The Influence of Energy Performance Levels on the Heating Demand in Dwellings: Case-Study Analyses on Neighbourhoods

Marc Delghust **Jelle Laverge, PhD** **Arnold Janssens, PhD**
Member ASHRAE
Elisabeth Cnockaert **Tracy Davidson**

ABSTRACT

Unforeseen variations in user behaviour can cause large differences between real and predicted heating demands in dwellings. While these discrepancies have been extensively documented in the literature, taking user behaviour into account in energy calculations remains challenging and could benefit from additional knowledge of the inhabitants' interactions with their houses and systems.

In response to this need for additional knowledge, case-study analyses were carried out on two different neighbourhoods, both consisting of nearly identical houses: one old neighbourhood with uninsulated houses and one recent neighbourhood built according to contemporary energy regulations. Information on user behaviour, on the building characteristics, and on the resulting performance was gathered both by in-situ measurements and by surveys of the inhabitants.

Correlations and contradictions between presence, heating, and ventilation profiles were identified as decisive elements for a better estimation of real heating demands. However, the analysis also illustrated that it is hardly possible to fully isolate user behaviour from building characteristics and assess these as distinct entities. This is caused by the direct correlation between the household typologies and the building typologies as well as by the influence of building characteristics on the user behaviour.

INTRODUCTION

The most commonly used tool for the evaluation of the energy performance of dwellings in Belgium, the governmental EPBD calculation tool (VEA [2013]; based on EN ISO 13790 [ISO 2007]), assumes an average user behaviour as well as average comfort criteria. However, field studies have demonstrated the large dependency of both energy use and indoor comfort on varying user profiles. Furthermore, shifts in user behaviour have also been noted depending on the buildings' characteristics, as indicated by Andersen (2009) and by Hens et al. (2009). This added complexity and variation in real life, when compared to EPBD calculations, is of huge concern for many actors within the building sector, from policy makers and architects to their building clients. This is certainly the case for the Belgian residential building sector. It consists mainly of small housing projects in which there is often no time or budget available for more advanced, tailor-made studies than mere EPBD calculations based on a quasi-steady-state heat balance with a single average user profile.

The aim of this study is to gain further insight info and knowledge of the relation between user behaviour (e.g., use of windows, ventilation, and heating devices), perceived comfort, and the resulting heating energy use in Belgian single-family houses. The data for this study were collected through surveys and measurements on housing neighbourhoods of different energy performances. The houses range from old, barely insulated houses and current standard houses to low-energy and passive houses. This paper presents findings from the first two neighbourhoods of single-family houses, comparing old, barely insulated houses with recently constructed houses built according to the current Belgian energy regulation standards.

***Marc Delghust** is a doctoral fellow of architectural engineering, Department of Architecture & Urban Planning, Ghent University, Ghent, Belgium, and holds a PhD fellowship from the Research Foundation Flanders, Brussels, Belgium (FWO) and the Flemish Institute for Technological Research, Mol, Belgium (VITO). **Jelle Laverge** is a post-doctoral assistant, **Arnold Janssens** is a full professor, and **Elisabeth Cnockaert** and **Tracy Davidson** have Master's degrees in architectural engineering, Department of Architecture & Urban Planning, Ghent University.*

MATERIALS AND METHODS

Case Description

The variation in building characteristics within the Belgian building stock is as vast as the variation in household typologies, resulting in an amount of possible situations that is too large to be encompassed by a very thorough field study. The challenge, therefore, lies in pursuing this field investigation through a pragmatic though comprehensive approach on a limited number of houses. On the one hand, for the cases to be complementary and usable for cross-comparisons, they were selected to be illustrative of the heterogeneity in thermal performance within the Belgian housing sector while still being houses of comparable size and typology. On the other hand, to differentiate the variations due to the users' behaviour from those due to the characteristics of buildings, uniform neighbourhoods were selected. Each selected neighbourhood had been built by one single construction company and one architect, in one time period, according to the standards of that time and with similar materials and services across all houses. As such, each neighbourhood is a separate cluster of nearly identical houses with different households.

This paper presents results from the analysis on two neighbourhoods of single-family houses, which include 62 households or 186 people. Both samples (neighbourhoods) share some basic characteristics that are typical for most Belgian houses. They both consist of two-storey single-family houses with brick cavity walls and tiled roofs. The living area (including a living room, a kitchen, and a toilet) is located on the ground floor. The sleeping area on the first floor consists of three bedrooms and one bathroom. Despite these similarities, the theoretical energy performances of both neighbourhoods are distinctively different.

The first sample (cs1: 36 houses) is an old social housing neighbourhood, dating from the 1960s. The houses are barely insulated, have no mechanical ventilation system, and are mainly heated by a single gas furnace in the living room. Small additional electric heaters are used in the bathrooms and sometimes in the bedroom. Over their 50 year lifespan, only a few houses have been refurbished and only to a limited extent.

The second sample (cs3: 26 houses) is a five-year-old neighbourhood of privately owned houses. The houses are representative of the present Belgian building standards, complying to the new energy performance regulations. All the houses have standard insulation levels, central exhaust ventilation systems, and central hydronic heating via modern gas boilers. While 16 out of the 26 houses are based on one single design, the remaining 10 houses have slightly different layouts, causing some limited building variation within this sample.

