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HEAT SAVING RESERVE IN RESIDENTIAL BUILDINGS

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Abstract. The paper concerns thermal energy consumption in residential buildings. Heat consumption data of more than two thousands buildings are compared. Special attention is given to compare heat consumption in identical buildings as former Soviet practice of housing construction has been based on repetitive multiflat buildings. Heat consumption in sister-buildings differs up to two times. The conclusion may be drawn up that this phenomenon is caused mainly by inappropriate behaviour of tenants, lack of qualified service and construction faults. Identical multiflat residential buildings heat consumption data gives the possibility to evaluate influence of local factors as maintenance, uncertainty of structure dimensions or construction materials thermal properties. Huge heat saving reserves lie not only in renovation but also in less visible but not less effective building maintenance scrutinization and control.

Keywords: residential buildings, heat consumption, heating.

1. Introduction.

Energy in a building is used to ensure operating of numerous building services. Heating, ventilation and air conditioning (HVAC) systems are the most energy consuming systems. Annual heat consumption in residential building for heating and ventilation depends on building thermal properties and climate severity.

In latter years building envelope thermal resistance became several times higher, especially in the Baltic States where required thermal resistance of building envelope has been markedly increased compared to thermal resistance twenty years ago, e.g., resistance of walls was heightened five times.

Real building heat loss and gain ratio differs from theoretical single building analysis; most of buildings outperform or underperform mean theoretical heat consumption value [1]. Highly influencing heat consumption factors as quality of works, building maintenance, behaviour of residents are rather indeterminated and not rated at building design phase. Soviet time's multiflat multifold standard residential buildings heat consumption gives a possibility to evaluate influence of these factors. Sufficiently reliable results may be obtained only if large data base is at disposition. District heating commercial payment computerised base contains thousands of carefully checked regular billing data. It gives possibility to compare heat consumption in identical sister-buildings, judging from the outside.

Residential buildings heat consumption scatter is well known natural phenomenon explained by construction peculiarities, various local circumstances, inequality of the same floor area buildings, etc. The question is what heat consumption difference would be if to eliminate construction and architectural solution influence. Identical multiflat residential buildings heat consumption data gives the possibility to evaluate influence of local factors as maintenance, uncertainty of structure dimensions or construction materials thermal properties.

2. Method

The analysis refers to Vilnius district heating company 2006/7 years heat consumption billing data [2]. District heating company provides with heat 3,5 thousands residential buildings, total area 13,5 mln. m^2 (Fig.1). Typical public buildings are not taken into account in this paper because of to small number.

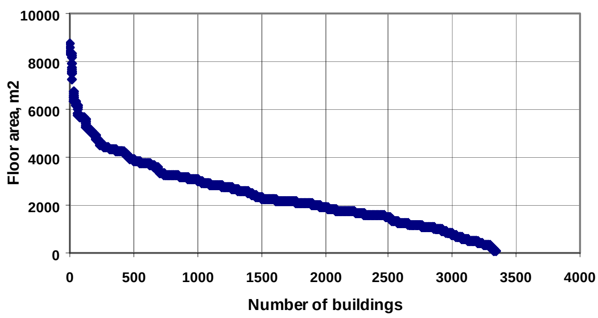

Fig.1 Distribution of residential buildings by floor area

All residential buildings may be divided into large groups in accordance with thermal insulation requirements held at the erection time-span (Table 1).

Thermal insulation requirements were permanently reviewed, however multiflat building proportions stood constant for a long time except last ten years thanks prevailing fenestration enlargement trend. The stability of proportions provides opportunity to parallel thermal transmittance coefficient values and building heat consumption. Acceptable relative values of multiflat building envelope parts were assessed by Lithuanian Architecture and Construction Institute [3]:

Roofs -0,24 m^2/m^2 heated floor area,
Floors over non-heated basement - 0,24 m^2/m^2,
Walls - 0,90 m^2/m^2,
Windows - 0,18 m^2/m^2,
Doors - 0,01 m^2/m^2.

Values of building envelope resultant heat transfer indices are given in the Table 1. In Soviet times building envelope thermal resistance coefficient value fluctuated about values up to the year 1994 given in the Table 1. Intensive energy saving policy started after Lithuania regained independency, in year 1992, till the Second World war there were any numerical values of building envelope thermal properties .

Table 1. Thermal resistance/heat transmittance coefficient legal values,(m^2K/W)/(W/m^2K).

