reliable results when a number of parameters are replaced simultaneously. This was done by comparing the EPB-calculation of recently built houses based on real input data with a calculation according to default values. In the original calculation, the real input parameters were replaced by corresponding default values depending on the project type.

Table 4:
Overview of default values according to ambition level

PARAMETER	STANDARD	STANDARD+	LOW-ENERGY	PASSIVE HOUSE	UNIT
U_{opaque}	0.25-0.35	0.2-0.3	0.15-0.25	0.10-0.15	W/m²K
$U_{windowframe}/U_{glass}$	2.0/1.1			0.8/0.6	W/m²K
v50: no attention	12			1	m³/hm²
v50: attention + test	3			1	m³/hm²
g-value glass	0.6				-
$g_{g+c,\perp}$: efficient system	0.1				-
$g_{g+c,\perp}$: less efficient system	0.3				-

Table 5:
Overview of cases

N°	PROJECT TYPE	DWELLING TYPE	THERMAL MASS	COMPACTNESS (m)	E-LEVEL	K-LEVEL	v50-value
1	Low-energy	Detached	Medium heavy	1.5	59	27	EPB default
2	Standard+	Detached	Medium heavy	1.5	62	33	EPB default
3	Standard	Terraced	Medium heavy	2.0	75	37	EPB default
4	Low-energy	Detached	Medium heavy	1.5	40	28	1.03m³/hm²
5	Low-energy	Detached	Lightweight	1.0	50	30	1.2m³/hm²
6	Standard	Detached	Heavy	1.3	81	43	EPB default
7	Passive house	Detached	Heavy	1.6	24	14	0.158m³/hm²
8	Standard+	Semi-detached	Medium heavy	1.6	58	32	EPB default
9	Passive house	Detached	Moderately heavy	1.3	7	17	0.225m³/hm²
10	Passive house	Detached	Lightweight	2.1	27	11	1.2m³/hm²
11	Standard	Semi-detached	Medium heavy	1.4	77	33	EPB default
12	Standard	Semi-detached	Medium heavy	1.6	71	31	EPB default

The research was conducted in two steps. First, architectural parameters were changed to determine their impact, while the characteristics of buildings systems remained fixed at original values. This way, the adequacy of the architectural default values could be investigated without influence of other aspects. In a second step, the impact of the installations was analyzed, but this paper only presents the results of the first step.

During the analysis, the building geometry (i.e. compactness, opaque and transparent area) remained unchanged, since this is usually known early in the design. However, a varied sample of dwellings, ranging from detached to terraced and from moderately insulated to passive house were considered, with a compactness varying between 1.0 and 2.1m. This is particularly important to test the validity of the default values, since they were determined on the basis of a single compactness. An overview of all cases is given in table 5.

The projects are categorized according to the four types defined earlier. The default values replacing the real values differ in function of the project type (table 4). For each dwelling, two variants are calculated for the opaque U-value, being one minimum and one maximum value (table 4). Further, following assumptions were considered: orientation is rounded off to the nearest main orientation (north, north-east, etc.) and thermal mass remains unchanged (table 5).

Results

Figure 8 and 9 show the results for the E- and K-level respectively and reveal the spread on both indicators as a result of the default values for the twelve cases. The small red and blue marks represent the results calculated accordingly the default values, and the yellow diamonds represent the results for the detailed original EPB-calculation. The spread on the results on the default values is caused by the range on the opaque U-value (minimum and maximum value).

In general, the results support the usability of the default values for evaluation of the energy performance in the early design phase, also for dwellings with a different compactness than the reference dwelling. The original E-level situates in between the results obtained by default values for half of the cases (figure 8). The original E-level of the passive houses (dwellings 7,9 and 10) is slightly lower than the E-levels obtained by the default values, which is partly due to a better air-tightness (dwelling 7,9). However for these dwellings, the difference in E-level is small and the final E-level is slightly better than the calculations according to default values, supporting the reliability of the results in EDP. The original E-level is only in one case higher than the E-level according to default values (dwelling 3). This appeared to be related to the method of calculating the ratio of glazing area and window frame. The EPB-method gives the opportunity to calculate the real ratio or to assume a default ratio of 30% window frame and 70% glazing area. In the original file, the percentage of glass per window is higher than 70%, resulting in higher cooling demand and a higher E-level. However, the difference in results is small, indicating that the simplified method for the ratio of glass and window frame is sufficiently accurate for an indication in early design phases.

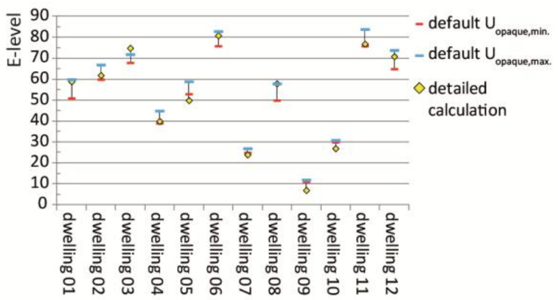

Figure 8 Spread on E-level due to default values

The entire spread on E-level varies between 3 and 9 E-points. This indicates that the default values provide a good indication of the E-level in the early design phase.

Similar findings are obtained for the K-level (figure 9). The original K-level situates in between the K-level obtained from the default values for the majority of cases. The entire spread varies between 4 and 9 K-points. The original K-level of the passive houses is slightly lower than or equal to the K-level according to default values, but the difference is small. Only for dwelling 8 the original K-level is slightly higher. This deviation is caused by the difference in mean U-value which is higher for the original calculation (0.39W/m²K) than for the default values (0.28W/m²K and 0.37W/m²K), but the difference is small.

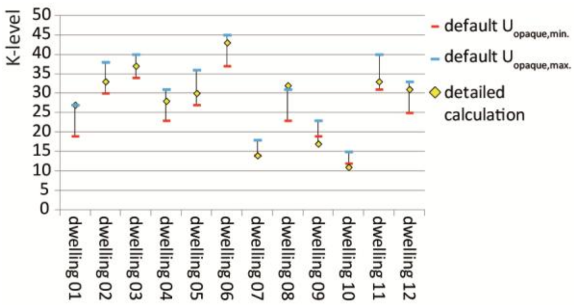

Figure 9 Spread on K-level due to default values

Besides E- and K-level, the usability of the default values was also examined for net heating demand and overheating indicator. In general, these results also supported the reliability of the default values for an indication of the energy performance in EDP. The results also validated the subdivision of default values according to the ambition level of the project for both Uopaque and air-tightness.

CONCLUSIONS

This paper studied the impact of architectural parameters on the energy performance of dwellings through an extensive parametric study. The data demonstrated that architectural parameters provide large opportunities to optimize the design regarding energy performance. Consequently, the integration of energy efficiency by architects in the early design phase should be stimulated, indicating the importance of early design support.

The results provided information to reduce the detailed input of EPB and adapt the design method to the input available in the early design phase by implementing default values. The default values were validated in twelve case studies. In general, the default values predict a good indication of the energy performance compared to detailed EPB-calculations, also when several default values are combined simultaneously. As such, the default values determined by the parametric study can be considered as adequate for use in the design tool.

Nonetheless, this study only considered architectural design parameters. Further research is needed on the impact of building systems, but also regarding overshadowing.

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