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ECONOMIC EVALUATION OF ENERGY-SAVING MEASURES ON PANEL BUILDINGS IN THE CZECH REPUBLIC

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Preliminary notes
In order to decrease energy consumption of buildings it is necessary to take energy-saving measures. Main attention is paid to panel buildings, particularly to housing stock in the Czech Republic. The paper contains the Czech state-of-the-art in the field of revitalization of older housing stock and achieving the EU energy objectives, introduces suitable energy saving measures and deals with the methodology of economic evaluation of planned revitalization projects and with energy monitoring. The implementation of the above mentioned methodology is shown on the case study in the city of Přerov. The obtained results confirmed practical experience that, over the years, a considerable progress has been achieved in the planning and implementation phase. Furthermore, the case study shows that even simple energy monitoring may bring a great benefit in terms of energy savings. Nevertheless, there are still some issues in the operational phase that need to be addressed. Therefore, current level of energy monitoring should be considerably enhanced in order to achieve full energy potential of buildings.

Keywords: *economic evaluation, energy saving measures, methodology, panel buildings, the Czech Republic*

Ekonomska evaluacija mjera za očuvanje energije kod modularne gradnje u Republici Češkoj

Prethodno priopćenje
Kako bi se smanjila potrošnja energije u građevinama, nužno je izvršiti mjere očuvanja energije. Ovaj rad predstavlja metodologiju za očuvanje energije kod modularne gradnje u Republici Češkoj. Članak prvo daje pregled dosadašnjih mjera za revitalizaciju starijih zgrada prema direktivama Europske unije, predstavlja odgovarajuće mjere očuvanja energije i objašnjava kako primijeniti metodologiju za ekonomsku evaluaciju mjera i njihovo praćenje tijekom faze primjene. Kako bi se metodologija potvrdila u praksi, u radu se prikazuje njezina implementacija na studiji slučaja u grada Prerov. Prikupljeni rezultati su pokazali kako se korištenjem ove metodologije uspostavio značajan napredak, posebice u fazama planiranja i provođenja mjera. Nadalje, dokazano je kako i minimalni sustav praćenja očuvanja energije može dovesti do značajnih ušteda. Ipak, tijekom testiranja ove metodologije, prepoznati su nedostaci, posebice u fazi uporabe, koji se u daljnjim istraživanjima moraju otkloniti.

Ključne riječi: *Češka Republika, ekonomska evaluacija, metodologija, mjere očuvanja energije, modularna izgradnja*

1 Introduction

The history of the construction of prefabricated panel buildings dates back to the beginning of 20th century. While in West Europe the first panel buildings had been built after the First World War (Netherlands), the panel technology was developed as late as 1940 in the Czech Republic in Zlín; the first experimental houses were built with panels being produced directly on the construction site. Whole town districts with thousands of flats and civil infrastructure (shops, schools, health centres) were constructed by panel technology during the golden times of panel (1960 ÷ 1990).

The main advantages of prefabricated construction were low costs, less labour consumption and therefore shorter construction time. Unfortunately, low price limit of panel flat set by respective authority forced engineers to lower the costs significantly already in the phase of building design. The main goal was to build as many dwellings as possible at minimum costs, while operating costs (e.g. costs for heating) were neglected.

Since 1959, 1 165 000 dwellings have been built by panel technology which represents 31 % of the total housing stock of the Czech Republic and 54 % of all dwellings in block of flats. Unsatisfactory state of sanitary units, insufficient thermal characteristics of buildings and frequent occurrence of failures and defects are the legacy of centrally planned construction of cheap panel buildings.

As the constantly rising prices of energy make the operation of panel buildings expensive, it is necessary to pay considerable attention to implementation of energy saving measures. These measures are secondarily followed by reduction of environmental burden as well as by improvement of the quality of internal environment inside the building.

This paper contains the Czech state-of-the-art in the field of revitalization of older housing stock, special attention is paid to the panel constructions. The important role of state aid is mentioned in connection with achieving the objectives of the EU climate and energy package. Suitable energy saving measures for panel buildings are listed here including average costs of the most implemented measures. Consequently, the methods of economic evaluation of planned measures are outlined as well as energy monitoring with degree-day method. The above mentioned methods are applied in case study.

