Analysis of Changes in Heat Consumption in the Developing Housing Estate

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Abstract

Payments for heating apartments, which account for the majority of building maintenance costs, were analysed. Generally, for all apartments in Central Europe payments for heating exceed 50% - 75% and more housing maintenance costs. Based on the analysis of heat consumption over many years, equations describing the heat consumption of residential buildings depending on the ordered power were determined. The model uses approximations obtained in publications. The theoretical value of degree days Do=1282 was determined, at which the buildings do not require heating due to internal heat gains and gains in solar radiation energy. A relationship was determined too showing heat consumption depending on the ordered heat power and the degree days in subsequent years of the building's operation. Calculations were made in accordance with the PN-82/B-02403 standard on the example of a town located in the third climatic zone in Poland, which corresponds to standard conditions of outdoor air temperature -20C and average annual outdoor air temperature of 7.6C. The calculations take into account real temperatures based on historical meteorological measurement data.

Keywords: *Heat, Heating, Hot Water, Cost, Degree Days, Meteorological Measurement Data.*

1. Introduction

Individual payments for heating apartments are a significant part of heat, hot water and electricity costs. Generally, for all apartments in Central Europe payments for heating exceed 50% energy cost. The total cost of the energy used exceeds 75% and more the cost of maintaining the apartment. Of course, for individual cities there is a strictly defined linear relationship between the degree-days DD and the heat consumption for heating buildings:

$$Q_{heating}\ [GWh] = a\ DD + b \tag{1}$$

where determined [1, 2] exemplary numerical values of the constants a and b are 0.1907 and -244.4345, respectively and confidence interval 0.95. The negative value of the b factor results, among other things, from gains in solar radiation energy [3-5] and internal heat gains [6-10]. The sources of internal heat gains include people, lights and equipment. From Eq. (1) and condition Eq. (2)

$$Q_{heating} = 0 \tag{2}$$

we obtain the hypothetical number of degree days DD0 at which the central heating installation will not have to be turned on, and for the given values of the coefficients a and b we get:

$$DD0 = -b/a. \tag{3}$$

For the given values of the coefficients a and b we get from Eg. (3) DD0 = 1282. For about 210 - 230 days of the heating season, this results in a temperature difference of about 6°C. This corresponds to an average outside air temperature of 14°C. Due to the internal heat gains as well as the daily accumulation of heat in the partitions of the building, it has been assumed that for outdoor air temperatures above 12°C, residential and office spaces are not heated. It has been assumed that if during three consecutive days at 9 pm the outside air temperature was lower than 12°C, the central heating should be turned on. Thus, the central heating is switched on when the difference between the air temperature in the rooms is 20°C and the outside air temperature is greater than 8°C.

Currently, due to the widespread use of weather regulation in central heating, heating is switched on according to the settings of the weather regulator.

1.1 Aim

Aim of the research is to analyse changes in heat consumption in the developing housing estate in Poland, in the third climatic zone with the design temperature of the outside air -20 C [11]. Individual buildings were handed over for living in subsequent years. Thus, changes in heat consumption resulted from the increase in living space and the number of inhabitants, as well as changes in outside air temperature and other weather conditions (wind, insolation).

2. Materials and Methods

Data from the heat supplier's invoices in 12 months of subsequent years was compiled and analysed, concerning:

ordered thermal power for heating and hot water for the analysed housing estate (Fig. 1) and for chosen building (Fig. 2) expressed in MW in the following months,

- heat consumptions for the analysed housing estate (Fig. 3) and for chosen building (Fig. 4),
- outside air temperatures based on historical measurement data,
- changes in the values of kWh/m2 and kWh/m2/HDD indicators.

The declared value of the ordered thermal power of the building may not be changed more than once a year. It can be seen in Figure 1 that as the construction works are completed and the buildings are occupied, the power ordered for hot water increases. This is due to the overestimated values of the ordered power given in the designs of heat substations of buildings and hot water use [12 - 15]. Better estimates based on actual heat consumption allow administrative decisions to reduce the ordered power.

In materials [16, 17] is given Equation

$$q_{cwu}^{max\,h} = q_m + O(n * Q_m - q_m) + A\sqrt{O * q_m}\sqrt{n * Q_m - q_m} \quad (4)$$

where designed maximum DHW flow for n apartments $q_{cwu}^{max\,h}$ is expressed in litres per second, n - number of apartments, qm = 0.15 total flow for the apartment determining the size of the heat exchanger, Qm = 0.20 total maximum flow for the apartment, O = 0.015 probability of exceeding qm, A = 2.1.

