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Summer Thermal Comfort in New and Old Apartment Buildings

Mikk Maivel[1]; Jarek Kurnitski[1]; Targo Kalamees[1]

[1] Tallinn University of Technology, Ehitajate tee 5, 19086, Tallinn, Estonia
mikk.maivel@ttu.ee

Abstract

In Nordic countries overheating and cooling systems have not been the issue in apartment buildings. Historically and even in the beginning of 2000 there were not indicated such problems. New architecture with larger windows and strict energy performance requirements has changed the situation. If adequate measures are not used, new buildings may be easily overheated. In the design this is a question of temperature simulations, and application of mostly passive design measures which might be needed to be supported with installation of active cooling system in some cases to fulfil minimum requirements for energy performance and thermal comfort. Even revised EPBD increase the role of overheating problems and suggest using passive cooling technologies like shadings. This study conducted field measurements in more than 100 Estonian apartments. Results show that the overheating occurs in modern buildings where average room temperature was about 1°C higher than in old buildings. According to criterion of weighted excess degree hours over +27 ºC, there was no overheating in old apartment buildings, but in new apartment buildings the criterion was exceeded in 13.7% of apartments in 5 week period. The paper reports field measurements and analyse ventilation, orientation etc. effect on overheating.

Keywords: thermal comfort, indoor climate, overheating problem, apartment building

1. Introduction

Indoor climate`s quality influence our everyday habits and have an substantial role for our health. According to Seppänen studies in Nordic climate people stays approximately 90% of time in artificial environment [1]. In Estonia approximately 63% of residents live in apartments. During last five years extensive analyses were conducted for Estonian housing stock. This paper includes the basic results and findings from two different investigations about housing groups: apartment buildings composed from prefabricated concrete elements [2] and recently built modern apartment buildings [3]. The aim of this paper is to analyse and compare new apartment buildings with soviet era building stock regarding thermal comfort. Paper focus on overheating effect in summer time which causes discomfort especially in recently built apartments. Some passive measures are analysed to avoid overheating in apartments. Thermal comfort analyses are based on actual temperature measurements.

2. Methods

2.1 Studied buildings

Indoor climate was studied in 100 apartments in 48 buildings (Figure 1). 39 apartments where built during the 1960-1990 and 61 during 2001-2010. All of them were in private ownership. From each building approximately two apartments were selected to be studied, mostly from the upper and the bottom floor. Apartments had usually two or three rooms with three inhabitants.

Figure 1 Examples of analysed building (old (left) and new (right)).

2.1.1 Apartment buildings composed of prefabricated concrete elements

Apartments from soviet era have basically three different main types which could have different renovated stage (e.g. partly insulated, new windows etc.). Typically, the studied dwellings had natural passive stack ventilation (73% of studied buildings). In some apartments kitchens were supplied with a hood. In all of the dwellings studied, windows could be opened for airing purposes. Though mechanical ventilation has been the standard installation in new dwellings in Estonia during the last decade, old apartment buildings have preserved natural ventilation due to the complexity of the ventilation renovation.

2.1.2 Modern apartment buildings

Recently built apartments were all with different typology. Buildings were selected with different external wall structures (Figure 2, left) and ventilation systems (Figure 2, right). The selection could represent an average of recently built Estonian apartment buildings.

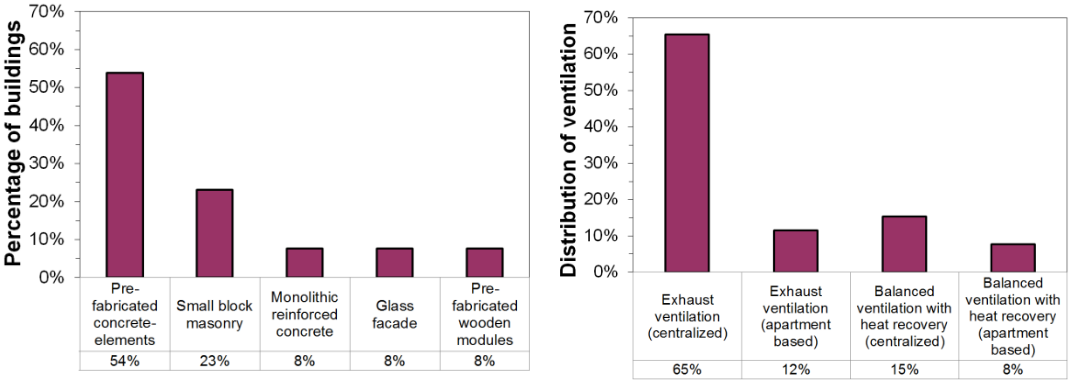


Figure 2 Distribution of studied apartments according to external wall type (left) and ventilation system (right).