Methodology

Information on the buildings and households was gathered by in-situ measurements, by a thorough survey of the inhabitants, and by collecting utility bills and meter readings for gas and electricity consumption. The focus of this study was on the heating energy demand and, therefore, measurements and surveys took place during the winter season. The measurements focused both on the building characteristics (through infrared thermography, heat-flux measurements, and airtightness measurements) as well as on the indoor climate (indoor temperature, humidity, carbon dioxide level). The aim was to gather data not only for cross-comparisons between houses but also for comparisons between real values and designed values (e.g., U-values of walls). The surveys of the inhabitants focused on the users themselves, their habits, and their interactions with the building as well as on their motivations, understanding of the building, and appreciation of the resulting performance (energy use and comfort). This way, measurements and surveys could be compared and their complementarity exploited.

Three considerations were made when setting up the survey strategy. First, as the neighbourhoods were relatively small (approximately 30 to 60 houses), reaching a good participation rate was crucial to end up with samples large enough for further analyses. Second, to be representative for the neighbourhoods' varying households, the final samples should not be composed merely of motivated inhabitants willing to participate actively in intrusive studies. For these first two reasons, the measurement and surveying procedures could not be too demanding and a balance had to be found between the researchers' scientific eagerness for data and the resulting intrusion into the inhabitants' daily routines and privacy. Third, care had to be taken that the surveys would not influence the inhabitants' behaviour during the measurements and yet that the gathered information would correspond as closely as possible to the measured conditions. Because of this third consideration, the surveys were submitted directly after the measurement periods, when collecting the measurement equipment. The participants were not asked to keep detailed diaries of all activities and behavioural aspects of interest at a high frequency over the whole week. Instead, they were asked to draw daily profiles for an average weekday and an average weekend day (e.g., directly concerning presence, heating, ventilation), and the survey also included specific questions to complement these profiles (e.g., Do you close the windows when it rains? Do you close the windows when the heating system is on?). When applicable, these questions allowed input per individual inhabitant as well as per different room or appliance. To avoid misinterpretations and to lower the workload for the participants, the surveys were adapted to each specific neighbourhood (e.g., the surveys omitted questions on the operation of mechanical ventilation systems for the old housing neighbourhoods without those systems).

RESULTS

The Dwellings

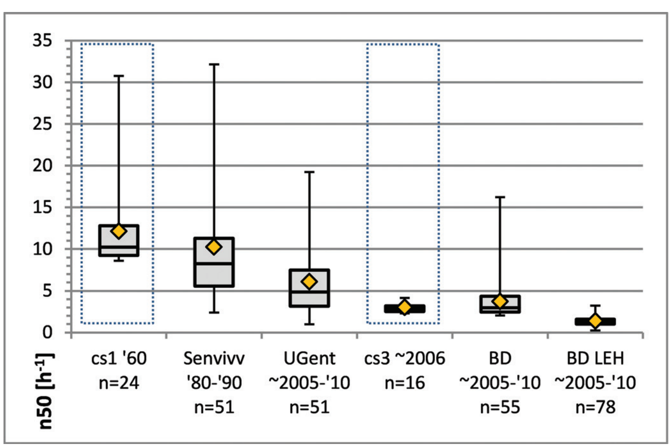
Due to the much higher recent building standards, the more recent houses are supposed to reach a much better energy performance than the old, barely renovated houses. Some differences were confirmed by in-situ measurements (airtightness and heat flux measurements, infrared thermography). By way of example, Figure 1a compares the airtightness for both samples with reference data for Belgian single-family houses. The reference data includes a random sample of houses built in the late 1980s and early 1990s from the Senvivv project (WTCB et al. 1998), a random sample of standard dwellings from the past five years (UGent), and recent measurement data from private-party consultants (BD), of which the explicit low-energy houses (LEH) are separated as a representation of today's "engaged" market segment, as discussed by Laverge et al. (2010). The measured airtightness in both neighbourhoods appeared to be in line with the expectations for their respective building periods and standards. The spread in airtightness within both neighbourhoods can be attributed to workmanship, occasional window replacements in the old houses, and the presence of a few semi-detached houses.

The heating energy demand derived from the meter readings, however, does not correspond to the theoretical predictions. Figure 1b compares the real heating energy demand with the theoretical demand according to the EPBD method. The real energy use is clearly less than the predictions. Finding a lower real energy demand might be considered to be a good thing. However, as the overestimation of the energy demand is higher in the old dwellings, the reduction in energy demand when shifting towards the new dwellings appeared to be much lower in practice than assumed: on average, approximately 75 kWh/(m^2·a) (24 000 Btu/[ft^2·yr]) instead of 225 kWh/(m^2·a) (71 000 Btu/[ft^2·yr]). Furthermore, within each neighbourhood, the real spread in energy use was much larger than in theory. While the accumulation of small aforementioned variations between the individual buildings does create some spread within the theoretical energy use according to the EPBD method, the much larger spread in real energy use can only be fully explained by taking the behaviour of the inhabitants into account.