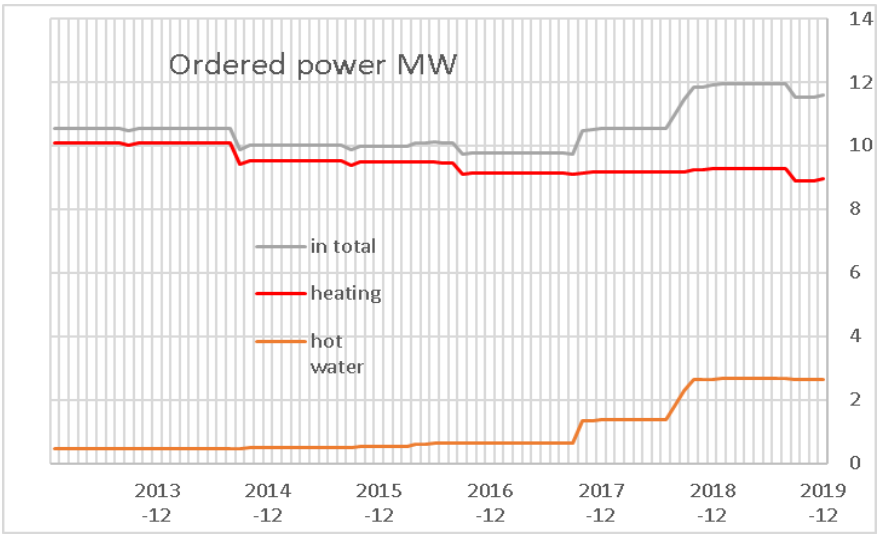

Fig. 1. Ordered thermal power for heating and hot water for the analysed housing estate.

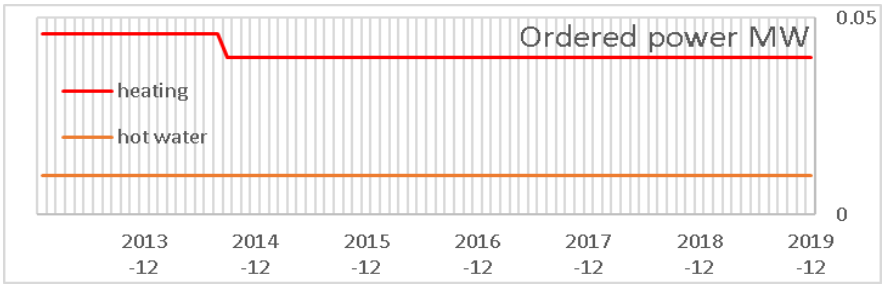

Fig. 2. Ordered thermal power for heating and hot water for one of the buildings.

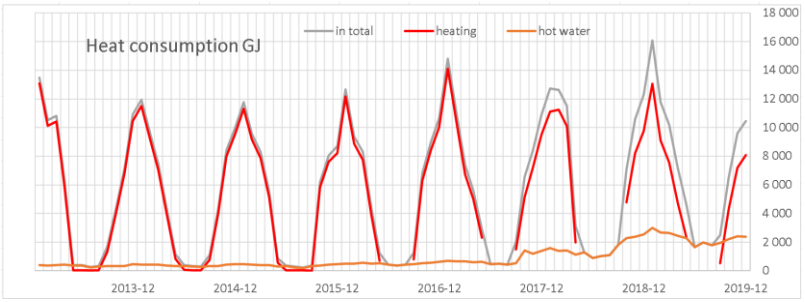

Fig. 3. Heat consumption for the analysed housing estate.

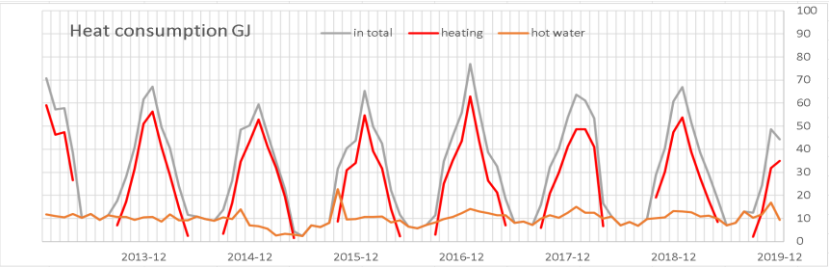

Fig. 4. Heat consumption for the analysed housing estate for one of the buildings.

