Budownictwo i Architektura 18(1) (2019) 23–32 **DOI: 10.24358/Bud-Arch_19_181_03**

Increasing The Energy Efficiency of Dwelling Houses: Case Study of Residentia; Quarter in Upper Silesia, Poland

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Abstract: The paper assesses thermomodernisation measures aimed at improving energy efficiency of dwelling houses in a city quarter in Upper Silesia, Poland. The area was encompassed by the city council's program of emission restriction that promoted energy saving activities. The assessment was carried out by means of thermographic examination. It confirmed the fact that the thermomodernisation measures taken so far provided considerable improvement, but did not solved all issues. Further works should be undertaken on the basis of thorough examination of the current condition of the buildings.

Keywords: energy efficiency, residential buildings, insulation, thermography

1 Introduction

Thermography is used worldwide in the construction industry for the research and quantity analyses [1, 2, 4, 7, 9, 15, 20] as well as quality analyses [5, 10, 17, 21]. Balance-sheets are made of the demand for energy [3, 10, 11, 16], as well as their analyses and then on their basis – the attempts at modelling the use of heat energy in order to obtain the optimum solutions [6, 12, 19].

In the currently analysed case of the Polish quarter of the Upper Silesia the program aimed at increasing the energetic quality of the dwelling houses was carried out in a positive manner thanks to the cooperation of the tenants, the self-government and the managers. The effect of those activities is limiting the emission of CO2 resulting mainly from the change of the source of heat used for heating the flats as well as obtaining warm water and the improvement of the thermal parameters of the walls and ceilings. In each of the modernized buildings the same range of thermomodernisation activities was carried out. The author estimated them in the aspect of insulation quality and the issues concerning heat escape from the building made visible after insulation.

2 Case study on the basis of a program accepted for the Upper Silesia in Poland

The program of limiting the emission of CO2 for the Polish quarter under analysis was established in 2007 [18]. The time of accomplishment of the program comprised the years 2008 – 2010. Financing the modernization activities made it possible for the final recipients to obtain funds for the actions they were taking up. Every owner of a flat in the analyzed quarter could take advantage of it.

2.1 The accomplished range of activities

The accepted investment tasks concerning dwelling houses according to the approved plan [17] consisted in: isolating the walls and ceilings (of the basement and the top floor), renovation of the flues and their exchange for combustion ones, exchange of most of the door woodwork and part of the window woodwork as well as the exchange of the heating system for the double-function gas stoves. The program comprised 610 flats in 39 dwelling houses owned by the city.

2.2 The effects of the activities within the limits of the modernization program of the quarter from 2008 to 2010 [19]

The accomplishment of the program of thermomodernisation activities made it possible to achieve 100% of the intended ecological effects in November 2010. Apart from the decrease of heat energy demand of the buildings it resulted in a substantial restriction of harmful chemical compounds emission to the atmosphere. At the same time it also restricted the generation of solid waste i.e. containing the harmful substances gathered in table 1.

Table 1. The obtained ecological effects [17]

No.	The ecological effect of the thermomodernisation investment
1	dust – 10.674 kg/a
2	SO2 - 5.977 kg/a
3	NOx - 532 kg/a
4	CO - 37.045 kg/a
5	CO2 - 802.895 kg/a
6	b-a-p - 8,07 kg/a
7	decrease of heat energy demand by about 5.934 GJ/a

The undertaken activities improved the living comfort of the inhabitants of the quarter under analysis and reduced the environment degradation, they also made the quarter more attractive as a dwelling place. The range of complex thermomodernisation of the houses connected with the modernization of the existing heating systems and their exchange into ecological ones included about 55% of all inhabitants of the quarter.

Due to the activities taken up in the quarter and accomplished in the years 2008 – 2010 on the basis of the accepted program of improvements. The heating demand in the quarter has been reduced by more than 72%.

