Modelling the Effect of the Domestic Occupancy Profiles on Predicted Energy Demand of the Energy Efficient House

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Abstract

The objective of the article is to present simulation results of the effect of domestic occupancy profiles on the energy performance of energy efficient house located in Lithuania. The study has assessed the influence of the dwellers’ characteristics and behaviour on the energy demand for heating, lighting and ventilation. Four different occupancy profiles were simulated over the period of one year using the time step of one hour. Four different thermal comfort strategies for different occupancy profiles were analysed as well. Simulation results clearly show that age, behaviour and number of occupants have to be taken into account when performing building energy simulations, especially for energy efficient houses. Results show that assumptions concerning the characteristics and behaviour of occupants play an important role in performing simulations of energy efficient residential houses. Therefore, it is recommended to collect as much as possible information on the occupants and their preferences, and avoid using preset occupancy profiles if more accurate data is available.

Keywords: occupancy profiles; comfort strategies; energy efficient house.

1. Introduction

A study carried out within the project "Building and Renewable Energy Sustainability Model (PATEnMod)" (hereinafter - the project) funded by the Research Council of Lithuania is presented in this paper. One of the aims of the project is to investigate low energy buildings. This objective corresponds to the European Union’s targets for 2020: deployment of nearly zero energy buildings. Architectural and engineering solutions of buildings must be adapted according to the climatic conditions. The goal of the project is to develop and test a model for the assessment of the energy, exergy (thermodynamic) and ecological (environmental impact during the whole life cycle) efficiency of building energy systems (heating, ventilation, cooling, hot water systems, lighting) using renewable energy. The study is based on the assumption that the highest energy efficiency potential is on end-user side. In most cases building energy systems function independently of each other. Interactions between different energy systems are not taken into account; therefore to optimise the energy consumption an integrated analysis of different building energy systems is required.

An integrated or whole building design process involves the analysis of the impacts and interactions of all building components and external factors on the energy demand. Such factors, as the location; the building envelope; the design of...
heating, ventilation, air conditioning (HVAC) and lighting systems, and chosen control strategies have significant impact on the energy consumption. Kim et al. [1] proposed an energy efficient building design process using data mining technology. The case study revealed that the data mining based energy simulation helps project teams to discover useful patterns for improving energy efficiency of the building during the design phase.

The energy efficiency of buildings has to be estimated at an early design stage. Solutions made at this stage determine building’s environmental performance during the entire life cycle. Souza [2] debates on rethinking and reassessing of what issues could be potentially addressed to allow the building simulation tools to be used in more efficient way throughout the whole building design process. The author invites to explore and expand the scope of possibilities for the research in this area by experimenting with new methods, focused initially on qualitative and participatory investigations. Later Souza [3] has analysed the steps designers undertake in solving design problem including thermal comfort, energy efficiency and the testing of passive design strategies.

Buildings usually do not perform as predicted, even when very sophisticated energy simulation methods are used [4-8]. Some scientists call it a ‘performance gap’ or ‘rebound effect’. One of the reasons of such discrepancy between models and real buildings is the influence of human behaviour and the preferences of occupants. For the prediction of energy consumption in particular building the energy consumption pattern in that building has to be known. In office buildings occupancy profiles, electricity load profiles as well as heat load profiles can be predicted properly, because it is known, when people are in the building and when the required comfort has to be maintained [9]. It is more difficult to predict the energy consumption patterns in residential buildings, especially in single family houses, since they depend on many factors, such as: price of energy, users awareness of energy issues, gender, age, employment, family size, socio-cultural belonging, etc. [10-14]. It means that the energy consumption profiles of HVAC systems, domestic hot water systems and electricity have to be known. The electricity consumption in buildings can be estimated indirectly by assuming the activities that people perform when they are at home and awake [15]. Active occupancy also depends on seasonality. Torriti [15] has explored peak electricity demand issues in residential buildings with regards to timing of active occupancy of single-person households in 15 European countries and assessed national variance in occupancy levels at the aggregate European level using Hetus (Harmonised European Time Use Survey) data. Hetus [16] provides statistical data of people’s use of time in different European countries. Analysis of these data shows that there are differences in time spent for different activities depending on culture. The dependency on the climate zone is also obvious. For example, the use of time in Lithuania (northern country) and Italy (southern country) differs. In southern part of Europe people spend more time for eating and leisure compared to north. (See Fig. 1).