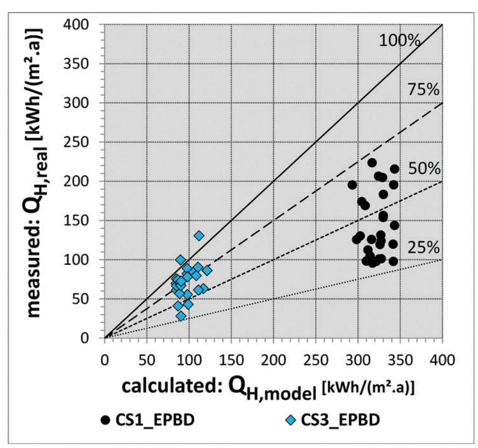
The Inhabitants

Demographics. The first neighbourhood consists of rented social houses, built and owned by a social housing company. The second neighbourhood was also built by a single construction firm, but many houses are inhabited by private owners. This neighbourhood mainly houses young families, while the first set of households is more heterogeneous, with, as shown in Figures 2a and 2b, more older people, lower education levels, and more retired and unemployed people. This correlation between the ages and performances of the buildings and their respective population sets is quite symptomatic of underlying sociodemographic factors such as the ages and incomes of the inhabitants. As will be shown here, these differences both in households as well as in building typologies coincide with differences in user behaviour.

Presence. Each inhabitant reported his or her presence in each room for an average weekday and for an average weekend day. This data allowed us to build daily profiles representing the probability of the presence of people in each room. Presence is directly related to the daily occupation of the inhabitants and thus on the type of household. As a reference, statistical data for Belgium is depicted in Figure 3a (Laverge et al. 2011), next to the results from both neighbourhoods. The stacked coloured areas represent the probability for one specific person to be present in a certain room of the house over the course of the day. A probability of 1 means that



(a)



(b)

__Figure 1__ (a) Measured airtightness (air change rate per hour at 50 Pa [0,0073 psi] pressure difference) and (b) measured vs. theoretical yearly heating energy demand (normalized per unit of floor area).

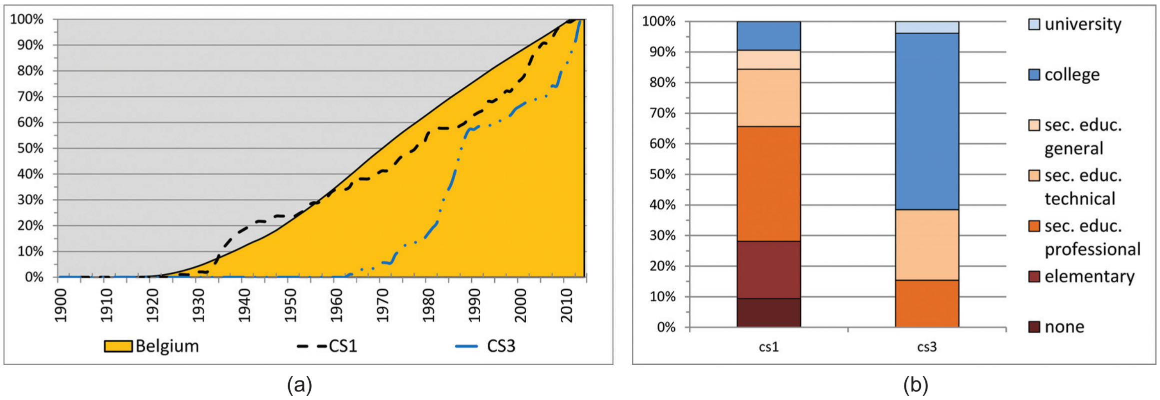


Figure 2 *(a) Date of birth: cs1 and cs3, compared to the Belgian population (cumulative distribution), and (b) degree of education: highest diploma within each household.*

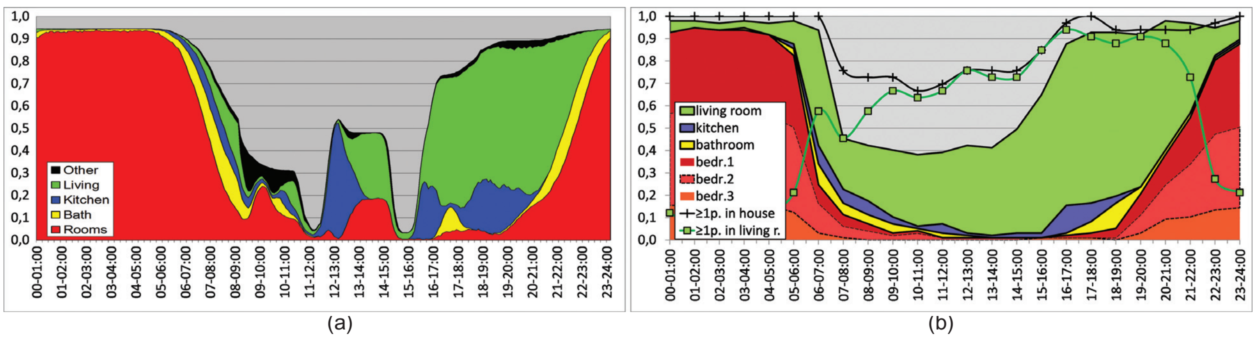


Figure 3 *Probability of presence: (a) Belgian reference data (Laverge et al. 2011) and (b) cs1.*
(Figure 3a reproduced from Laverge et al. [2011] with permission of ELSEVIER SCIENCE.)