Time span, years	Wall	Window	Roof	Floor	Resultant h. tr. coeff.
Up to the year 1994	1/ 1	0,4/ 2,5	1,2/ 0,83	1,2/ 0,83	1,75
1994-1998-	3,6/ 0,28	0,5/ 2	4,5 / 0,22	2,5/ 0,4	0,70
1998-2005	3,9/ 0,26	0,7/ 1,43	5,7/ 0,18	3,9/ 0,26	0,67
After 2006	5/ 0,2	0,6/ 1,67	6,4/ 0,16	5/ 0,2	0,51

Table 1 is constructed assuming that design and construction works last at least one year, so the first houses designed in accordance with Regulations that came in force in year 2005 were erected in year 2006 and so on. It is expected heat consumption to diminish due air infiltration in the same degree because of more strict airtightness requirements.

Commercial payments base does not include building erection years; it was found tracing new street section or suburb origin or renovation years, buildings of unknown erection year were excluded. Also buildings were excluded which heat consumption figures fluctuated not proportional to indoor/outdoor temperature difference, buildings with domestic hot water electrical heaters, if a building was heated not full period or any doubt has arisen concerning heat consumption figures. After data filtering approx. two thousands buildings were left

The most visible and reliable heat consumption difference takes place at the lowest outdoor temperatures, in the heating season 2006/7 it was February with mean month temperature -7 ^{0}C. Mean outdoor temperature of all other heating season months – October till April was positive. Heating season has begun at October 25 and ended at April 20. Heat consumption was not recalculated to standard year temperature seeing that the task of this analysis do not include annual consumption comparison.

Space heating heat consumption for billing needs is calculated as

$$Q_h = Q_t - G_{d.h.w}(\theta_s - \theta_c)c - Q_{d.h.w.loss}. \qquad (1)$$

and specific heat consumption for heating

$$q = \frac{Q_h}{A_f}, \text{ kWh/m}^2, \qquad (2)$$

where: Q_h – heat consumption for space heating, MWh/month, Q_t – total heat consumption in a building for space and hot water heating, $Q_{d.h.w.loss}$ – domestic hot water system heat loss, $G_{d.h.w}$ – hot water consumption per month, θ_s, ,θ_c – respectively hot and cold water temperatures, c – specific water heat, A_f – total heated area in a building, m^2.

The second constituent in (1) in accordance with [6] is assessed as 51,17 kWh/m^3. Formula (1) is applied only for the billing need. Domestic hot water system heat loss depends on system type, pipe length, power and other factors, e.g. toweldryer type in a bathroom. System equipment is mounted in a building, therefore system heat losses really act as internal heat gains and space heating heat consumption should be calculated without subtracting domestic hot water system heat loss.

Every building is equipped with central water heating system and domestic hot water systems, both connected to district network via separate heat exchangers. All heat substations are computer-assisted, metering data are transmitted to company computational center.

Building heat consumption is measured by general heatmeter and hot water consumption - by flowmeter. Total heat and domestic hot water consumption are measured values. Specific heat consumption, kWh/m^2month, may be calculated in two ways. The first, as it is done by heat supplier using f-la (1). The second, domestic hot water system loss is not taken into account, as domestic hot water system loss takes place in a building and compensates part of infiltration and transmission losses:

$$Q_h = Q_t - G_{d.h.w}(\theta_s - \theta_c)c \qquad (3)$$

Heat billing peculiarities may cause inaccuracy when comparing specific heat consumption in various states, cities or heat consumption in ordinary buildings vs experimental buildings especially equipped by measurement devices.

Domestic hot water system monthly loss (value calculated by DH Company) was checked. The examination has shown that calculation methodology needs to be corrected. Consequently, space heating heat consumption data were recalculated when it was of substantial importance to make conclusions. In a case of sister-buildings recalculation was not carried out since it does not changes heat consumption scattering picture.

New buildings after year 1992 are erected in every circuit, multiflat panel buildings are grouped in strictly delineated circuits, and for short these suburbs are labelled: Baltupiai-B, Fabijoniskes- F, Justiniskes- J, Karoliniskes- K, Lazdynai- L, Virsuliskes- V, Zirmunai-Z. Prewar buildings prevail in the old town.

2. Results

2006/7 heating season may be evaluated as the warmest during the last fifteen years, number of degree-days on the 18 ^{0}C base equals 2836 DD when standard year contains 3815 DD (Fig. 2).