![Fig. 1. Illustration of time use during the day in (a) Lithuania and (b) Italy. Source: Harmonised European Time Use Survey [16]](image-url)
It is seen from the Fig. 2 that people in different EU countries spend their time differently. The most notable difference in spending time is related to the employment. Inhabitants in Lithuania, Latvia and Estonia, spend more time at work compared to other countries. In Lithuania people spend less time on leisure activities and more on domestic work. Meanwhile in Finland, Germany and Norway people spend comparatively more time on leisure activities. People in France and in Bulgaria spend more time on personal care (sleeping, eating, etc.) compared to other countries. Summarizing the analysis of the use of time it could be concluded that in different countries inhabitants behave differently. It has to be taken into account when predicting the building energy demand using simulation tools at the design stage.

The research of Al-Mumin et al. [17] confirms the findings of Torriti [15]. In their study they compared the occupancy patterns in the households in USA and Kuwait. They showed that there is an obvious difference in lifestyles and behaviour of residents in these countries. Therefore, the energy consumption patterns are also different. In their study the increase of electricity demand by 21 % was observed when the occupancy profile, included in the simulation tool, was compared with the measured occupancy pattern in Kuwait.

De Meester et al. [18] investigated the influence of three factors related to human behaviour: family size, the control mode of the heating system and management of the heated area, on the heating loads of a standard dwelling in Belgium. The simulations of the building with different insulation levels showed that the impact of internal gains (occupant’s lifestyle) on energy consumption is more significant for the building with better thermal insulation. Guerra Santín et al. [19] analysed the effect of occupants’ behaviour on energy consumption for heating. Results of their study showed that the behaviour of occupants affect the energy demand significantly. Deurinck et al. [20] analysed the effect of building retrofit taking into account different occupancy patterns.

The effect of occupants’ behaviour on building energy consumption was examined by Yu et al. [21] research. Study of Ampatzi and Knight [22] revealed that the balance between potential solar contribution and the need for heat storage are strongly influenced by different variables (weather data, thermal comfort operating schedule, lighting and plug loads) and the effects are more marked in recent, heavily insulated housing. Blom et al. [23] reported that the electricity consumption in buildings with low heat demand had more significant effect on environmental performance of the building.

Although there are many studies on prediction of energy performance in buildings, there is still little information on the effect of occupants’ behaviour on energy consumption. The aim of this article is to investigate, using simulation and modelling tools, the effect of building occupancy on the energy performance in energy efficient house in Lithuanian climate conditions.

2. Methods for assessing energy consumption in buildings

In common engineering practice simplified building energy demand calculation methods prevail. Usually construction elements and engineering systems are evaluated separately, and human behaviour is assessed only minimally. In Lithuania, according to national methodologies, the energy demand in building is calculated for each month using average monthly values of temperature, solar radiation, etc. Energy demand calculations can also be carried out in accordance with ISO standard “Energy performance of buildings - Calculation of energy use for space heating and cooling” (ISO 13790:2008).
According to Clarke [25] the building should be seen as a complex, dynamic and nonlinear system (multiple parts of a whole and connected with each other in many different interactions) where parameters change at different speeds, and they depend on the thermodynamic state). Simplified methods, used in the engineering practice, are not always capable of evaluating complex systems. Therefore, the use of computer simulation programs is required.

Incorporation of computational methods in architecture makes building performance analysis possible at the early stage of the design process. Capturing complex dependencies and viewing the building as a system makes new approaches in architecture possible. Schlueter and Thesseling [26] in their research calculated energy balances and used the concept of exergy to evaluate the quality of energy sources. Researchers described a prototypical tool integrated into a building information modelling software, enabling instantaneous energy and exergy calculations and graphical visualisation of the resulting performance indices. Vakiloroaya et al. [27] showed in their study how to minimise efficiently the overall power consumption of the whole system with controlled variables by using simulation tools. Authors used simulation and optimization to maximise energy savings of a central cooling plant in an office building. Simulation–experimental results showed that significant improvements in energy-efficiency and performance of the air-cooled central cooling plant HVAC system can be achieved, especially at part load conditions. Korjenic and Bednar [28] presented the concept of using dynamic simulation as an instrument for increasing the total energy performance and conducted analysis of HVAC systems in office building. The research showed that initial information on building energy demand profiles including the energy use for HVAC equipment was necessary to predict the energy consumption correctly and to obtain accurate results.