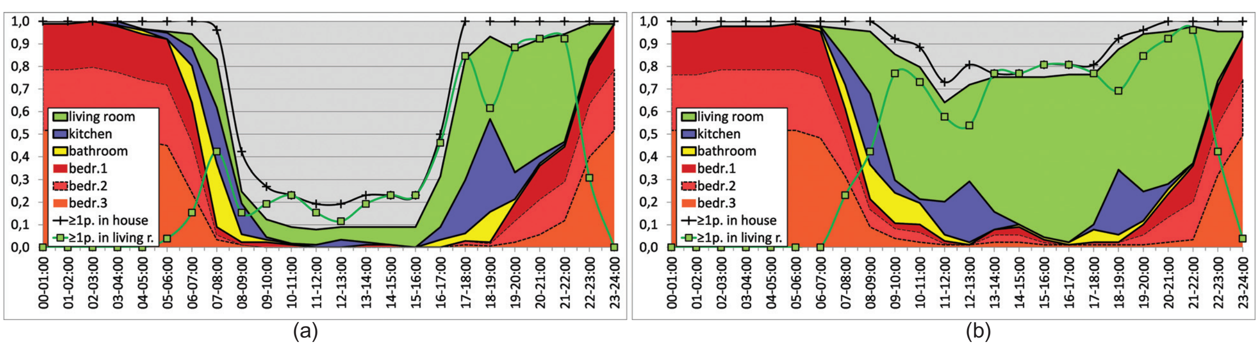
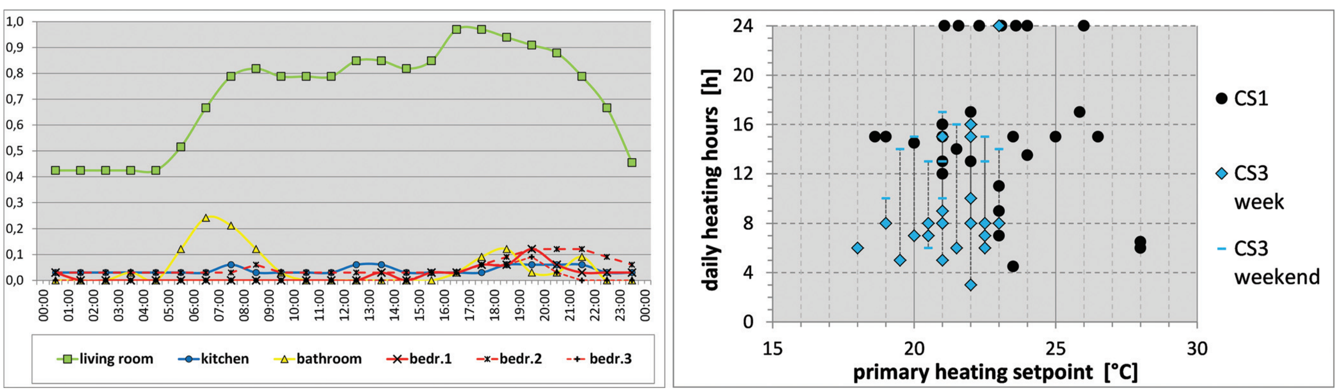


Figure 4 *Probability of presence in cs3 (a) weekday (b) weekend.*

everyone is stated to be present in the house at that time of the day, while reaching 0 means that no one is stated to be at home at that time. Additionally, the lines show the probability of at least one person being present in the room and are thus also dependent on the size of the household. In cs1 (Figure 3b), the probability of presence in the houses (and more specifically in the living room) during weekdays was much higher than the Belgian reference level. The opposite was true for cs3 (Figure 4a). This could be explained by the higher number of unemployed and retired people in cs1, as indicated by Guerra-Santin (2010). Also, the increased presence in the kitchen and the living room during lunchtime in the reference data was not found in either of the two samples. While no direct cause was reported in the surveys, one explanation of the limited use of the kitchens in cs1 could come from their very poor state and their small size, making the directly heated and thus more comfortable living room the preferred eating place. During the weekend, the occupancy profiles in cs3 changed dramatically, as shown in Figure 4b. Small time-shifts in the morning and in the evening, increased presence in the living room, and a wider spread of use of the kitchen over lunchtime and dinnertime were the most obvious and noticeable differences.