3 Estimation of the state of dwelling houses after thermomodernisation carried out in the years 2008-2010

The estimation of energy absorption of the building structures was carried out by means of thermovisual examination. The author is convinced that the best non-destructive method for the houses after thermomodernisation is using the thermographic method. This is the way to obtain information concerning the technical-energetic state of the analyzed buildings. The author made the first research in 2006 together with W. Adamczewski an expert as far as thermographic research is concerned. The source of the research and the analysis was described in a dissertation [14]. Later on the author carried out cyclic research by means of a thermovisual camera and presented the analysis during the years 2011-2012. Thus her opinion concerning the estimation of the energetic quality of the buildings is mainly based upon her own research carried out cyclically since 2006 in the region of south-eastern Poland. The conviction is also confirmed by long-term research made among others by H. Nowak [6], as well as Wł. Adamczewski [1], Al. Wróbel et al. [13, 20] and T. Kisielewicz [7]. Quantitative analyses carried out by E. Grinzato [2] with his team for detecting defects in the dynamic state seem better that those made in the static state, which means that the infra-red examination should be carried out during the heating period, at low temperatures. The author made use of the method in the quantitative analysis of her own thermographic research. Information obtained by means of modern thermographic diagnostics is not only useful while managing separate buildings but also a housing estate and a quarter. In the author's opinion this is the non-invasive way to obtain large-scale trustworthy data concerning the thermomodernised Silesian buildings under analysis and their elements characterized by the excessive emission of heat energy. That is why in February 2012 the author carried out thermographic research in a chosen quarter in order to estimate the state of traditional buildings after the accomplished process of the earlier invented and accepted by the inhabitants thermomodernisation. The analysis confirmed the generally good quality of the investment accomplishment which resulted in a considerable decrease of heating demand and testified to the sensibleness and effectiveness of the undertaken activities. The quality estimation of the accomplished insulations was carried out by means of thermovisual camera, at night. The thermographic research was made in February 2012. The measurement was made with the FLIR B350 appliance. The analysis of thermograms was done by means of analytic instruments from the program: FLIR Reporter 8,5 and 9,0 where the following parameters were used: temperature field, the line on the thermogram also described the minimum and maximum temperature) and the colour palette InvertedGrey. The obtained thermic profiles of the external divisions were analysed and provided with comment under each figure. Also the environment conditions and the established rules of accomplishment were taken into account. During the cyclic thermographic research the following details were observed from the ground level: ground courses, walls, portfenetres, door and window woodwork as well as roofs and chimneys. It was important to make sure that the temperature of the air outside should slowly fall from -5°C to -10°C for 4 hours before examination and during the research it should be stable and stay at about -10°C. The research was made at night. Attention was paid to the rule that no sunlit walls should be examined before 6-8 hours [1] after research. The wind was to be weak or very weak, south-western and faster than 2m/s. The temperature inside was about 20°C and it was not regulated for 4 hours before the research.

The analysis of the selected result of thermographic research was restricted to the characteristic cases recurrent in many buildings in the quarter, which was presented by means of thermograms accompanying diagrams that presented line profiles of particular thermal sections. Under the figures there were descriptions of elements, junction points or certain points of the elevation specified on the basis of the accomplished result analysis as emitting most heat on the level minimum 3K with reference to the other elements of a buildings or neighbourhood (e.g. a tree).

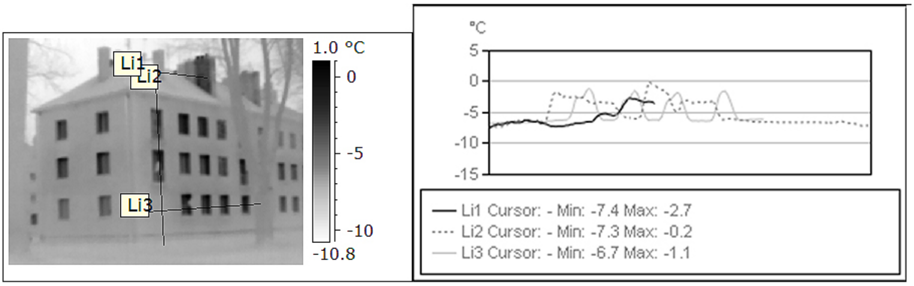

Fig. 1. Southern Poland 2012, a traditional technology after insulation. Thermogram and the analysis of the particular elements of the elevation (grand course, walls, doors, windows, chimneys)- description in the text