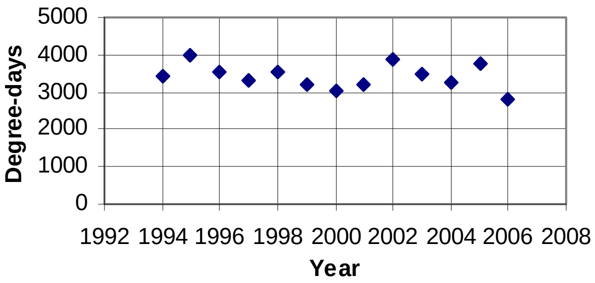

Fig.2 Annual number of degree-days

Specific heat consumption for space heating, kWh/m^2, situation in February is presented on the Fig. 3 (DHW system heat loss is subtracted).

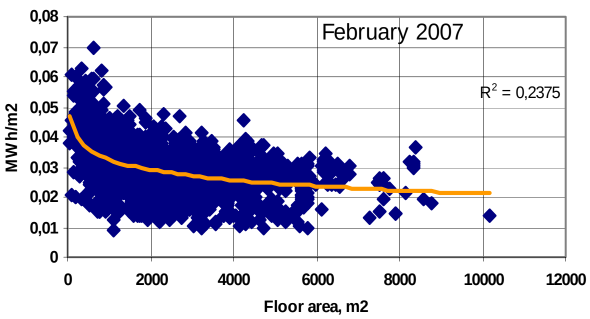

Fig. 3 Specific heat consumption in February versus building floor area

One can see large heat consumption difference up to 6…7 times between the best and worst cases. It does not witness reliably that real difference is so significant even the data were carefully selected in accordance with formal attributes. In this case, R^2 is simply the square of a correlation coefficient. Low or high heat consumption values can happen because of non-regular payment, disorder, fraud, thermal renovation or other reasons.

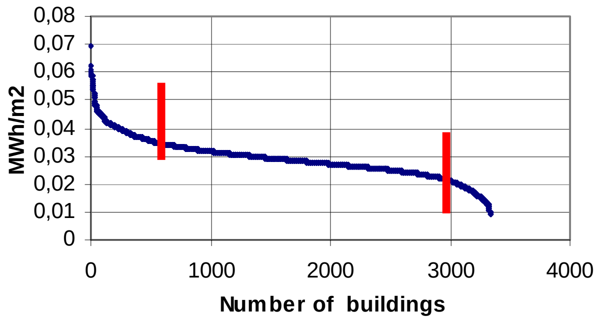

Fig. 4 Specific heat consumption in February versus number of buildings

Heat consumption curve both ends on the Fig. 5 are marked by vertical lines intercepting 10 % best and worst cases. Heat consumption in the 80 % of buildings varies between 40 and 20 kWh/m^2.

Almost all twentieth century total heat consumption was at the same level, only during the last decade we see cardinal changes as the result of real attention to energy saving, and more strict thermal requirements [4, 5].

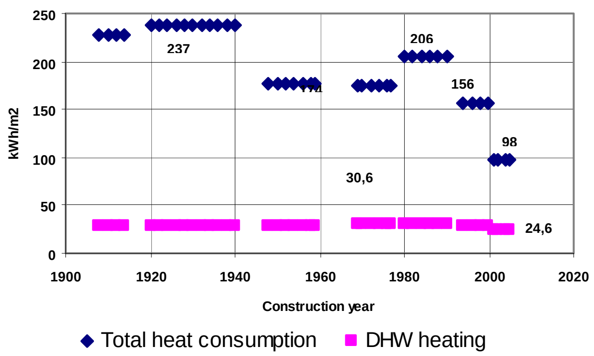

Fig. 5 Annual specific heat consumption trend in Vilnius

Vilnius heat consumption data are worth comparing with Moscow 2006/7 heating season results. Resumptive conclusions of more than 300 Moscow residential buildings are given in [7].

Heat consumption deviation from mean value in Moscow runs at 40-50 %; heat consumption ratio in most consuming/least consuming buildings runs at 2,5 and more (Figs. 6 and 7) or more than in Vilnius case. Moscow data are classified according to the number of floors, so the buildings are similar hower not identical. It causes the larger deviation. More severe Moscow climate causes higher annual heat consumption, not higher disproportions between separate buildings.

Overextending of heat in Moscow case is explained by authorities as the result of non-adjusted district heating water flow and supply water temperature non-correspondence to outdoor air temperature. Heat suppliers are interested in selling more heat. Tenants are used to high by indoor temperature 24-25 ^{0}C and intensive natural ventilation [7].