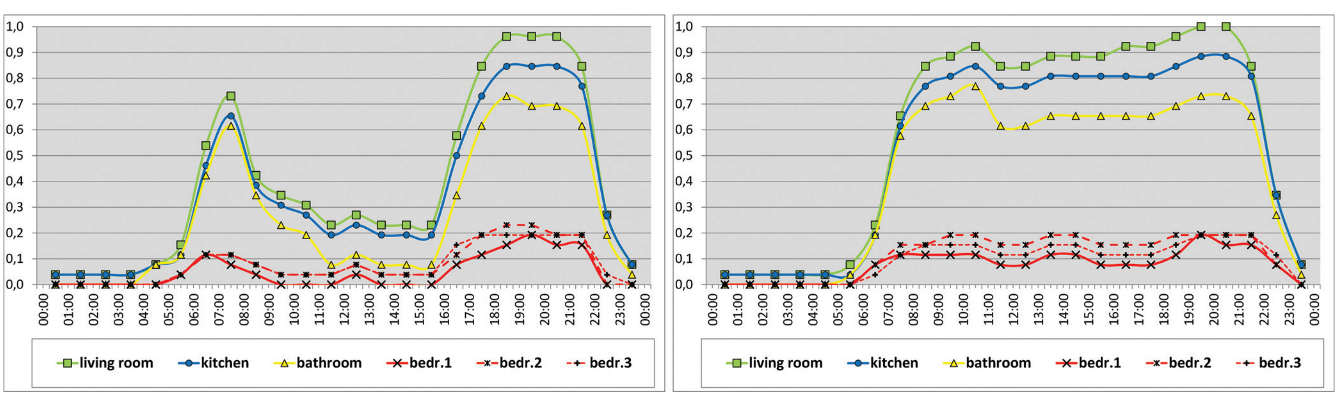
Heating. Daily probability profiles for the heating of each room were derived from the questionnaires, in a similar way as the presence probability profiles. Both profiles proved to be strongly correlated, especially for the living rooms. This is obvious when comparing the heating profile of the living room, as shown in Figure 5a for cs1 and Figure 6 for cs3, with the probability of having at least one person present in the living room (the green lines in Figures 3 and 4). For cs3, the heating profile of the kitchens was much higher than that of cs1 and closely followed the profile of the living rooms. The higher functional and qualitative value of the kitchens in cs3 was not the only reason. The close fit in heating profiles between living rooms and kitchens in cs3 is also caused by the frequent occurrence of open kitchens and the use of one centralized heating system, in most cases controlled by one single clock-thermostat. In the other rooms, the direct link between presence and heating was not always as obvious as in the living room. The electric heaters in the bathrooms of cs1 were reported to be turned on only when the bathroom was in use. However, in most bathrooms of cs3, the heating appeared to remain on from the moment someone was present in the house during the daytime, synchronously to the heating in the living area. In general, in the bedrooms, the heating devices were barely used, merely occasionally to heat up the room before going to sleep. Although the higher thermal performance of the new dwellings should improve the thermal comfort in the bedrooms of cs3, even without heating them directly, the bedroom radiators were used more frequently in cs3 than in cs1. The higher expense of electric heating and the idea of a lowered heating demand due the higher insulation levels in cs3, further emphasized by differences in income between the two groups of households, might explain these apparent rebound-effects with regard to the heating in the bathrooms and the bedrooms, as illustrated by Hens et al. (2009).

The large spread in daily heating profiles is illustrated even better in Figure 5b. This figure shows the average number of heating hours per day as well as the heating setpoints for each living room in both neighbourhoods. These were deduced by cross-analysis of the heating period data from the surveys together with the continuous indoor temperature measurements. Heating times ranged from 4 hours to 24 hours per day. The overall gap between cs1 and cs3 is shown to be



(a) (b)

Figure 5 *(a) Probability of heating in cs1 and (b) daily heating hours and primary setpoints for the living rooms (cs1 and cs3).*



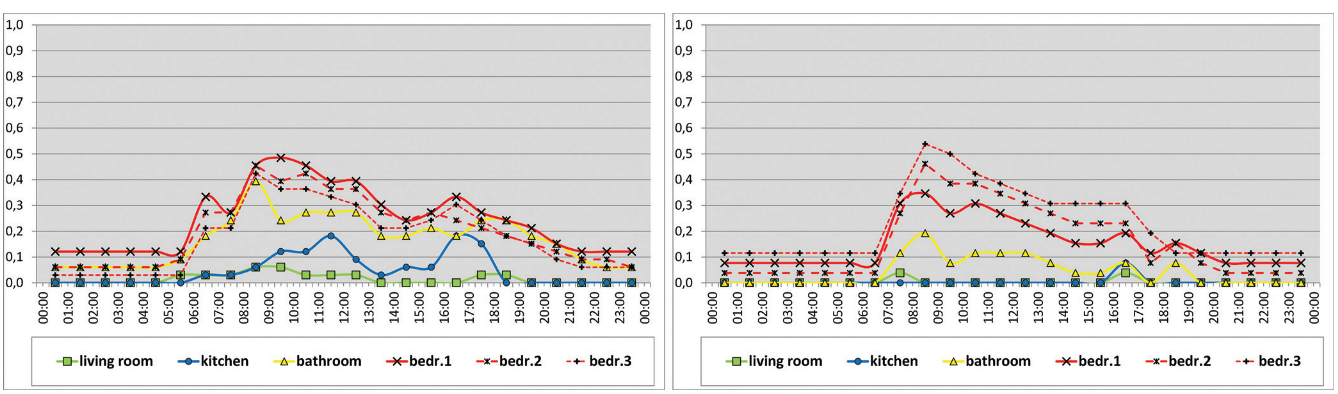
(a) (b)