2.2 Measurement methods

The values of temperature were measured with data loggers at 1 hour intervals over a 1 year period. The data loggers were located on the partitioning walls mainly in master bedrooms.

Outdoor temperature was obtained from the nearest weather station.

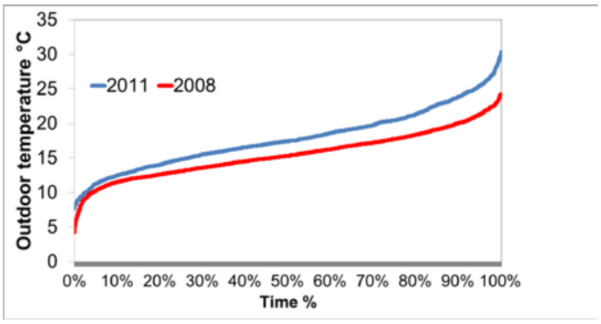
2.3 Assessment of indoor climate

Indoor thermal conditions in the studied apartments were assessed based on the target values from the standards [4], [5]. The II indoor climate category (normal level of expectation, for new buildings: PPD ≈ <10%) and the III indoor climate category (acceptable, moderate level of expectation, for existing buildings: PPD ≈ <15%) were selected for the comparison.

EPBD directive [6] sets mandatory for member states to launch appropriate legislation for new buildings and buildings under major renovations to control and avoid possible overheating. Estonian energy performance of minimum requirements [7] sets as a criteria in apartment buildings 150°C·h over indoor temperature +27°C during the period of 1st. June to 31 august. It is in the same level as suggested by Olesen and Parsons [8] and van der Linden et al. [9] that an acceptable annual weighting time of 100–150 hours may be used as a standard in office buildings.

2.4 Analysing period

Field measurements were carried out in different years (for old apartments 2008 and for new 2011). Overheating was typically investigated for the summer period starting 1st June to 31 August. To make results comparable, the similar weeks of outdoor climate were selected. Average outdoor temperature in 2011 summer was 14.3°C compared to 2008 13.2°C (Figure 3).



Type	Year	(01.june-31.aug) Cooling Degree Hours >17°C
Old	2008	1639
New	2011	4702

Figure 3 Comparison of 2008 and 2011 summer.

To find the weeks with similar outdoor temperature and solar radiation, two summers were compared week by week. (Figure 4, 5)

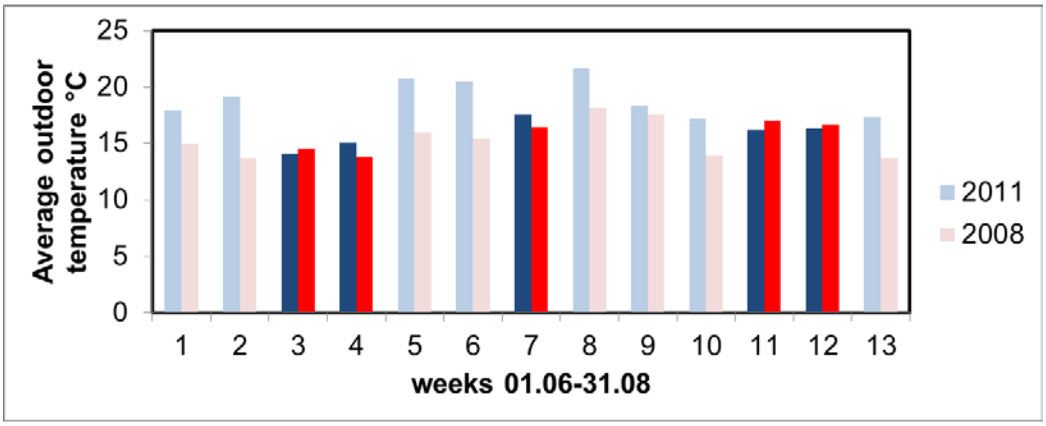


Figure 4 Comparison of 2008 and 2011 summer outdoor temperature.