Simulation tools can be supported by numerical or analytical integrated simulation techniques. Integrated simulation methods can be divided into two groups: analytical and numerical. They are described in details by Clarke [25] and Underwood and Yik [29]. Despite the fact that both of these method groups have their advantages and disadvantages, both are suitable for the building energy performance assessment.

In this study DesignBuilder, which is an interface of simulation engine EnergyPlus, has been used. The DesignBuilder is a dynamic building simulation tool that uses an analytical response function method. To obtain the model that is physically realistic the elements are linked in a simultaneous solution scheme. The entire integrated solution is represented as a series of functional elements connected by two fluid loops: air loop (between the demand zone and the system) and water loop (between the system and the plant). The basis for the zone and air system integration of the EnergyPlus engine is to formulate energy and moisture balances for the zone air and solve the resulting ordinary differential equations using a predictor-corrector approach. Solution scheme generally relies on successive substitution iteration to reconcile supply and demand using the Gauss-Seidell philosophy of continuous updating [30]. Validation of the tool and the principle of operation is described in more detail in Motuziene’s [31] dissertation.

Using the DesignBuilder the geometry of the building model is created. Building energy simulations using selected 1 hour time step for the period of one year are performed using EnergyPlus program. The results are obtained in the DesignBuilder and later are imported into Excel file. Then data processing and analysis are carried out.

At the beginning the location of the building, including climatic data, is defined. In the next step the building geometry is created. Then the selection of building structures, occupancy patterns, operation profiles of HVAC equipment and heat gains are selected from the database or created. Finally, the desired building comfort conditions are set and parameters of lighting and HVAC systems are indicated.

3. Concept of the model

Geometry. One-storey, square-shaped house was selected as an object for the analysis (Fig. 3). When creating a building model, several assumptions were made:

- the house was designed for the standard Lithuanian family consisting of 4 members (2 adults and 2 children);
- thermal (for the heating period, since summer comfort is not analysed in this paper) and visual comfort, corresponding to requirements of national hygiene norms, was maintained during the occupancy hours;
- the shape of the building was compact (small surface/volume ratio);
- the plan and geometry of the house were suitable for developing a multi-storey residential building model for future analysis;
- the building was energy efficient.

The total area of the analysed building was 81 m².

Weather data. Typical meteorological weather data of Kaunas city (Lithuania) was used. In the analysis the whole typical year from the IWEC [32] data files were taken. The design temperature for heating in Kaunas of –19.3 ºC was assumed.
Structural elements of the building. Structural elements of the building were selected according to the requirements of the national standard STR 2.01.09:2012 [33] for buildings with an energy performance label A+. Economical availability of construction materials was also taken into account. To minimise the risk of overheating in summer and heat losses in winter the size of windows in different orientation facades was selected taking into account the recommendations given by NorthPass project [34] and according to the requirement of national standard STR 2.02.09:2005 [35]. The minimum allowable sizes of windows were selected to satisfy minimum lighting levels during the day time. Thermal properties of the structural elements are presented in table 1.

Lighting. It was assumed that lighting system operated during the occupancy. Lighting levels were chosen according to the national regulations (STR 2.02.09:2005) [35]: bathroom – 75 lx, bedrooms – 200 lx, living room and kitchen – 300 lx, hall – 100 lx. Assumed specific lamp power of 3 W/m$^2$/100 lx was used.

| Construction        | U-value, W/m2K |
|---------------------|----------------|
| External wall       | 0.112          |
| Foundation          | 0.567          |
| Floor on the ground | 0.140          |
| Roof                | 0.105          |
| Internal partitions | 1.493          |
| Windows             | 0.77           |

Table 1: U-values of the building partitions

| Room      | Standard required temperature, ºC |
|-----------|-----------------------------------|
| Kitchen   | 18-22                             |
| Bathroom  | 20-23                             |
| Bedroom 1 | 18-22                             |
| Bedroom 2 | 18-22                             |
| Lounge    | 18-22                             |
| Hall (circulation area) | 14-16                          |