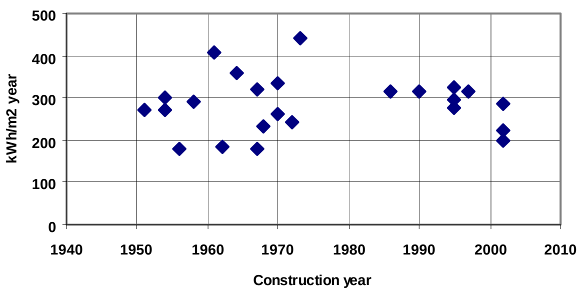

Fig. 6 Annual specific heat consumption in 4-5 floor Moscow buildings

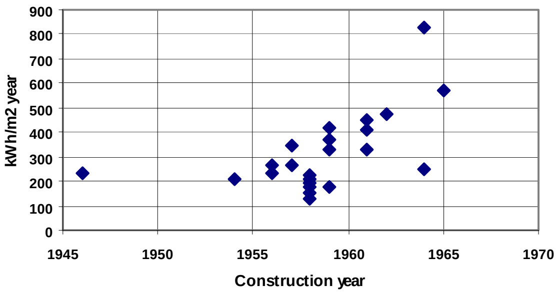

Fig. 7 Annual specific heat consumption in 6-9 floor Moscow buildings

Hot water consumption in Vilnius follows the same pattern as total consumption; it drops from 28-30 kWh/m^2 to 25 kWh/m^2 in the last decade also.

Resolving of the Fig. 3 by circuits and construction year enables to specify heat consumption pattern. The largest heat consumption discrepancy between similar floor area buildings is found in the oldest buildings built before the First World War (Fig. 8). The ratio of maximal and minimal values touches three or even more. No conclusions may be drawn up about influence of not rated circumstances because every building is particular.

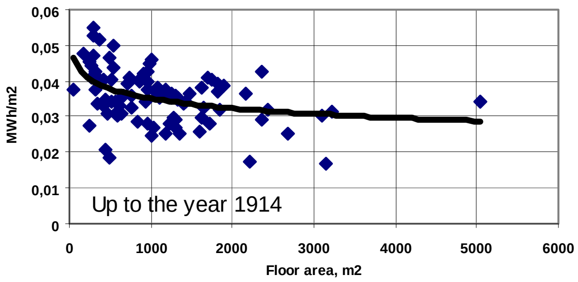

Fig. 8 Specific heat consumption in old buildings

Only multiflat panel buildings are included on Fig. 9. Measurement points are highly dissipated though conversely to old buildings there are distinctly seen vertical ribbons or groups of similar floor area buildings. Panel buildings contain unified area flats so the same floor area may be in vertical or horizontal blocks that is not the same from heat loss view.

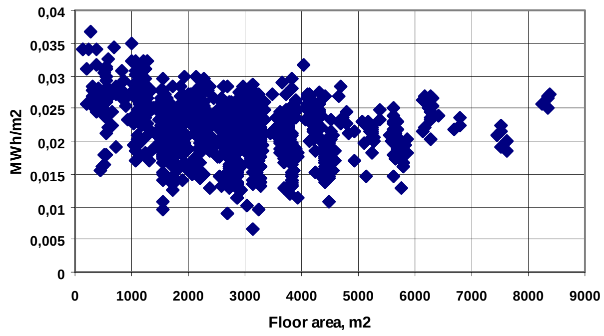

Fig. 9 Specific heat consumption in the circuits L, K, V, Z, J in February

Circuit K is extracted on Fig. 10 from general picture Fig. 9. Vertical point series on the Fig. 10 reflect heat consumption in sister-buildings. The difference between the best and worst cases is up to two times. Explanation of the difference by building surroundings and other inevitable circumstances influence does not seems compelling. Probably the main reason lies in building construction and maintenance faults.

The same situation is found in other multiflat panel buildings circuits when non-panel buildings were excluded – similar buildings heat consumption scatter vertical ribbons are distinctly visible.

Heat consumption data without this screening forms non-speaking cloud (Fig. 3). That is one of the reasons why too little attention is paid to building maintenance as far less expensive heat saving measure than renovation.

