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HEAT ENERGY CONSUMPTION IN HEATING AND HOT TAP WATER SYSTEMS IN APARTMENT BUILDINGS

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Abstract. This paper describes heat consumption in the heating and hot tap water systems in panel apartment buildings in Tallinn (Estonia). Factual heat consumption for heating and hot tap water in a typical apartment building is presented. The dependence of weekly heat energy consumption on the outdoor temperature for a typical apartment building is discussed.

Key words: heat energy consumption, energy consumption for heating and hot tap water, apartment buildings.

1. INTRODUCTION

In general, energy consumption in apartment buildings is influenced by
– the natural environment (site and climate)
– the built environment (buildings and systems)
– the lifestyle of the residents (users and operation)

Until recently, the range of measured data concerning energy consumption in apartment buildings was quite narrow. However, some investigations have presented calculations of energy consumption. According to [1], in Tallinn, energy consumption rate in apartment buildings is 300 kWh/m^2 per year. More precisely, for a five-storeyed panel apartment building, this rate is 301–307 and for a nine-storeyed building – 293–300 kWh/m^2 per year. These calculations are based on the buildings constructed between 1960–1980.

In the calculations, we took into account the natural environment and building constructions, however, user activity and system adjusting may also have an effect. In today's district heating system in Tallinn, approximately 2/3 of heat substations have heat meters.

Extensive measurement of the consumed heat energy allows to carry out consumption analysis and to choose best energy conservation measures.

2. DESCRIPTION OF INVESTIGATED BUILDINGS

In this investigation, 172 different panel apartment buildings of the Mustamäe district (Tallinn) were analyzed. These five- and nine-storeyed buildings were constructed in the years 1963–1973. The table shows the distribution of the buildings according to the number of apartments and floors.

Distribution of buildings according to the number of apartments and floors

Number of floors	Number of apartments	Number of buildings
5	30	14
5	40	8
5	60	44
5	80	31
5	90	31
5	119	14
9	72	10
9	144	10
9	216	10
		Total 172

We can classify the investigated buildings into three groups:

1) old design five-storeyed buildings (1–2 room apartments): buildings consisting of 40, 80, and 60 apartments – 46 buildings;

2) new design 30-, 60-, 90-, and 119-apartment five-storeyed buildings (1–4 room apartments) – 96 buildings;

3) 72-, 144-, and 216-apartment nine-storeyed buildings (1–3 room apartments) – 30 buildings.

The investigated buildings, as a rule, have a one-pipe heating system and central hot tap water system with circulation and with towel-dryers in bathrooms. The buildings are connected to the district heating network and have heat substations with heating and domestic hot water temperature controllers and heat meters. Heating systems in buildings are balanced. To analyze real heat consumption of buildings, general construction parameters and approximate indoor temperature were used (all controllers were adjusted to 20 °C indoor temperature). In the investigation, factual heat energy consumption data for 1997 were used. Degree-day calculation is based on outdoor temperatures in Tallinn for a period of twenty six years (1967–1992) [2].

3. FACTUAL HEAT ENERGY CONSUMPTION

Heat energy consumption per apartment area (m^2) per year was calculated to characterize factual heat consumption. For the 172 apartment buildings investigated, general heat consumption (heating and hot tap water) was 274, for heating 192 and for hot tap water 82 kWh/m^2 per year. Heat energy consumption for hot tap water accounted for 30% of the total consumption.

Even within the same group, (60 apartment buildings in group 2), the variation of general heat consumption was from 249 to 322 kWh/m^2 per year.

If the difference between factual and calculated [1] general energy consumption was about 10%, then the deviation of the factual from the calculated heat consumption was from –25% to +8%.

The distribution of buildings according to general heat consumption is presented in Fig. 1.

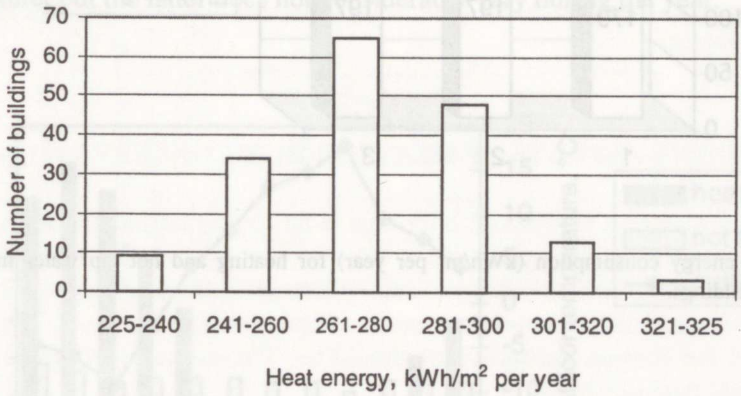

Fig. 1. Distribution of buildings according to general heat consumption.

According to [1], in Scandinavian countries, the general energy consumption in the apartment buildings (constructed between 1961–1970) was 170–190 kWh/m^2 per year. The average difference from the investigated buildings was 50%.