Table 2: Internal required temperatures (HN 42:2009)

Comfort. Internal temperatures were selected according to the requirements of the standard (HN 42:2009) [36], see Table 2. For the base case, during the occupancy hours, the highest temperature was selected, assuming that high comfort level should be maintained. Since in reality occupants tend to heat their homes just at the time of their presence [20], the comfort temperature was maintained during the occupancy hours only and one hour before the occupants came back home. For the base case, heating set back temperature was set 3°C lower compared with the standard temperature for all rooms except the hall. The setback temperature is a temperature that is maintained when rooms are unoccupied.

Mechanical ventilation system with heat recovery unit was designed in the building. Air flows were selected according to the requirements of national standards. Fresh air was supplied during the hours when building was occupied and one hour before the occupants came back home. During the unoccupied hours the system operated in recirculation mode. The total air change rate in the building of 0.6 h$^{-1}$ was assumed including the infiltration and mechanical ventilation. The air change rate
was kept constant for all occupancy patterns, since the supplied air flows were selected according to the area of the building, but not according to the number of occupants.

**Occupancy profiles.** Building profiles describe how buildings are used. For the base case the default occupancy schedules proposed by the simulation software were assumed. Occupancy was taken separately for weekdays, weekends and holidays, i.e. schedules varied during the year. Lighting, heating and ventilation systems operated as described above.

Since occupancy profiles of residential buildings included in the DesignBuilder (EnergyPlus) did not correspond to the life style of northern Europe dwellers and did not reflect the age of occupants and their activities, more realistic alternatives were simulated and compared, see Table 3).

Table 3. Description of alternative occupancy profiles

| Occupancy profile | Household characteristics |
|-------------------|---------------------------|
| OP1               | Standard residential occupancy profile for different zones of the building designed in DesignBuilder. Household size is 4 people |
| OP2               | Household size is 4 people (statistical Lithuanian family is 3.5 people), parents are actively working, 2 children stay at school or kindergarten during the working hours, children come back home together with parents. |
| OP3               | Household size is 2 people, actively working couple |
| OP4               | Household size is 2 people, retired couple |

Occupancy patterns for the cases OP2-OP4 were created according to Belgian [18] and Hetus [16] data and taking into account the habits of the dwellers in Lithuania. Occupancy profile of the hall was not analysed as no reliable data except DesignBuilder had been found.

The maximum occupancy in premises was assumed:
- bedroom 1 (in case of OP1, OP2 it’s used as bedroom of children, OP3 – used as office room, OP4 – is used as spare bedroom) – 2 persons,
- bedroom 2 – 2 persons,
- kitchen – 2 or 4 persons (depending on the size of household),
- living room – 2 or 4 persons (depending on the size of household),
- bathroom – 1 person.

Occupancy profiles were expressed using the occupancy profiles, which were calculated as a ratio of actual and maximum possible occupancies (Fig. 4).

**Heating strategies.** Appropriate use of programmable thermostats is the easiest ways to save energy without reducing the comfort. However, even if the occupancy profiles are known, it is difficult to predict the preferences of occupants, before the building energy system starts its operation. In this study the effect different heating strategies on energy consumption in the building was analysed assuming different building occupancy profiles.

Four different thermal comfort strategies using different occupancy patterns were analysed (see table 4):
- COM1: high internal temperatures are maintained during the occupied hours, the setback temperatures were set 3ºC below the maximum value during the unoccupied hours. The exception is the hall, where temperature was always low. This case was assumed as the base case, when the influence of the occupancy profiles was analysed;
- COM2: high internal temperatures are maintained during the occupied hours, the setback temperatures were set 4ºC below the maximum value during the unoccupied hours;
- COM3: average temperatures are maintained during the occupied hours, the setback temperatures were set 2ºC below the maximum value during the unoccupied hours;
- COM4: average temperatures are maintained during the occupied hours and unoccupied hours without temperature reduction.