The thermogram analysis (fig. 1) testified to heat escape through chimneys (vents), where the temperature difference is 5K. Heat also escapes through the non-insulated casings of the door and window woodwork (temperature difference 6K) and the junction point of the insulation of basement walls and the ground floor walls (temperature difference up to 3K).

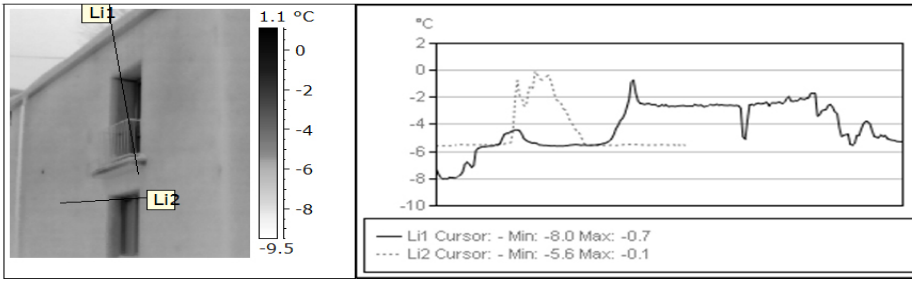

Fig 2. Southern Poland 2012, a building made in the traditional technology after insulation. Thermogram and the analysis of a fragment of the gamble wall with a portfenetre – description in the text

The accomplished analysis of the thermogram (fig. 2) testified to the escape of heat through the responds (horizontal and vertical) where the temperature difference on both thermal profiles is 5.5 K.

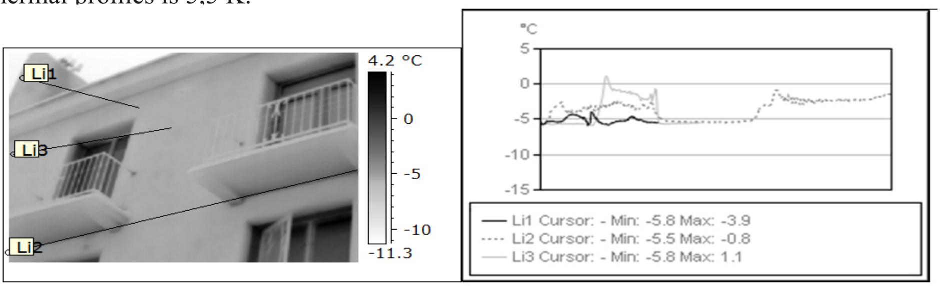

Fig. 3. Southern Poland 2012 a building made in the traditional technology, after insulation. Thermogram and the analysis of a fragment of the longitudinal wall with balconies – description in the text

The accomplished analysis of thermogram (fig. 3) testified to the escape of heat through the door responds where the temperature difference on both thermal profiles is 6K. Heat also escapes through the non-insulated balcony slabs (temperature difference 4,5 K).

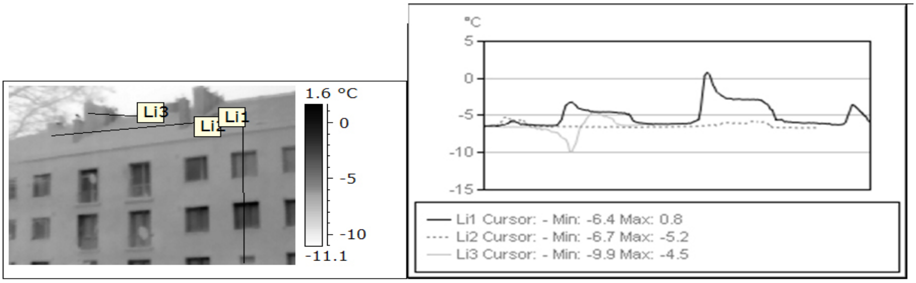

Fig. 4. Southern Poland 2012, a building made in the traditional technology after insulation. Thermogram and the analysis of a fragment of longitudinal elevation (window, woodwork, chimneys) – description in the text

The thermogram analysis (fig. 4) testified to the escape of heat through the non-insulated responds of the window woodwork (temperature difference 7K). Heat also escapes through chimneys (flues) where the temperature difference is 5K.