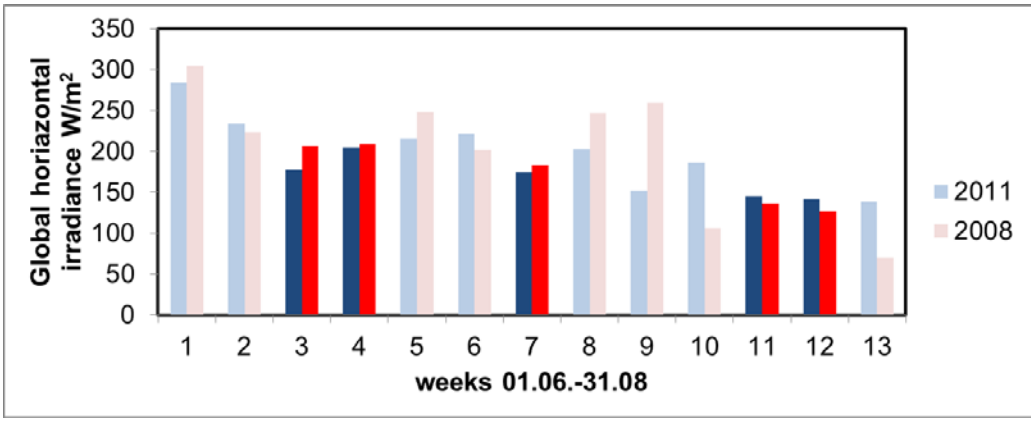


Figure 5 Comparison of 2008 and 2011 summer global irradiance.

Selected weeks are shown as a bold columns. Analyses were based on 5 selected weeks (week no. 3,4,7,11 and 12) during which the outdoor temperature and global irradiance were almost the same as can be seen from duration curves in Figure 6.

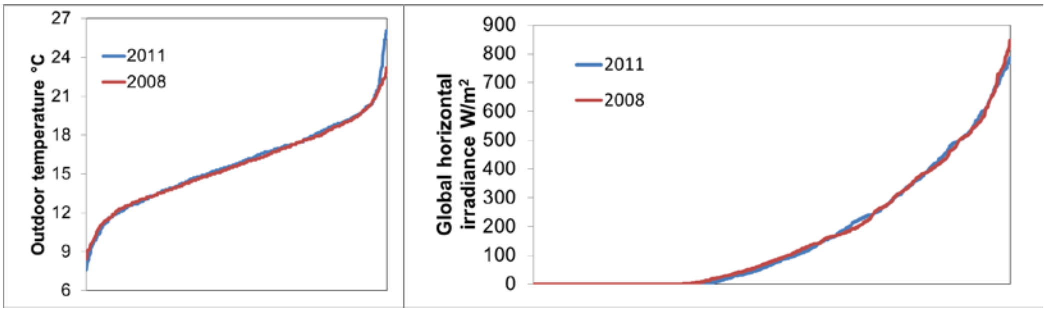


Figure 6 Comparison of 2008 and 2011 summer in selected 5 week period. Duration curve of outdoor temperature (left) and solar radiation (right).

Because of very different summers, the results calculated for three summer months provided biased comparison between old and new buildings: Figure 7 shows that 65% of new apartments exceeded the limit criteria +27ºC in the summer of 2011 compared to 5.1% of old apartments exceeded the limit in 2008.