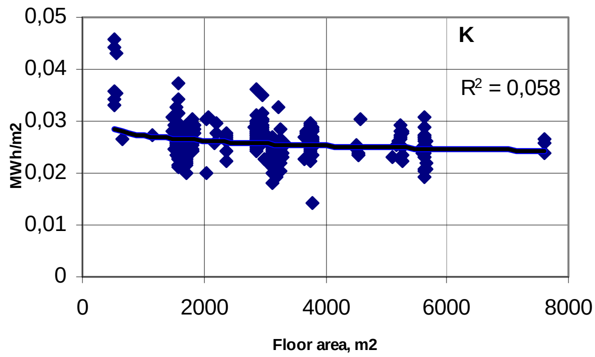

Fig. 10 Specific heat consumption in the circuit K

If similar buildings heat consumption differs up to two times and this phenomenon is not an exception one may conclude that heat saving reserves lie not only in renovation but also in inappropriate behaviour of tenants, lack of qualified service, absence of every much heat consuming building scrutinization.

Fig. 11 presents heat consumption in ten 2710…2715 m^2 sister buildings from the same circuit in February 2007. Heated area floor difference is only 0,2 %, unfortunately consumption in two of them is beyond 2 square deviations from the mean value. Maximal and minimal consumption ratio exceeds 1,7.

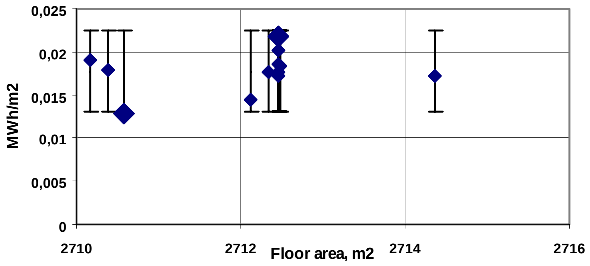

Fig. 11 Specific heat consumption in 2713 m^2 sister-buildings

Similar picture we see in the case of twice large buildings (Fig. 12). Specific heat consumption mean value in February as follows from Figs. 11 and 12 was 17,7 kWh/m^2 month and 1,99 kWh/m^2 month respectively in 2713 m^2 and 5637 m^2 sister-buildings. Heat consumption reduction if all consumption values are below current mean value would be 5-7 % and in total 20-25 % if all specific consumption values are as in the most energy saving building.

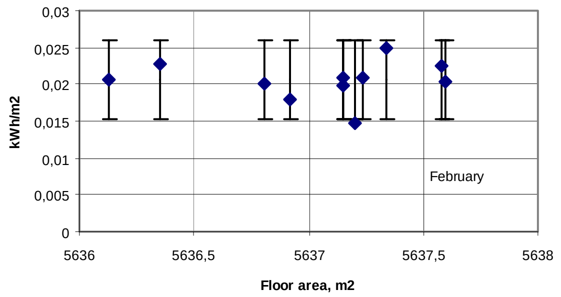

Fig. 12 Specific heat consumption in 5637 m^2 sister-buildings

In Western countries multiflat residential buildings are more diverse, consequently there is complicated to find sufficient number of sister-buildings to draw reliable conclusions.

New well insulated residential houses are built in accordance with up-to-date energy saving requirements. Heat consumption in the best 2001-2005 year buildings is distinctly less however mean value do not correspond to expectations (compare Figs. 11, 12 and 13).

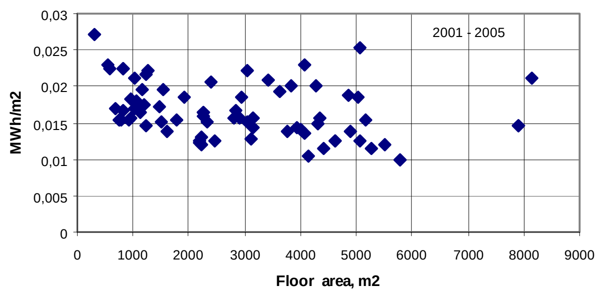

Fig. 13 New buildings specific heat consumption versus floor area

New houses are seldom repeated; there is no possibility to compare sister-buildings however heat consumption scatter is not less than in the old buildings (Fig. 13). This attests low quality of the construction works.

3. Conclusions

1. Sister-buildings heat consumption analysis is a useful tool in searching of heat saving reserves, it excludes influence of building shape, architectural solution, and different building materials.
2. The analysis of annual heat consumption in sister -buildings reveals that heat consumption in them may differ up to two times irrespective to erection site and climate.
3. The comparison of identical buildings shows heat consumption reduction ranging up to 5-7 % if all buildings consumption values are below current mean value and in total 20-25 % if all specific consumption values are as in the most energy saving building.
4. Huge heat consumption difference between identical buildings implies to pay more attention to building maintenance scrutinization and tenants education as less expensive heat saving measure than thermal renovation of a building.

Acknowledgement

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