2 Literature review

A panel building is an object constructed by utilization of the standardized structural wall system from prefabricated panels. List of standardized structural systems of panel houses is stated in Nařízení vlády č. 299/2001 Sb. (Government Regulation No. 299/2001 Coll.), Appendix 1 [1]. This list defines 53 main standardized structural systems which have different specific regional variations.

2.1 State-of-the-art of panel buildings and governmental support of regeneration

Panel buildings are 20 ÷ 50 years old at present, during the operation residents and owners discover a number of failures and defects. Panel buildings which have not been reconstructed meet neither the current technical standards and norms which are much stricter than in the last century (thermal insulation, safety of elevators etc.) nor the users' standards for quality and comfortable living. The same poor conditions of panel buildings are detected e.g. in Lithuania by Zavadskas et al. [2]. It is estimated that 80 % of the total number of investments in panel buildings is neglected. Similarly large potential is registered e.g. in the Republic of Macedonia, see [3].

Due to requirements for low cost construction money was saved up especially on:

- Quality of flat equipment,
- Cheap sanitary units,
- Utilization of less-valuable materials,
- Insufficient thermal insulation of outside walls,
- Insufficient sound insulation,
- Installation of simple windows and doors,
- Erection works.

Figure 1 Example of defects and failures on panel buildings (exposed armature and missing thermal insulation between panels), Brno, Černého Street

As a consequence of low-quality construction, safety failures are registered. Those failures are caused by corrosion of load-bearing constructions (see Figure 1), especially on those which are exposed to weather conditions (balconies and loggias).

Corrosion is caused not only by usage of inappropriate material, but also by insufficient concrete cover. From the thermal point of view, panel buildings show low thermal resistance and existence of thermal bridges. Thermal insulation is weakened, e.g. on the perimeter of panels due to drainage of panel joints or on the place of connections of the blocks. Parameters of sealing materials deteriorate. Due to weather conditions, materials lose water-tightness and air-tightness. All the mentioned defects and failures are accompanied by deterioration in quality of indoor climate (e.g. occurrence of fungus, leakage of rain water in top floor flats).

Table 1 Statistic Data on Renovated Flats in Apartment Houses in the Czech Republic [4, 5]

	All apartment houses	Panel buildings	Other apartment houses
Total no. of permanently settled flats	2 160 730	1 199 168	961 562
Share of already renovated flats on total housing stock in apartment houses	36 %	55 %	12 %

Note: Share of renovated flats comprehends both full and partial reconstruction.

Although panel technology displays many structural problems, panel buildings are safe constructions for normal use and a large portion of the Czech population will continue to live there. Serious failures of load-bearing construction are registered only in connection with the occurrence of exceptional events (e.g. gas explosion).

Data mentioned in Tab. 1 show results of *Panel SCAN* study [4]; the main part of housing stock is still waiting for the renovation. There is a significant disproportion between the share of already renovated flats in the two sub-categories (panel buildings and other apartment houses). This results from two facts: 1) the initial conditions of panel buildings are considerably worse that the conditions of other apartment houses, therefore the renovation of panel buildings is more acute; 2) special supporting program *Panel* (later renamed *Nový Panel*) was founded for the regeneration of panel houses, established by the State Housing Development Fund [6] (Státní fond rozvoje bydlení, SFRB). Unfortunately, due to the current governmental policy of "reducing the fiscal deficit" SFRB has registered lack of financial sources, and thus SFRB did not provide any direct subsidies in 2011. Revitalization provides not only technical improvements, but also enhances the aesthetic value of housing stock (see Fig. 2).

Figure 2 Comparison of buildings before and after revitalization (two floor extension, window replacement, balcony replacement, additional thermal insulation and entrance premises modification); Brno, Černého Street

It should be noted that the *Ministry of the Environment of the Czech Republic* through the medium of the *State Environmental Fund of the Czech Republic* [6] supports the execution of quality insulation of family houses and non-panel multiple-dwelling houses, the replacement of environmentally unfriendly heating for low-emission biomass-fired boilers and efficient heat pumps, installations of these sources in new low-energy buildings, as well as construction of new houses in the passive energy standard within the frame of *The Green Savings Programme* (*Zelenáúsporám*). The Czech Republic has raised funds for this programme from the sale of emission credits under the Kyoto Protocol on greenhouse gas emissions with anticipated overall programme allocation around 25 billion Czech crowns. Also *The Green Savings Programme* was closed for year 2011 and did not accept new applications. However, this programme does not allow providing financial support to the implementation of thermal insulation on panel buildings.