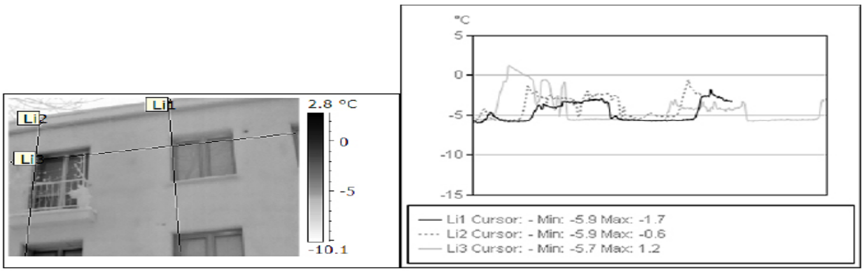

Fig. 5. Southern Poland 2012, a building made in the traditional technology after insulation. Thermogram and the analysis of door and window woodwork and the portfenetres description in the text

The accomplished analysis of the thermogram (fig. 5) testified to the escape of heat through the non-insulated responds of the door woodwork (temperature difference 7K) as well as window woodwork (temperature difference even 5,5K). Heat escapes through the portfenetres, where temperature difference between them and the wall is even 5K.

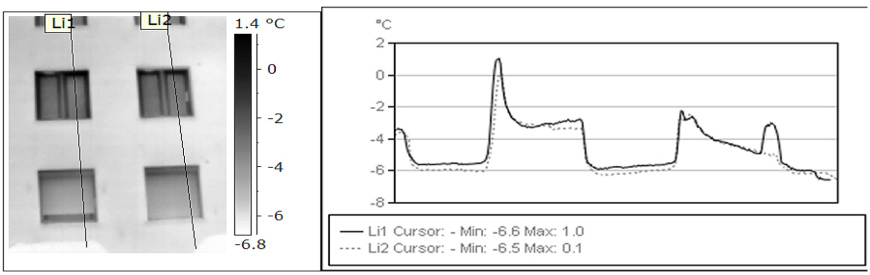

Fig. 6. Southern Poland 2012, a building made in the traditional technology after insulation. Thermogram and the analysis of window woodwork in a longitudinal wall-description in the text’

Analysis of the thermogram (fig. 6) testified to the escape of heat through the non-insulated responds of window woodwork (temperature difference 5,5K). External roller blinds were fitted in the ground floor windows that reduced the temperature difference between the window and the wall to 2K.

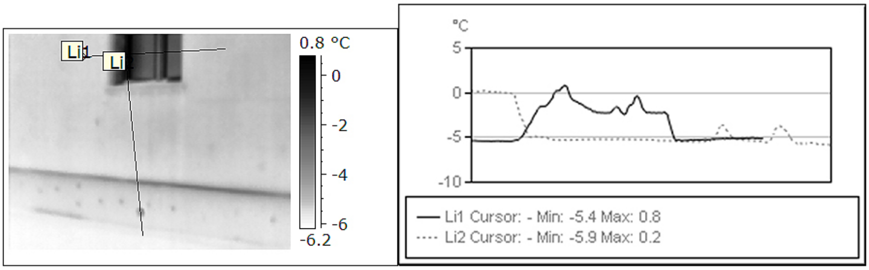

Fig. 7. Southern Poland 2012 a building made in a traditional technology after insulation. Thermogram and the analysis of a window in a gable wall and the area of the ground course – description in the text.