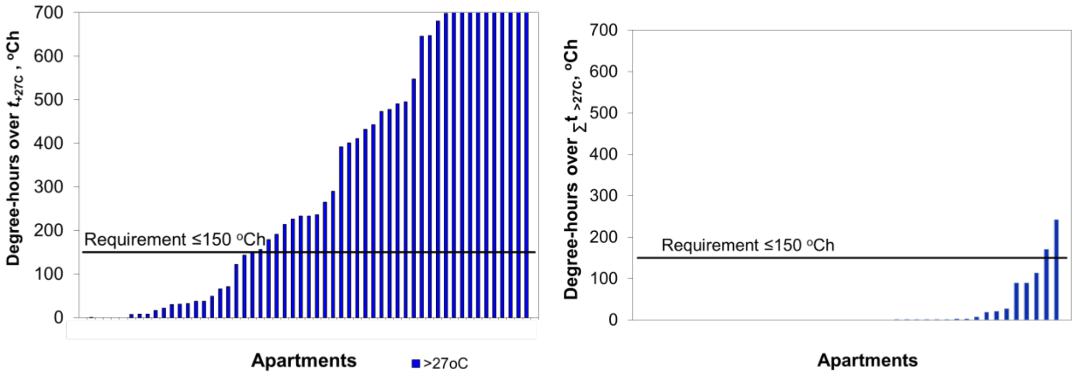


Figure 7 The amount of weighted excess degree hours over +27 °C in three summer months in new (left) compared to old (right) – the results do not provide objective comparison between building types because outdoor temperature was much higher in the case of left figure.

3. Results

The results reported in this chapter are from selected 5 weeks period, which enables objective comparison between old and new apartment buildings.

3.1. Ventilation impact on possible overheating.

Ventilation has a substantial role for indoor quality. As reported in previous section analysed building has different ventilation systems (Figure 2). Normally old buildings have natural (passive stack) ventilation and summer time air change occurred mostly by airing the windows. Stack ventilation during summer is minimum duo to small difference of indoor and outdoor temperatures.

New buildings have normally more advanced ventilation systems (Figure 3).

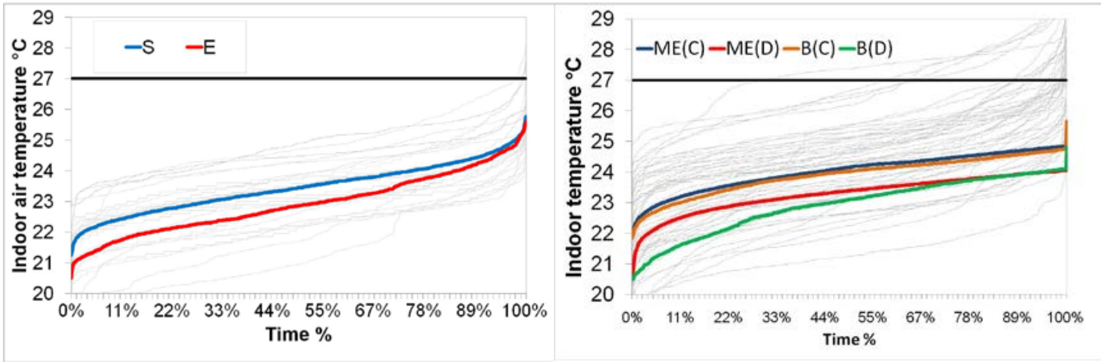


Figure 8 ventilation effect on indoor temperature in old buildings(left) and new buildings (right) (S – passive stack ventilation; E – apartment with mechanical exhaust ventilation; ME(C) – centralized exhaust ventilation; ME(D) – apartment based exhaust ventilation; B(C) – centralized balanced ventilation with heat recovery; B(D) – apartment based balanced ventilation with heat recovery).

Figure 8 shows that old apartments with mehanical ventilation have a slightly lower indoor temperature (average with natural stack ventilation is 23.4°C (st.dev. 0.79°C) compared to 22.9°C (st.dev. 0.97ºC with mechanical exhaust ventilation).

In new buildings apartment ventilation units have ensured approximately 0.8 °C lower indoor temperature than centralized systems. With apartment exhaust ventilation units, average indoor temperature was 23.2°C (st.dev. 0.59°C) compared to centralized exhaust ventilation 24.01°C (st.dev. 0.60°C). The same tendency was in heat recovery systems where apartment supply and extract ventilation units with heat recovery showed average indoor temperature of 22.9°C (st.dev. 0.90°C) and centralized balanced ventilation system 23.89°C (st.dev. 0.61°C).

3.2 Cooling impact on possible overheating.

One solution to avoid overheating is to install active cooling system, Figure 9. Active cooling systems are expensive and obviously add extra energy for cooling making it difficult to fulfil minimum requirements for energy performance [10]. Only one building in this study had an active cooling system. This building was high rise (25 storeys) and with high-share of glass façade. Rooms with active cooling had an average indoor temperature during 5 week time 23.1°C (st.dev 1.25°C) and indoor temperature in similar building without active cooling was 24.62°C (st.dev 1.06°C).