Tab. 2 shows how important the programme Panel is since it brought 58 % of the total aid allocated to panel houses and generated even 75 % of total realized supported investments. Decrease in intensity of repair works can be expected as it was observed that e.g.

intensity of window replacement was directly proportional to the intensity of state aid in recent years.

It is clear that attainment of the objectives of the EU climate and energy package [7] called "20-20-20 targets":

- cutting greenhouse gases by at least 20 % of 1990 levels (30 % if other developed countries commit to comparable cuts),
- cutting energy consumption by 20 % of projected 2020 levels – by improving energy efficiency,
- increasing use of renewable (wind, solar, biomass, etc.) to 20 % of total energy production.

Table 2 Survey of State Aid to the Reconstruction of Panel Buildings 1992 – 2008 (in million EUR) [4]

Type of Supporting Programme	Panel	ČEA	VPV	SVPV	POMBF	Total
Allocated State Aid	408,0	80,3	184,9	7,7	24,7	705,6
Total Investments Generated by State Aid	1837,7	148,5	420,3	7,7	49,5	2463,7

Note: ČEA = Českáenergetickáagentura (Czech Energetic Agency), VPV – Vadypanelovévýstavby (Panel Construction Defects), SVPV – Specifickévadypanelovévýstavby (Specific Panel Construction Defects), POMBF – Podporaoprav a modernizacebytovéhofondu (Support of Repairs and Modernization of Housing Fund).

Table 3 Costs of Construction Works on Panel Buildings 1992 – 2008 (EUR) [4]

Type of Construction Work	Average Costs per 1 Housing Unit	Total Costs (in million EUR)	Share of Construction Work on Total Costs / %
Static Works	612	171	3,9
Loggia or Balcony Replacement or Repair	1429	470	10,8
Thermal Insulation	2245	1068	**24,6**
Window Replacement	2204	1133	**26,1**
Roof Works	1224	552	12,7
Lift	1224	307	7,1
Loggia Glazing	816	148	3,4
Others (sanitary units, kitchen, shared premises, …)	2246	494	11,4
Total	12 000	4343	100

This requires a considerable investment in sectors such as industry, transport and housing, as well as in public and commercial buildings. Attainment of these objectives in the residential building sector will be very difficult if the government continues its policy of expenditure cuts and imposes the whole financial burden connected with the implementation of energy saving measures on residents only.

2.2 Suitable energy saving measures on panel buildings

The range of possible energy saving measures is relatively broad. Nevertheless, most of the funds are invested especially in measures which primarily reduce heat loss from the interior of the building. Data from building experience show that the following measures are implemented on panel buildings in the Czech Republic:

1) Energy saving measures:

- additional thermal insulation of building envelope including basement and attic (practice shows that insulation to a thickness of 10 ÷ 14 cm has to be added to achieve the recommended values stated by the Czech national norm [8]; experience from Brno, district Nový Lískovec gives the average optimal additional thickness of thermal insulation 16 cm;),
- additional thermal insulation of roof deck (usually connected with roof repair, replacement of flat roof with gabled roof or hipped roof, building up superstructure – new upper floors),
- window replacement (replacement of old wooden or metal windows with new plastic windows with proper value of thermal transmittance value U (W/(m^2·K)); see Fig. 3),
- brick in unnecessary windows (especially windows in basements and on corridors, condition of sufficient lightness in respective premises must be satisfied at the same time),
- entrance premises modification (new doors, reduction of the area of glass parts; see Fig. 4),
- implementation of regulatory elements (functional valves on radiators, this enables the residents to regulate their individual consumption registered by ratio heat consumption meter),
- regulation of heating system (requires good energy monitoring and use of *E-T* curves),
- replacement and insulation of internal distribution systems (e.g. hot water piping),
- loggia glazing (loggia forms a large part of cooled surface structures on certain panel buildings and thus considerably affects energy balance of the building),

Figure 3 Comparison of original metal windows and new plastic windows in cellar premises, Brno, Černého Street

Figure 4 Comparison of original and reconstructed entrance premises (the area of glass parts is reduced, metal doors and windows are replaced with plastic), Brno, Černého Street

- boiler room modernization (also possibility of decentralization of hot water preparation should be

considered if applicable – obstacle is a lack of suitable premises),
- upgrading of ventilation,
- controlled ventilation with recuperation,
- use of renewables (e.g. installation of photovoltaic devices on roofs or loggia railing).