There is only a slight difference in the average energy consumption within each apartment building groups (Fig. 2). But significant differences exist in hot tap water consumption.

Heat energy consumption in group 1 was lower than in other groups. One of the reasons of lower heat energy consumption is lower air change in older buildings with smaller ventilation duct areas and long-time operation without duct cleaning.

Figure 3 shows the distribution of relative heat energy consumption in group 1. The ratio of the area of windows to the external constructions is close design five-storeyed buildings was 0.3–0.4. The approximate *k*-values (*u*-values) of the envelope elements of the building were, $W/m^2 \cdot k$:

roof-ceilings	–	0.9
external walls	–	1.0
windows	–	2.9
ground floor	–	1.5

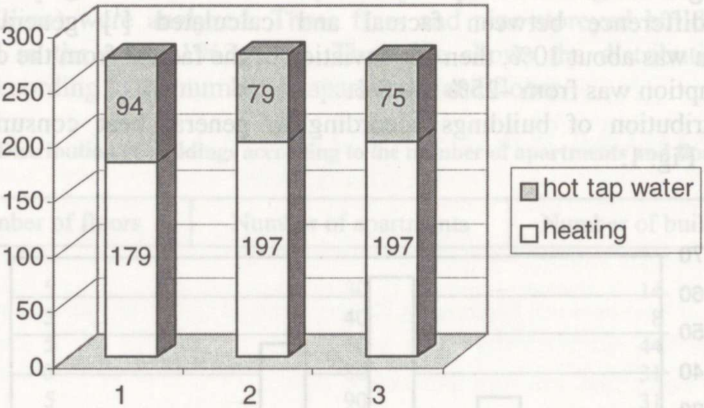

Fig. 2. Heat energy consumption (kWh/m² per year) for heating and hot tap water in different groups of buildings.

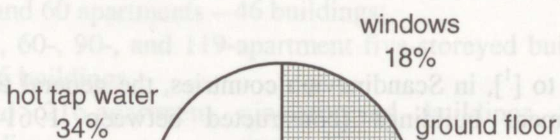

Fig. 3. Distribution of heat energy consumption in old design buildings.

Predominantly, the heat energy consumed in an apartment building covers heat losses, consisting of

– transmission heat losses through
  – the roof
  – external walls
  – windows
  – the ground floor
– ventilation losses (heating of air).

To characterize energy consumption for heating in a building in different climatic conditions, energy consumption, Wh/m^2 per °Cd (per degree-day), was calculated. For the buildings investigated, the average heat consumption was 44 Wh/m^2 per °Cd.

As shown in Fig. 4, a substantial difference in energy consumption in the heating and hot tap water systems exists: the former depends greatly on external temperature, but the latter does not considerably vary during the year.

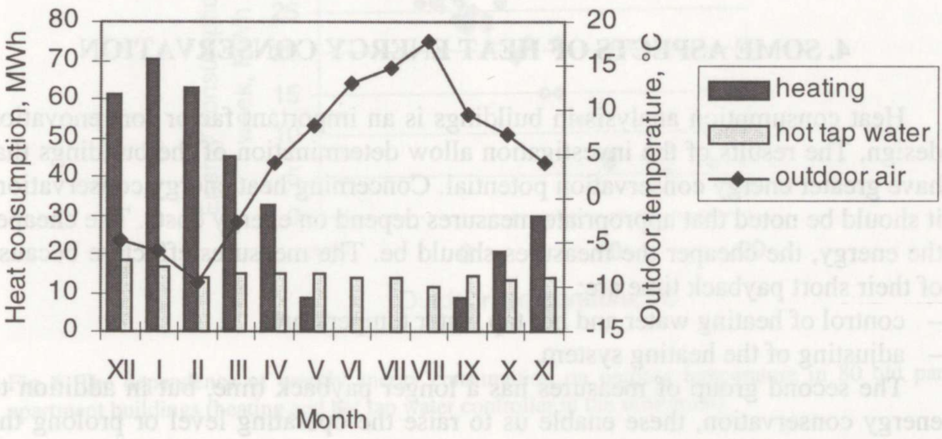

Fig. 4. Energy consumption for heating and hot tap water in an old design 60-apartment building and outdoor temperatures (Dec. 1995–Nov. 1996).

In the 60-apartment building (Fig. 4), the rate of hot tap water consumption in the general heat energy consumption accounts for 35%, which exceeds the average rate (30%) for the investigated 172 buildings. This depends greatly on the number of inhabitants and on their lifestyle. However, an accurate number of inhabitants was not available.

The distribution of the apartment buildings according to the ratio of the calculated and factual heating energy consumption is presented in Fig. 5. The average ratio was 1.20.