The analysis of the thermogram (fig. 7.) testified to the heat escape through the non-insulated responds of the window woodwork (temperature difference 6K). Heat also escapes through the junction point of the insulated ground course with the ground floor wall and the wallplugs (the temperature difference is from 1,5 to 2K) but the escape is negligible.

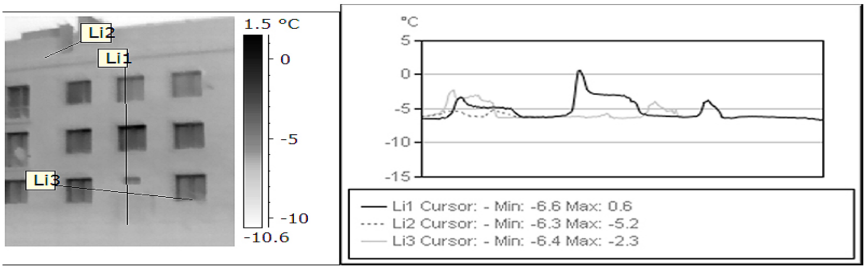

Fig. 8. Southern Poland 2012, a building made in the traditional technology after insulation. The thermogram and the analysis of the particular elements of elevation (the grand course, the wall, windows, the entrance door, the chimney) – description in the text

The analysis of the thermogram (fig. 8) testified to the escape of heat through the window responds (temperature difference from 3 to 6,5K). The temperature on the wooden entrance door is similar to the temperature of an insulated wall.

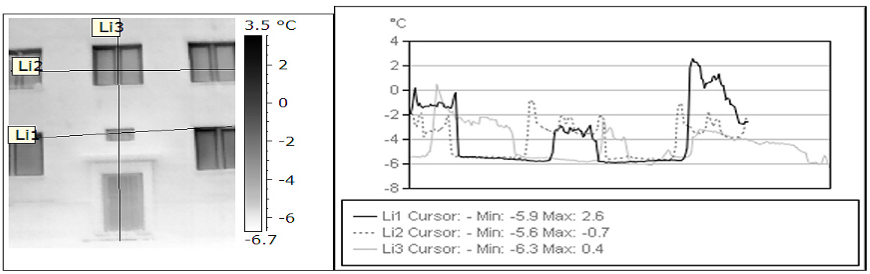

Fig. 9. Southern Poland 2012, a building made in the traditional technology after insulation. Thermogram and the analysis of the particular elements of the elevation (the wall, windows, the entrance door) –

description in the text

The accomplished analysis of the thermogram (fig. 9) testified to heat escape through the window responds (temperature difference from 4 to 8,5K). Temperature at the entrance door (exchanged) is not similar to the temperature of an insulated wall as it is with wooden (old type, not exchanged) door; in this case the temperature difference is 3K.

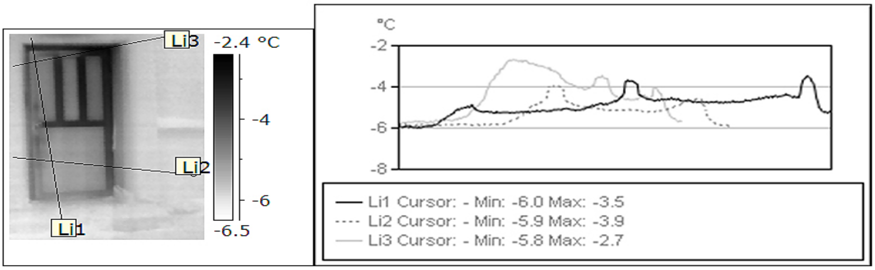

Fig. 10. Southern Poland 2012, a building made in the traditional technology after insulation. Thermogram and an analysis of the entrance door – description in the text

The analysis of the thermogram (fig. 10) testified to heat escape through the responds and casings of the exchange entrance door (temperature difference to 3,5K). Temperature at the aluminium entrance door, insulated and with a thermal glass pane is not similar to the temperature of the insulated wall and is 2,5K an average. During the analysis of the results of thermographic activities carried out in a Silesian district in southern Poland it was stated that, in spite of the insulations made during the period of 2008-2010 in 39 buildings, there are still some activities left to be accomplished during the process of complex thermomodernization.