Table 4. Assumed temperatures depending on the occupancy profiles

| Room     | Assumed set /setback temperatures, ºC |
|----------|---------------------------------------|
|          | COM1 | COM2 | COM3 | COM4 |
| Kitchen  | 22/19| 22/18| 20/18| 20   |
| Bathroom | 23/20| 23/19| 21/19| 21   |
| Bedroom 1| 22/19| 22/18| 20/18| 20   |
| Bedroom 2| 22/19| 22/18| 20/18| 20   |
| Lounge   | 22/19| 22/18| 20/18| 20   |
4. Simulation results

Influence of occupancy profiles. The primary aim of the study was to assess the influence of the dwellers’ characteristics (number and age of the occupants) and behaviour on the energy consumption for heating, ventilation and lighting systems. Four different cases of occupancy profiles were simulated during the period of one year using the time step of one hour. Energy demand for domestic hot water systems was not taken into account in this study.

Results (Fig. 5) show that for a family of four, using the adapted more realistic occupancy profiles of European family, the difference in heating energy demand is 8%, electricity for lighting is 7%, and auxiliary electricity for HVAC equipment is –4% compared with the default profiles available in the simulation tool DesignBuilder. These differences are relatively small, so it can be concluded that the profiles set in the DesignBuilder are suitable for use for European houses, when the objective is to evaluate the energy performance of the building with above mentioned household size.

If different occupancy profiles are considered in the same building, significant differences in energy consumption may be expected. For example, if there are only two adult occupants (OP3) in a house, the increase of 30% for heating, 1% for electricity for auxiliary equipment and the reduction of 25% for lighting is observed compared with the case OP2. Moreover, if the case with retired couple (OP4), they spend almost all of the day at home and have a spare bedroom is analysed a 43% increase in energy consumption for heating, 30% increase in electricity consumption for auxiliary equipment and 7% rise in energy consumption for lighting is observed compared with the case OP2. It is related to the fact that the ventilation system operates longer and the option of the room temperature is maintained constantly high.
Influence of the heating strategy. When analysing influence of the occupation profiles on the energy demand of the house, heating strategy COM1 was used (high thermal comfort during the heating season and temperatures setback during unoccupied hours). Occupants may have different preferences concerning the internal temperatures during the occupied hours and may apply different heating system management schemes. Therefore influence of the management of the heating system was also simulated to show, how it may influence energy demand of the house.

Simulation was performed for 16 different cases using four occupancy profiles in combination with four heating strategies. The case COM1 was used as the base case for comparison with other control strategies. Results show (Fig. 6) that the base case COM1 and the case COM2 are not the most efficient strategies. Using strategies COM3 and COM4 with different occupancy profiles an increase in savings by 23-31% and 13-24% respectively is observed compared with COM1 case. Using these control strategies significantly higher savings are obtained for the occupancy patterns OP1 and OP2 with four persons in a household. The main reason is that for households with two persons an additional bedroom is used only one hour (case OP3) or is not used at all (occupancy profile OP4). The setback temperature is used for this bedroom all the time. From the results it is seen that the best strategy is to keep an average temperature at +20 °C during the occupied hours.

Fig. 5. Influence of the occupancy profiles on annual energy demand of the building: (a) for heating (gas demand); (b) for lighting (electricity) demand; (c) HVAC auxiliary energy (electricity of fans and pumps).

Fig. 6. Influence of the heating strategy on heating energy demand: (a) heating energy consumption; (b) difference from base case profile COM1.
5. Conclusions

Simulation results clearly show that the age, behaviour and number of occupants have to be taken into account when performing building energy simulations, especially for energy efficient houses.

Preset occupancy profiles available in the simulation tool DesignBuilder can be used for simulations of European houses only for the households with four active persons, when houses are unoccupied during the daytime hours of weekdays. If other occupancy profiles OP3 or OP4 are used large deviations are observed; therefore, the preset occupancy profiles are not suitable.

Analysis of the influence of heating strategies on different occupancy profiles has shown that for all cases savings of 13-31% are observed compared with the base case COM1. Higher savings are obtained for the households with 4 occupants using the same strategies.

Results presented in the paper have illustrated the importance of making correct assumptions concerning the occupancy profiles and heating strategies, and have shown how incorrectly chosen input data can affect the calculation of energy consumption in the building. Seeking to avoid these issues, it is recommended to collect as much as possible information about the occupancy of the house, comfort preferences of the occupants and avoid using standard profiles, before performing building energy simulations. Since ventilation systems have considerable effect on the energy performance of efficient buildings it is planned to perform analysis on their impact on energy consumption in the nearest future.