Figure 6 *Probability of heating in cs3: (a) weekday and (b) weekend.*

largely bridged during the weekend (error bars). The variation in heating behaviour was even more striking when taking into account the heating setpoints, which ranged from 18°C (64°F) to 28°C (82°F). It is also important to note that the highest values were found in the old neighbourhood. Most likely, the reasons for this are to be found both in the different users (e.g., older people requiring higher indoor temperatures, as concluded by Mishra and Ramgopal [2013]) as well as in the different building characteristics. The poor thermal performance of the building envelope of the old houses (as pointed out by the airtightness and heat flux measurements and the presence of large single-glazing areas), in combination with the centrally located gas furnace, may have caused draught, radiation asymmetry, and cold floor temperatures. Increasing the heating setpoint can partially compensate these forms of local discomfort. It is therefore impossible to give one unique and indisputable cause for these higher setpoints.There seems to be a contradiction between, on the one hand, the higher setpoints and longer heating durations in the living rooms of the old houses and, on the other, the larger overestimation of energy use in these same houses. The differences in heating profiles, between different houses and between different rooms, are not the only missing factors in the standardized boundary conditions of the EPBD calculation. Other related factors include the real, user-influenced ventilation heat losses in the different zones.

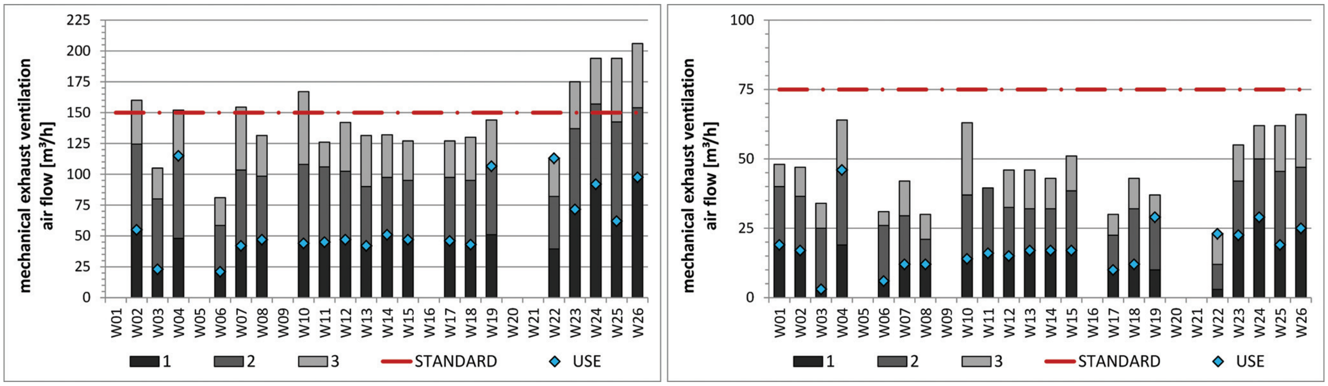
Ventilation. For both the old and the recent dwellings, the surveys showed a recurrent asynchrony, in time and space, between the opening of windows on the one hand and both the presence in and the heating of rooms on the other hand. As shown in Figure 7, windows in the most heated rooms, the living rooms, were reported to be opened only very rarely, while the windows in the rarely heated bedrooms were often opened during the day, especially in the morning when leaving the bedroom. Except for a small shift in time, no significant difference was noted between the two neighbourhoods with regard to the use of the bedroom windows. However, the use of the bathroom and kitchen windows did differ significantly between the old and recent neighbourhoods. The bathroom and kitchen windows were opened much more frequently in the old houses than in the new houses. Only the new houses, however, have an exhaust ventilation system and an improved insulation level. Therefore, in the bathrooms of the older houses, high humidity levels were measured and condensation spots were reported on the uninsulated walls. In the absence of any mechanical ventilation system, opening the windows became the inhabitants' logical approach to tackling the problem.

The mechanical exhaust ventilation in cs3 could be thought of as a more effective ventilation solution, technically more robust than window airing and still freely controllable by the users. However, the measurements demonstrated large divergences in installed flow rates between the different houses, while the surveys showed a very uniform use of the ventilation systems across all households. According to the local ventilation standard, for these houses the highest total exhaust flow must reach 150 m^3/h (88,3 cfm) (75 m^3/h [44,1 cfm] for the kitchen, 50 m^3/h [29,4 cfm] for the bathroom, and 25 m^3/h [14,7 cfm] for the toilet) and the user must be able to select one of three preset ventilation flow rates. However, almost every household stated that they left the ventilation system at its lowest flow rate all the time, while the total installed exhaust flows ranged from 81 m^3/h (47,7 cfm) to 206 m^3/h (121 cfm) at full power (Figure 8a). The discrepancy between installed and prescribed flow rates was even more striking when looking at the rooms separately. The prescribed 75 m^3/h (44,1 cfm) could not be reached in any of the kitchens (Figure 8b), while in most toilets the 25 m^3/h (14,7 cfm) target was reached at the second or even the lowest flow rate (Figure 9b). These findings about installation and use of ventilation systems appeared to be in line with findings from previous field studies in Belgium and the Netherlands by Rosseel (2008) and by van Dijken and Boerstra (2010).