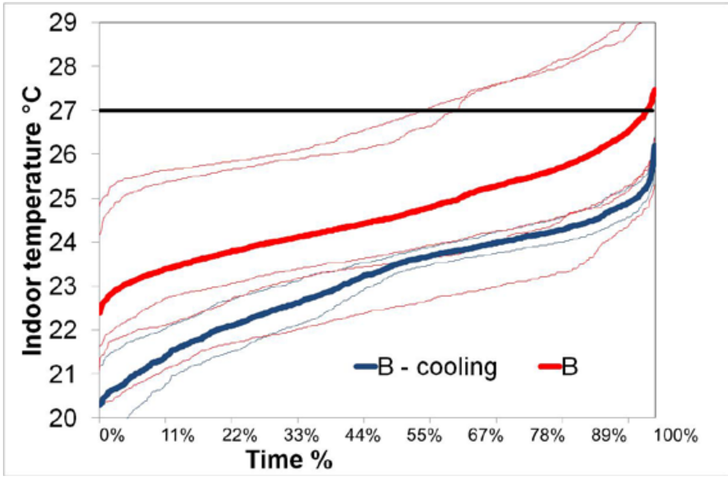


Figure 9 Cooling effect for indoor temperature in new building (B-cooling – balanced ventilation with cooling; B – balanced ventilation).

3.3. Window area and orientation impact on possible overheating.

New buildings have higher-share of windows than old ones. In new buildings window area per room floor area where in the range of 0.18 to 0.45 (average 0.25) and in old buildings between 0.1 to 0.21 (average 0.15), (Figure 10).

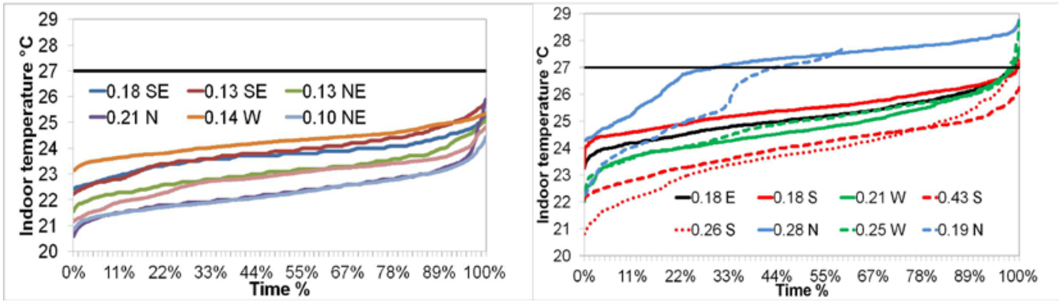


Figure 10 Indoor temperatures as a function of window to floor ratio and orientation, old buildings in the left and new buildings in the right. Code: 0.18 SE means window to floor ration 0.18 and SE orientation of windows (N-north, SE – South-East, NE – north east, W-west).

Some of results in Figure 10 are logical, but some ones are not. Possible explanation are many confounding factors which are not possible to take into account in such field measurements (shadings by balconies, and other buildings, differences in window airing and internal heat gains etc.).

3.4 Indoor temperature as a function of the outdoor temperature.

Hourly average indoor temperatures in all new apartments were by about +1°C higher than in old apartments (Figure 11).

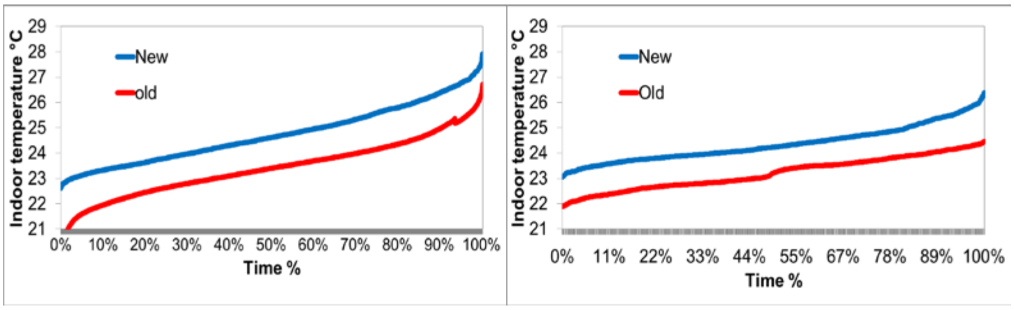


Figure 11 Comparison of new and old apartment indoor temperature during 5 week period (right), 3 month period (left)).