4 Discussing the research results

The analysis of the effect of thermomodernization of the buildings confirmed the fact that not all elements were insulated in a complex manner, which has been presented in table 2.

Table 2. A specification of results of thermographic research on the basis of an insulated multi-family building, made in the traditional technology

No.	Problem	Estimation expressed by the average temperature of the heat escape through a given element	The percentage of mistakes against the number of analysed buildings	Recommendation
1	Chimneys – combustion flues	5,00K	95,00%	Heat should be regained from the combustion flues.

No.	Problem	Estimation expressed by the average temperature of the heat escape through a given element	The percentage of mistakes against the number of analysed buildings	Recommendation
2	Door and windows external woodwork in flats and the responds (external reveals)	5,95K	63,00%	Roller blinds should be fitted and the responds should be insulated.
3	Portfeneters or balconies	4,75K	99,00%	They should be insulated.
4	The woodwork of the entrance door	3,00K	57,00%	Casing profiles should be insulated and the thermal quality of the door woodwork after exchange should be improved (the frame profiles).
5	Discontinuities of insulation (cornices the junction point of grand floor wall insulation with the basement wall, the wallplugs, etc.)	1,75K	92,00%	Cornices may be insulated, and the insulation of the ground course can be extended.

The accomplished analysis of the research shows that the door and window external woodwork and the non-insulated responds constitute the biggest problem and present the worst state as far as the average temperature of heat escape is concerned, as they are varied thermally as well as in the aspect of the material (5,95K). The next items are chimneys (5K) and the French windows or balconies (4,75K). The average heat escape through the entrance door is not substantially smaller (3K). Heat escape through the discontinuities of insulation – both the linear ones and the punctual are negligible in the overall heat balance of a building and of the quarter, as they are 1,75K on average.

It was also stated that the highest percentage of mistakes is connected with the shortcomings in the insulation of French windows or balconies (99%), not much lower as far the chimneys are concerned (95%) and the insulation discontinuities (92%). There are also mistakes in the choice of quality of the exchanged door and window woodwork in the flats

(63%) and the entrance door (57%).

In the author's opinion the further improvement works should be connected, first of all with the insulation of French windows and balconies, then with the regain of heat from the chimneys, as well as fitting the roller-blinds and reveals insulation. Moreover, in the exchanged woodwork of the entrance door it is necessary to insulate the frames and tightening of the casings. The above elements specified in the order of urgency of the improvement activities influence directly the energetic quality of the buildings in the heat balance of a dwelling house and the whole quarter. The activities are accepted by the inhabitants which, is also confirmed by the social research carried out by the author since 2004, in Poland.

5 Recapitulation and conclusions

Multifamily houses built in the 50s or the 60s of the previous century in Poland demand the finishing of the modernization process. Typical thermomodernisation activities in the houses made in the traditional technology reduce their cost of maintenance and improve the quality of living of the inhabitants. They also increase the cost of the living space at the property market and the attractiveness of living in a given quarter.

The accomplishment of the discussed range of activities is connected with the cost paid by the final recipient. Taking advantage of the system of subsidies gave some relative gains in the further exploitation of the buildings.

The analysis of the example of the Silesian quarter in southern Poland confirmed the fact that the accomplishment of the properly designed program of modernization subsidized from the external sources gives really good results and constitutes an immense potential of energetic effectiveness in the energetic balance of the quarter. In the above analysed case the savings of 70% of energy on the scale of the whole quarter have been obtained. In view of the complexity of the thermomodernisation process there are still certain works to be done that can increase the effectiveness of the hitherto accomplished activities, which was presented in detail in p. 4. The author is convinced that the possibilities of new solutions should be taken into account which, were discussed in the following publications [8, 12, 11, 13, 14, 15].

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