2) Other measures (implemented in order to increase the quality of housing or to remove the failures and defects)
- balcony replacement,
- replacement of bells and post boxes,
- replacement of sanitary units and kitchen units,
- replacement of electric power wiring,
- lift replacement.

Thermal insulation of building envelope and window replacement are among the first implemented measures because they bring the greatest "effect". This "effect" can be expressed by means of criteria of investment efficiency (payback period, net present value and internal rate of return) – see chapter Economic Evaluation Methodology.

Tab. 3 confirms the fact that works on thermal insulation and window replacement are among the most frequently implemented measures on panel buildings and represent on the whole 50,7 % of total investments. The reasons are high annual energy savings and reasonable payback period of invested money; whereas e.g. the replacement of the lift is done for security reasons and does not bring any positive financial effect (savings on operating costs of the lift in comparison with investment costs are negligible).

Unfortunately, experience has shown that from today's point of view many executed works were carried out in inadequate or even incorrect way which reduces the effect of the reconstruction. This is caused mainly by:
- changing requirements on technical standards (e.g. thermal insulation thickness),
- usage of new materials and technologies at present,
- selection procedure (contractor was selected on the basis of the quotation, professional competence of the supplier was a minor),
- low quality of executed work (inexperienced workers, lack of quality control from the side of investor).

For example, the effect of window replacement is usually reduced by unsatisfactory value of the coefficient *U*, bad static of the window itself, occurrence of dew ret or fungus. Even though the construction works were performed well, the proposed savings are sometimes not achieved. The reason could be found in the neglect of regulation of heating system and missing energy monitoring.

In addition, new problems arise, both legal and technological. For example, connecting of new photovoltaic devices to transmission system facilities was temporarily suspended since the current capacity is not sufficient to ensure the operation of transmission system on very sunny days. This situation was caused by generous incentives for solar energy business in recent years (which made the Czech Republic the third biggest solar power country in Europe in terms of newly-installed capacity in 2009) [9].

3 Methods of energy saving measures

3.1 Economic evaluation methodology

Investments in energy saving measures are not just expensive but also long-term with payback period of 15-40 years. Therefore, people have to pay a considerable attention to these investments and the whole project should be prepared precisely.

The first prerequisite for success of the project is to elaborate energy audit. Even though panel buildings are uniform in general, each building is unique and requires individual approach. Energy audit evaluates the energy potential in detail; energy auditing is based on the inspection and measurements carried out in the building, and it includes an evaluation and analysis of the existing situation and various measures. Real-life data in the Czech Republic confirmed that in view of the climatic conditions all non-reconstructed panel buildings have energy potential and therefore energy saving measures should be applied.

ENCON process (ENergyCONservation) [10] means achieving energy savings with both financial and environmental benefits. Energy conservation process comprehends: 1) evaluation of energy consumption potential of particular building (formed by sum of the relevant measures, energy savings, investment costs and payback period); 2) implementation of relevant measures for profitable energy savings (recommended measures should be implemented according to priorities); 3) achievement of calculated energy saving potential and provision of a permanently correct level of energy consumption.

While ENCON potential depends especially on technical parameters (building envelope, heating system, mechanical ventilation system, hot water system, lightning etc.), achievement of calculated energy potential is contingent on skilled maintenance and operation crew and appropriate maintenance and operation routines as well.

ENCON process should be developed in six main steps: 1) project identification, 2) scanning, 3) energy audit, 4) business plan, 5) implementation and 6) operation (maintenance and energy monitoring).