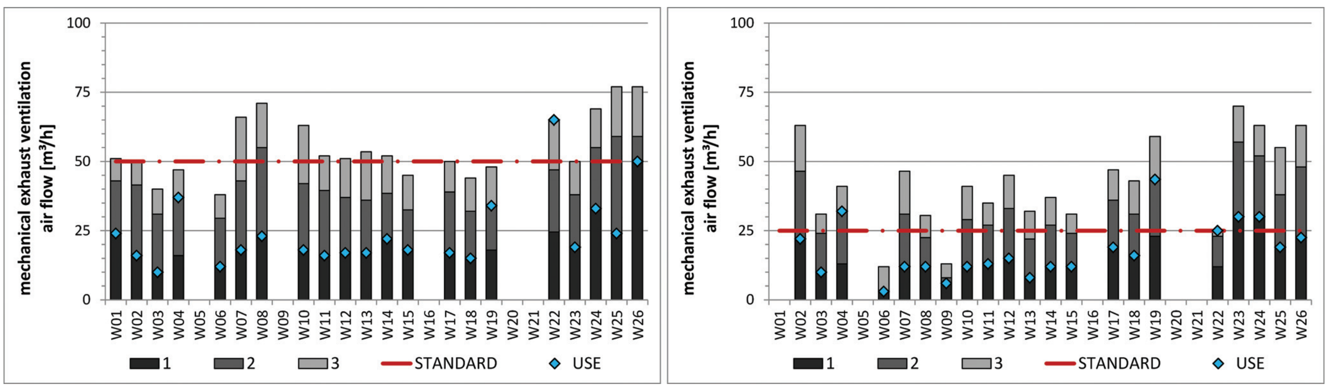
(a) (b)

Figure 7 *Probability of airing the windows in (a) cs1 and (b) cs3.*



(a) (b)

Figure 8 *Exhaust ventilation airflows in cs3: (a) total and (b) kitchen.*



(a) (b)

Figure 9 *Exhaust ventilation airflows in cs3: (a) bathroom and (b) toilet.*

DISCUSSION: PREDICTING AND ASSESSING HEATING ENERGY USE

Ultimately, the goal of increasing knowledge on user behaviour and real energy use is to improve the accuracy of calculated predictions of heating demands (before building the houses) and to enable a correct assessment of the real building performances (after completion). Big challenges arise from the huge variations in user behaviour both within a house (between different rooms) as well as between different houses (depending on the properties of the building envelope, the HVAC systems, and their controls).

Prediction

To come to a fairly accurate prediction of the energy use, beyond the accuracy of simple calculation methods using standardized boundary conditions (such as the EPBD software), one has to take into account both the discrepancies between theoretical and real technical characteristics (e.g., the airtightness and the installed ventilation flow rates) as well as the specific user profiles (e.g., heating duration and setpoints, use of windows, and mechanical ventilation systems). Advanced, dynamic simulation tools, by their complex physical algorithms and input flexibility, allow thorough modelling of many of these parameters, as illustrated by de Meester et al. (2013). However, more pragmatic, simplified models can also be used to reach vastly improved predictions. To illustrate this, Figure 10 adds to Figure 1b the calculated values for cs1 from an improved yet simple model. Similarly to the EPBD software, this fast calculation tool is based on a monthly quasi-steady-state method. The improved predictions arise mainly from the extension to a multi-zone model in which the differences in heating setpoints and daily heating times are taken into account as well as the lower, more realistic ventilation airflows, as discussed by Delghust et al. (2012). The remaining errors result both from the limitation of the model as well as from the remaining uncertainties about the building and the user behaviour. It is worth considering whether the benefit of a more complex advanced model will be valuable in daily building practice when making predictions on yearly energy use in small single-family houses. The use of more advanced modelling tools would increase the calculation time while the improved model's precision would be made partly

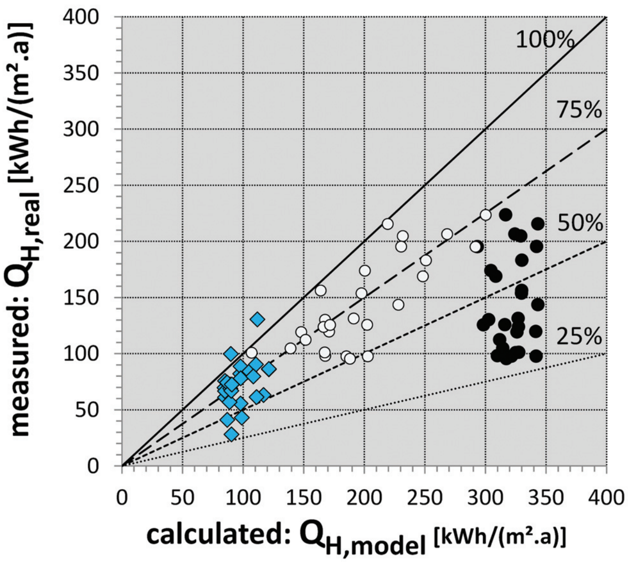


Figure 10 *Yearly heating energy demand, normalized per unit of floor area: real vs. calculated values.*

superfluous due to limited available data on the building and the user behaviour before construction starts and thus before the users move in. Balancing these considerations might result in different modelling choices dependent on the type of building, the available time and expertise, the required calculation accuracy, and the goal of the analyses (e.g., estimating peak loads instead of total yearly energy use, focusing on individual buildings or building stocks).