3. Results and Discussions

Figures 1 and 2 show that changes in the ordered power are most often introduced in the autumn. During seven years of stabilisation of the number of residents in the estate, the power ordered PO for:

- hot water increased from 0.459 MW to 2.639 MW, i.e. almost six times,
- central heating from 10.078 MW to 8.967 MW, i.e. decreased by 11%,
- total power for heating and hot water increased from 10.537 MW to 11.606 MW, i.e. increased by 11%.

At the end of the long-term observations, the power ordered for heating purposes is 8.967 MW, the power ordered for hot water is 2.639 MW, i.e. almost 30% the power ordered for heating purposes.

Figures 3 and 4 show that heating consumption HC varies from month to month mainly depending on the mean outside air temperature te. Coefficient Ψ was introduced, which is the quotient of heat consumption HC to the ordered thermal power OP:

$$\Psi = \frac{heating\ consumption\ HC\ [GJ]}{ordered\ thermal\ power\ [MW]}. \tag{5}$$

The values of the Ψ coefficient depends on the outside air temperature and are shown in Figure 5. Rejecting almost zero values of the Ψ coefficient for heating for temperatures above 16 ºC, we get the following approximation equation:

$$\Psi_{heating} = 74\ (te - 16). \tag{6}$$

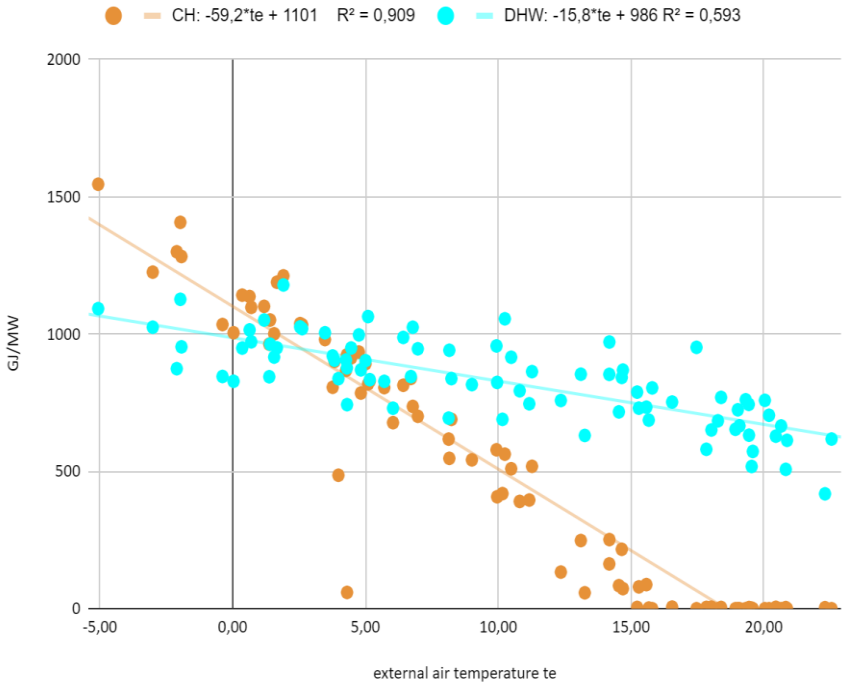

Fig. 5. The Ψ coefficient values for central heating and values for domestic hot water versus mean in month outside air temperature te

The coefficient -15.8 in the approximating equation ΨDHW for hot water consumption does not result from the variability of hot water consumption, but rather from the increase in heat losses in transmission in district heating networks. For the average annual outdoor air temperature of +8 °C, we get

$$\Psi_{DHW} = -15.8 \cdot 8 + 986 = 860\ \text{GJ/MW}. \tag{7}$$

The average value of the coefficient Ψ_{DHW} r the whole year could be assumed as 860 GJ/MW. However, this estimate is made for a housing estate with an unstable number of inhabitants over time.

4. Conclusions

In the paper are analysed changes in heat consumption in a developing housing estate in Poland, i.e. in the case of new buildings that are gradually being inhabited. The numerical data are values obtained from the technical documentation of buildings, contracts with the heat supplier, and readings of values measured by heat meters. During the seven years of stabilization of the number of residents of the estate, the power ordered for domestic hot water increased almost sixfold, and for central heating increased by 11%. The Ψ coefficient was introduced, which is the quotient of heat consumption HC to the ordered thermal power OP. The dependencies of the Ψ coefficient were determined in relation to hot water and central heating versus the outside air temperature.

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