If the first two steps are evaluated as beneficial, energy audit has to be elaborated. According to the Act on Energy Management [11, in §9], an energy audit shall be carried out by an energy auditor and elaborated with the use of energy-efficient materials and processes objectively and truthfully. It shall contain:
- an assessment of the present level of the analyzed energy facility and buildings;
- the overall level of energy savings achieved, including the input and output information and calculation methods used;
- a proposal of the selected variant recommended for the achievement of energy savings, including financial reasons.

An energy audit contains the evaluation of ENCON potential for the whole building determined in physical units, i.e. in (GJ/year) or (kWh/m^{2}year). Such evaluation should be done with utilization of relevant calculation software, e.g. ENSI Key Number Software [see more in

12] which distributes energy potential among heating system, mechanical ventilation system, domestic hot water system, fans and pumps, lighting, cooling and others. ENSI Key Number Software describes the most relevant measures by so called Key Number Parameters. For example, heating system is described by U-wall, U-window, U-roof, Form-factor, Window Area, Total solar gain, Infiltration, Lighting, Indoor temperature etc. For instance, U-wall describes an average thermal transmittance value of walls in (W/(m^2·K)). Another relevant SW can be used, e.g. Národní kalkulačníná stroj (National Calculation Tool).

Consequently, the energy savings must be converted into monetary units (EUR, CZK, …). Economic evaluation is influenced by many factors, such as the unit prices of heat in particular locality or the chosen method of financing and its parameters (bank loan, interest rate, savings, and possible public support). Energy audit report should contain final calculations of the following criteria of investment efficiency:

- Payback Period – calculates how long it takes for incoming returns to cover costs

$$PP = \frac{IC}{CF}, \tag{1}$$

where IC – investment costs, CF – annual cash flow,

- Discounted Payback Period (since the investment in energy saving measures is long-term it is necessary to take the time value of money into account). Generally, the discounted payback period should be shorter than the lifetime of the project. Discounted Payback Period is achieved if

$$\sum_{t=1}^{DPP} \frac{CF_t}{(1+r)^t} - IC = 0. \tag{2}$$

- Net Present Value – describes the difference between the present value of cash flows and investment costs

$$NPV = \sum_{i=1}^{n} \frac{CF_i}{(1+r)^i} - IC, \tag{3}$$

where r – discount rate, n – lifetime of the project (length of period under review in years),

- Internal Rate of Return – expresses average percentage of the annual gain of a project for the whole lifetime

$$IRR = r_1 + \frac{NPV+}{|NPV+| + |NPV-|} \cdot (r_2 - r_1). \tag{4}$$

Where r_1 – estimate for positive NPV, r_2 – estimate for negative NPV.

3.2 Energy monitoring

Currently, investors have already learned from previous mistakes and pay adequate attention to quality control of works performed. Although works were performed well, planned energy savings are not achieved entirely in practice. The problem is that quality economic evaluations are often conducted in the design phase as part of the energy audit, but in the operational phase such evaluations are sometimes neglected. This is the task for Energy Monitoring (Energy Management), the last phase of ENCON process, since real savings are not achieved on the paper but only during the operation of regenerated building. Users are often satisfied with registered achieved savings and do not examine whether these savings have reached their maximum potential.

Furthermore, experience shows that energy consumption in regenerated buildings starts to increase after 2 or 3 years (this is valid for new buildings as well). This is caused by errors in operation and maintenance in relation to the absence of systematic procedures for the ongoing control of operating conditions and energy consumption. Energy monitoring is a management tool for maintaining the appropriate level of energy consumption and should be based on weekly readings of energy consumption and outdoor temperature records. Implementation of energy management has been assessed as highly beneficial e.g. in Nový Lískovec (a district in Brno) [13].

Values indicating outdoor temperature (°C) and the relevant energy consumption (kW·h/(m^2·week)) are shown by Energy-Temperature Curve (*E-T* curve). The *E-T* curve describes the correct energy consumption for a building. The problems, i.e. malfunctioning equipment indicated by deviations from *E-T* curve, should be investigated and remedied. Every building has its own *E-T* curve and thus the regulation of its systems (e.g. heating systems) has to be based on the analysis of the *E-T* curve.