Assessment

When carrying out an assessment of existing buildings and their real energy use, through measurements and/or surveys, we often want to differentiate the *performance of the buildings* from the effect of the specific user's behaviour on the resulting energy bill. This seems a justifiable goal when aiming at assessing the workmanship and the reliability of the design performance, when taking into account a certain predefined use, agreed upon between all parties at the start of the project. However, the findings from in-situ analyses question whether this is possible, even in theory (assuming perfect measurement and simulation tools), from the moment the real use differs from the predefined one. As the properties of the buildings influence users' behaviours, while user behaviour is also influenced by other parameters (e.g., socio-economical parameters), it is doubtful whether this maze of causal connections could be fully disentangled. Can we fully attribute divergent heating setpoints and use of windows to the user on the one hand, or to the building on the other, when local discomfort, health conditions, etc., can also play a role? Applying statistical methods to large-scale samples might give a solution when looking, for example, at larger building stock levels. Findings from these analyses might, in turn, be used for improved assessment models on smaller samples or individual buildings. The robustness of such approaches for the assessment of individual projects, e.g., for energy labelling, might become an interesting challenge for future research.

CONCLUSIONS

While the collected data and the findings from these case studies are much more extensive than presented here, this paper illustrates the complexity of the problem. First, the variation in user behaviours has a large impact on the real energy use in old and new houses, adding an important uncertainty to the predicted energy use. Second, both the tuning and the use of the ventilation systems differ significantly from their design targets. The installed flow rates do not correspond with the design values, and the inhabitants almost never use the control buttons. Third, the technical differences between old and new houses also influence user behavior. The most striking example was noted in the bathroom, where different heating and window airing profiles coincided with the differences in heating and ventilation systems.

The paper also demonstrates the valuable complementarity between the different data sources (measurements and surveys) in order to investigate these interactions between the buildings and their users. It appeared very challenging to differentiate the influences of building choices from those of a specific household's behaviour, e.g., with regard to heating setpoints and the use of ventilation systems and windows in the different rooms. This is a major challenge both for making realistic prediction models on future energy use as well as for assessments of energy performances of buildings in use. Statistical analyses on large though detailed datasets would be of considerable help in understanding and quantifying the underlying phenomena. However, the steps towards detailed assessment of the performance of individual buildings will probably remain very challenging.

ACKNOWLEDGMENTS

The authors would like to thank the Flemish Association for Social Housing (VMSW), the local social housing company (MGW Mechelen), and all the inhabitants who participated willingly in this project.

REFERENCES

Andersen, R.V. 2009. Occupant behaviour with regard to control of the indoor environment. PhD thesis, Department of Civil Engineering, Technical University of Denmark.

Delghust, M., et al. 2012. The influence of user behaviour on energy use in old dwellings: Case-study analysis of a social housing neighbourhood. *Proceedings of the 5th International Building Physics Conference (IBPC 2012), Kyoto, Japan*, pp. 809–16

de Meester, T., et al. 2013. Impacts of occupant behaviours on residential heating consumption for detached houses in a temperate climate in the northern part of Europe. *Energy and Buildings* 57:313–23.

Guerra Santin, O., 2010. Actual energy consumption in dwellings. The effect of energy performance regulations and occupant behavior. PhD thesis, IOS Press BV, Amsterdam, The Netherlands.

Hens, H., et al. 2009. Energy consumption for heating and rebound effects. *Energy and Buildings* 42(1):105–10.

ISO. 2007. EN ISO 13790, *Energy performance of buildings – Calculation of energy use for space heating and cooling*. Geneva: International Organization for Standardization.

Laverge, J., et al. 2010. Airtightness assessment of newly built single family houses in Belgium, Building and ductwork air-tightness. *Proceedings of the 5th International Symposium on Building and Ductwork Air-tightness (Buildair 2010)*, Copenhagen/Lyngby, Denmark.

Laverge, J., et al. 2011. Energy saving potential and repercussions on indoor air quality of demand controlled residential ventilation strategies. *Building and Environment* 46: 1497–1503.

Mishra, A.K,. and Ramgopal, M., 2013. Field studies on human thermal comfort—An overview. *Building and Environment* 64:94–106.

Rosseel, S. 2008. Optimalisatie van concepten voor vraaggestuurde residentiële ventilatie. (In Dutch. Optimalisation of concepts for demand-controlled residential ventilation.) Master's thesis, Ghent University, Ghent, Belgium.

van Dijken, F., and A.C. Boerstra. 2010. Onderzoek naar de kwaliteit van ventilatiesystemen in nieuwbouw eengezinswoningen. (In Dutch. Research on the quality of ventilation systems in new single family houses.) BBA Binnenmilieu, Netherlands.

VEA. 2013. EPB-software Vlaanderen, Version 1.7.2. Vlaams Energieagentschap (Flemish Energy Agency), Brussels, Belgium.

WTCB, WENK, VLIET. 1998. *Senvviv: Study on the energy related aspects of new built houses in Flanders: Insulation, ventilation, heating*. (In Dutch. Senvviv: Studie van de energieaspecten van nieuwbouwwoningen in Vlaanderen: Isolatie, ventilatie, verwarming.)