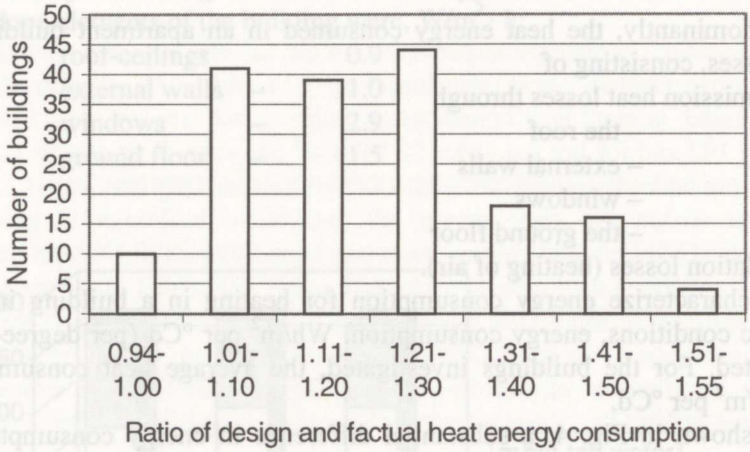

Fig. 5. Distribution of apartment buildings according to the ratio of the calculated and factual heat energy consumption.

4. SOME ASPECTS OF HEAT ENERGY CONSERVATION

Heat consumption analysis in buildings is an important factor for renovation design. The results of the investigation allow determination of the buildings that have greater energy conservation potential. Concerning heat energy conservation, it should be noted that appropriate measures depend on energy costs. The cheaper the energy, the cheaper the measures should be. The measures effective because of their short payback time are:

- control of heating water and hot tap water temperatures,
- adjusting of the heating system.

The second group of measures has a longer payback time, but in addition to energy conservation, these enable us to raise the operating level or prolong the life-time of a building:

- renovation of roofs (secures waterproofness),
- renovation of gables and facades (thermal insulation prolongs the life-time of panels and improves the microclimate),
- renovation of the hot tap water system with piping insulation (water conservation).

It is very important to inform the consumers about the real situation in heat energy consumption. Analysis of the dependence of daily or weekly energy consumption on external temperature (*E–T* graph) provides a clear picture of the effectiveness of energy consumption. An example of energy consumption on the *E–T* graph in two 80-apartment buildings of similar design is shown in Fig. 6.

a

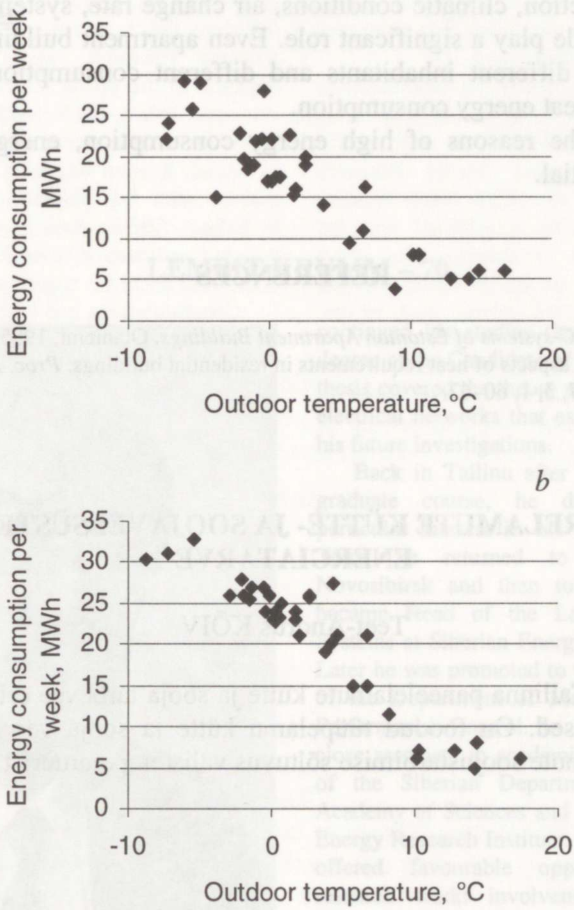

Fig. 6. The dependence of weekly energy consumption on outdoor temperature in 80 old panel apartment buildings (heating and hot tap water controller in the substation).

In building *b*, heat consumption was approximately 30% higher. Half of that increase was induced by higher indoor temperature and the other half, by higher hot tap water consumption. In building *a*, heat consumption was lower, but dispersion was high largely due to variable hot tap water consumption.

5. CONCLUSIONS

The factual heat energy consumption in the investigated panel apartment buildings in Tallinn varies largely, from 225 to 325 kWh/m^2 per year, averaging at 274 kWh/m^2 per year. Energy consumption for hot tap water formed 30% of the total consumption on the average.

In heat energy consumption in apartment buildings, in addition to envelope element construction, climatic conditions, air change rate, system adjusting, and residents' lifestyle play a significant role. Even apartment buildings of the same type with their different inhabitants and different consumption systems vary greatly in their heat energy consumption.

To explain the reasons of high energy consumption, energy consumption analysis is essential.

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KORTERELAMUTE KÜTTE- JA SOOJAVEESÜSTEEMIDE ENERGIATARVE

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On esitatud Tallinna paneelelamute kütte ja sooja tarbevee erisoojustarbimise uurimise tulemused. On toodud tüüpelamu kütte ja sooja vee soojustarbimise graafik ning elamute soojustarbimise sõltuvus välistemperatuurist.