To see the outdoor temperature dependency, from each room at each hourly outdoor air temperature (the step of 1°C was used), all hourly daily indoor temperature values were plotted, Figure 12. Each individual thin solid curve shows the average indoor temperature hourly values at the corresponding outdoor temperature value in one apartment. The dotted curve represents the average curve from all the apartments

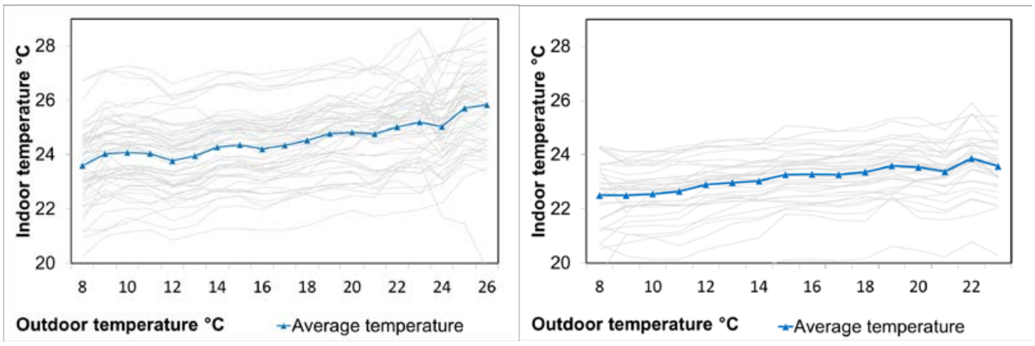


Figure 12 Indoor temperature as a fuction of outdoor temperature in new (left) and old (right) apartments, the results are reported from three summer months.

3.5 Overheating

To analyse the overheating, the amount of weighted excess degree hours over +27 ºC was calculated for selected 5 weeks period. Because the Estonian criterion of 150 °Ch applies for three summer months (13 weeks), the results shown in Figure 13 need to be multiplied with factor of 13/5=2.6 in order to take into account the effect of shorter analysing period. Results show no overheating in old apartment buildings, but in new apartment buildings the criterion of 150/2.6 °Ch was exceeded in 13.7% of apartments.

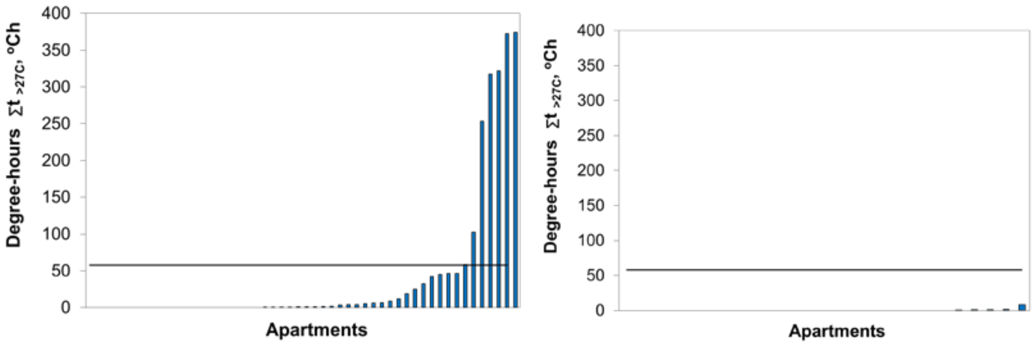


Figure 13 The amount of weighted excess degree hours over +27 °C in five summer week in new (left) compared to old (right).

4. Conclusion

The possible overheating effect in recently built apartment buildings compared with old prefabricated concrete apartment buildings was analysed in this study. The results show that in new Estonian apartment buildings average room temperatures were by about 1°C higher than in old buildings. Larger windows partially explained higher temperatures, but the correlation was weak and sometimes inconsistent because of many confounding factors not possible to control in this type of field measurements. Further analyses are needed to explain the reasons of significantly higher temperature in new apartments. High room temperatures indicate that more attention should be paid to passive solar shading and airing measures. According to criterion of weighted excess degree hours over +27 ºC, there was no overheating in old apartment buildings, but in new apartment buildings the criterion was exceeded in 13.7% of apartments in 5 week period.

Acknowledgment

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