What to do if energy monitoring is not implemented in the building and evaluation of savings is required? Evaluation of registered annual energy consumption itself is not enough, since it is necessary to take the "strength of winter" into account. In such case approximate evaluation should be based on Degree-Day Method. The value of Degree-Day $D°$ is calculated separately for each day of the analysed period.

$$D°(t_\mathrm{i}) = d \cdot (t_\mathrm{i} - t_\mathrm{e}),, \tag{5}$$

where $D°(t_\mathrm{i})$ – number of Degree-Days for analysed period and location, d – duration of heating season in days, t_i – average inside temperature, t_e – average outside temperature.

Evaluation of efficiency of energy saving measures by Degree-day Method is shown on case study (see in the next Chapter).

4 Methodology

Firstly, the authors carried out a literature review on Czech experience in the field of implementation of energy saving measures on residential buildings. Consequently, the method of calculation applicable to economic evaluation of planned energy saving measures and to evaluation of achieved energy savings within the frame of energy monitoring is described. Methods are followed by the case study.

The objective of the case study is to show that due to missing energy monitoring goals outlined in energy audit may not be fulfilled during the operational phase. The situation in Přerov city is presented on residential panel building with 40 flats. The case study uses economic evaluation method and compares expected values of economic parameters stated in energy audit and achieved values registered in real operation. Performed comparison takes the strength of the winter into account when using the degree-day method.

The data analysed in the case study are obtained from relevant institutions and official documents valid for Přerov city, respectively for the analysed building. Those are: Construction and Housing Association Přerov, Heating Plant Přerov and Energy audit: apartment building Přerov, street Hranická No 21 [14]. The analyzed building is constructed in one of typical panel structural systems (OP 1.11).

The importance of the case study lies in the fact that proposed simple and undemanding form of energy monitoring based on degree-day method may bring a great benefit for users and owners of apartments. However, obtained results themselves cannot detect the cause of potential problem. On the other way, results should be an incentive to carry out a thorough inspection. This method is applicable especially for housing associations as well as for companies that administer apartment and housing stock. Implementation of the proposed method can help to reduce energy consumption and to reach energy potential of residential buildings.

5 Case study

This case study analyses a panel building in Přerov, Hranická street, where energy monitoring is not practised. Basic characteristics of the building are given in Tab. 4. Due to high energy consumption for heating (the building did not meet parameters of the Czech Technical Norm ČSN 730540) it was decided to realize energy saving measures. The following measures have already been realized:

- installation of thermostatic valves (1998),
- reconstruction of roof emergency condition including implementation of additional thermal insulation (2000),
- thermal insulation of floor on ground floor.

Table 4 Parameters of the building [15]

Parameter	Value
Type of structural system	OP 1.11
Built in	1983
Enclosure	9280 m^3
Built-up Area	347 m^2
Total Floor Area	2776 m^2
No. of Flats	40
Elevator Machine Room	On the roof

Tab. 5 shows values of thermal parameters of the analyzed building identified in energy audit. It is obvious that the building does not meet thermal requirements stated by the norm. Therefore energy audit has recommended the implementation of the following measures:

- Replacement of wooden double windows with plastic insulated double paned windows.
- Installation of additional thermal insulation (system Stomix Therm Alfa, EPS-F boards, thickness 100 mm (in loggia premises 80 mm).
- Replacement of the loggia railing with solid panel and implementation of loggia glazing (system Aluvista).
- Reconstruction of entrance premises: southern entrance – replacement of metal doors with plastic insulated double paned doors, northern entrance – replacement of the glass partition with walling (Ytong, 365 mm), replacement of metal doors with plastic insulated double paned doors.
- Reconstruction of interior lighting (this measure is not taken into consideration).