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References

[1] Kim, H., Stumpf, A., Kim, W., 2011. Analysis of an energy efficient building design through data mining approach, Automation in Construction 20, pp. 37-43. http://dx.doi.org/10.1016/j.autcon.2010.07.006

[2] Bleil de Souza, C. 2012. Contrasting paradigms of design thinking: The building thermal simulation tool user vs. the building designer, Automation in Construction 22, pp. 112-122. http://dx.doi.org/10.1016/j.autcon.2011.09.008

[3] Bleil de Souza, C., 2013. Studies into the use of building thermal physics to inform design decision making. Automation in Construction 30, p. 81-93. doi:10.1016/j.autcon.2012.11.026

[4] Menezes, A.C., Cripps, A., Bouchlaghem, D., Buswell, R., 2012. Predicted vs. actual energy performance of non-domestic buildings: Using post-occupancy evaluation data to reduce the performance gap. Applied Energy 97, pp. 355-364. http://dx.doi.org/10.1016/j.apenergy.2011.11.075

[5] Bordass, B., Cohen, R., Standeven, M., Leaman, A. 2001. Assessing building performance in use 3: energy performance of the Probe buildings, Building Research & Information 29, pp. 114-128. http://dx.doi.org/10.1080/096132100100080836

[6] Sunikka-Blank, M. and Galvin, R. 2012. Introducing the prebound effect: the gap between performance and actual energy consumption, Building Research and Information 40(3), pp. 260-273. http://dx.doi.org/10.1080/096132109573096

[7] Majcen, D., Itard, L.C.M., Visscher, H., 2013. Theoretical vs. actual energy consumption of labelled dwellings in the Netherlands: Discrepancies and policy implications, Energy Policy 54, pp. 125-136. http://dx.doi.org/10.1016/j.enpol.2012.11.008

[8] Branco, G., Luchal, B., Gallinelli, P., Weber, W., 2004. Predicted versus observed heat consumption of a low energy multifamily complex in Switzerland based on long-term experimental data, Energy and Buildings 36, p. 543–555. http://dx.doi.org/10.1016/j.enbuild.2004.01.028

[9] Azar, E., Menassa, C. C., 2012. A comprehensive analysis of the impact of occupancy parameters in energy simulation of office buildings, Energy and Buildings 55, pp. 841-853. http://dx.doi.org/10.1016/j.enbuild.2012.10.002

[10] Lindén, A.-L., Carlsson-Kanyama, A., Eriksson, B., 2006. Efficient and inefficient aspects of residential energy behaviour: What are the policy instruments for change? Energy Policy 34, pp. 1918-1927. http://dx.doi.org/10.1016/j.enpol.2005.01.015

[11] Carlsson-Kanyama, A., Lindén, A.-L., 2007. Energy efficiency in residences - Challenges for women and men in the North, Energy Policy 35, p. 2163–2172. http://dx.doi.org/10.1016/j.enpol.2006.06.018

[12] Andersen, R.V., Toftum, J., Andersen, K.K., Olesen, B.W. 2009. Survey of occupant behaviour and control of indoor environment in Danish dwellings, Energy and Buildings 41, pp. 11–16. http://dx.doi.org/10.1016/j.enbuild.2008.07.004

[13] Pett, J., Guertler, P. 2004. User behaviour in energy efficient homes Phase 2, Report, p. 68

[14] Kelly, S., Shipworth, M., Shipworth, D., Gentry, M., Wright, A., Pollitt, M., Crawford-Brown, D., Lomas, K., 2012. Predicting the diversity of internal temperatures from the English residential sector using panel methods, Applied Energy 102, pp. 601-621. http://dx.doi.org/10.1016/j.apenergy.2012.08.015

[15] Torriti, J. 2012. Demand Side Management for the European Supergrid: Occupancy variances of European single-person households, Energy Policy 44, p. 199-206. http://dx.doi.org/10.1016/j.enpol.2012.01.039

[16] Hetus (Harmonised European Time Use Survey) [interactive]. Available from Internet: https://www.h2.scb.se/tus/tus/AreaGraphCID.html

[17] Al-Mumin, A., Khattab, O., Sridhar, G., 2003. Occupants' behavior and activity patterns influencing the energy consumption in the Kuwait residences, Energy and Buildings 35, p.549–559. http://dx.doi.org/10.1016/S0378-7788(02)00167-6

[18] De Meester, T., Marique, A.-F., De Herde, A., Reiter, S., 2012. Impacts of occupant behaviours on residential heating consumption for detached houses in a temperate climate of the northern part of Europe, Energy and Buildings 55, pp. 313–323. doi:10.1016/j.enbuild.2012.11.005

[19] Guerra Santin, O., Itard, L., Visscher, H., 2009. The effect of occupancy and building characteristics on energy use for space and water heating in Dutch residential stock, Energy and Buildings 41, pp. 1223-1232. http://dx.doi.org/10.1016/j.enbuild.2009.07.002
[20] Deurinck, M., Saelens, D., Roels, S., 2012. Assessment of the physical part of the temperature takeback for residential retrofits, Energy and Buildings 52, pp. 112-121.

[21] Yu, Z., Fung, B. C. M., Haghighat, F., Yoshino, H., Morofsky, E., 2011. A systematic procedure to study the influence of occupant behavior on building energy consumption, Energy and Buildings 43, pp. 1409-1417. http://dx.doi.org/10.1016/j.enbuild.2011.02.002

[22] Ampatzi, E., Knight, I., 2012. Modelling the effect of realistic domestic energy demand profiles and internal gains on the predicted performance of solar thermal systems. Energy and Buildings 55, pp. 285-298. http://dx.doi.org/10.1016/j.enbuild.2012.08.031

[23] Blom, I., Itard, L., Meijer, A., 2011. Environmental impact of building-related and user-related energy consumption in dwellings, Building and Environment 46, pp. 1657-1669. http://dx.doi.org/10.1016/j.buildenv.2011.02.002

[24] ISO 13790:2008 Energy performance of buildings - Calculation of energy use for space heating and cooling.

[25] Clarke, J.A. 2001. Energy Simulation in Building Design. 2nd Edition. Oxford: Butterworth-Heinemann. 384 p.

[26] Schlueter, A., Thesseling, F., 2009. Building information model based energy/exergy performance assessment in early design stages, Automation in Construction 18, pp. 153-163. http://dx.doi.org/10.1016/j.autcon.2008.07.003

[27] Vakiloroaya, V., Ha, Q.P., Samali, B. 2013. Energy-efficient HVAC systems: Simulation–empirical modelling and gradient optimization, Automation in Construction 31, pp. 176-185. http://dx.doi.org/10.1016/j.autcon.2012.12.006

[28] Korjenic, A., Bednar, T., 2012. Validation and evaluation of total energy use in office buildings: A case study, Automation in Construction 23, p. 64-70. http://dx.doi.org/10.1016/j.autcon.2012.01.001

[29] Underwood, C.P., Yik, F.W. H., 2004. Modelling Methods for Energy in Buildings. Oxford: Blackwell Publishing. 295 p.

[30] EnergyPlus Energy Simulation Software. EnergyPlus Engineering Reference [interactive]. Available from Internet: http://apps1.eere.energy.gov/buildings/energyplus/pdfs/engineeringreference.pdf

[31] Motuziene, V., 2010. Complex analysis of the influence of glazing on energy demand of public buildings: dissertation, p. 158.

[32] IWEC, Weather Files (International Weather for Energy Calculations), ASHRAE, Atlanta, USA, 2009.

[33] STR 2.01.09.2012 “Pastatų energinis naudingumas. Energinio naudingumo sertifikavimas” (The energy efficiency in buildings. The energy certification of buildings).

[34] Principles of low-energy houses applicable in North European countries and their applicability throughout the EU. NorthPass project report, Oct 2010.

[35] STR 2.02.09.2005 “Vienbučiai ir dvibučiai gyvenamieji pastatai” [One and two flat dwellings] (in Lithuanian).

[36] HN 42.2009 “Gyvenamųjų ir visuomeninių pastatų patalpų mikroklimatas” [Indoor climate of residential and public buildings] (in Lithuanian).