Table 5 Thermal parameters of the building [14], W/(m^2·K)

Type of construction	*U* (before measures)	*U* (required by technical norm)	Satisfactory
Outside walls	0,58	0,38	No
Loggia walls	0,8	0,38	No
Roof	0,3	0,3	Yes
Entrance doors	4,2	3,5	No
Windows	2,7	1,8	No

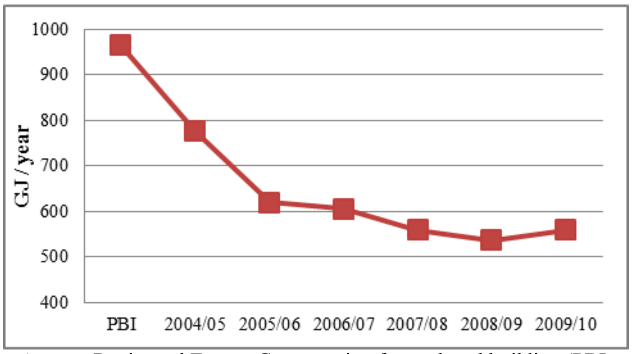

Figure 5 Registered Energy Consumption for analyzed building (PBI - average value for period before implementation of measures).Created according to values in [15], data obtained from annual accounts created by Construction and Housing Association Přerov.

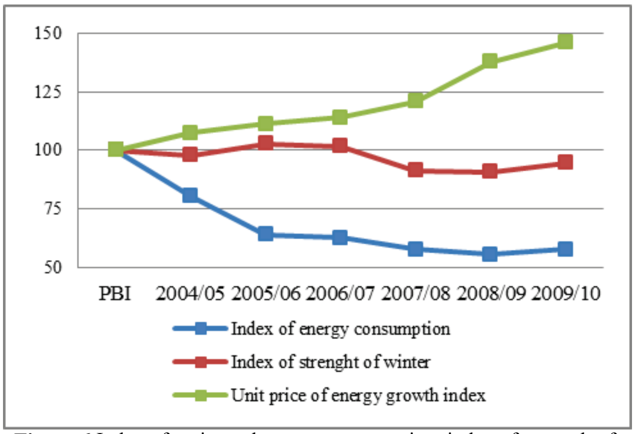

Figure 6 Index of registered energy consumption, index of strength of winter and index of unit price of energy growth for analyzed building (PBI - period before implementation of measures). Created according to values in [15]. Note: Period before implementation of measures = 100.

Fig. 5 shows data on energy consumption registered for the analyzed building. Decreasing trend of annual energy consumption is caused by performed energy saving measures (window replacement in 2004, additional thermal insulation 2005). Deflections during 2005/06 –

2009/10 are caused by strength of winter (valid for the period 2005/06).

Fig. 6 contains data expressed in the form of indexes on strength of winter (obtained from heating plant in Přerov, valid for Přerov city), energy consumption and unit price of energy (both valid for analyzed building). Fig. 6 depicts constantly rising price of energy, achieved energy savings (38 %) and the influence of strength of winter on energy consumption (the smaller value of index of strength of winter, the smaller registered energy consumption.

Window replacement was performed in 2004, thermal insulation of outside walls and other measures in 2005. Tab. 6 shows data on economic evaluation. Expected values are calculated in energy audit and achieved values are registered during real operation and calculated by Degree-day method.

Table 6 Economic evaluation

Parameter	Unit of measure	Expected value	Achieved value
Energy savings	GJ/year	511	367,2
Energy savings	%	53,0	38,1
Energy savings	EUR/year	8104	5824
Investment costs	EUR	191 020	230 984
Disc. payback period	years	21,6	33,5 (PP_A)
NPV_{30}	EUR	+89 626	–29 296
IRR	%	7,7	4,3

The results of economic evaluation stated in Tab. 6 show that real energy savings differ profoundly (by 28 %) from the potential stated in the energy audit. Consequently, the discounted payback period is extended by 12 years and the average percentage of annual gain is decreased from 7,7 % to 4,3 %. The consequent short inspection has shown that this unfavourable situation is caused by more factors: 1) heating system was not sufficiently regulated; 2) rooms were overheated and excessive heat was ventilated through open windows; 3) investment costs increased by 21 %, although the prices of materials and labour at the time of implementation were adequate to prices reported in the audit (due to high competition in this sector), e.g. the costs for implementation of additional thermal insulation per one housing unit were 2590 EUR (compare with average costs in Tab. 3).

Such simple assessment of both potential and real energy savings and calculation of related indicators of investment efficiency cannot detect the cause of eventual problem by itself, but it can be an incentive to carry out a thorough inspection of the conditions of the building and to start conduct energy monitoring.

6 Discussion and conclusion

In this study we found out that a considerable progress was achieved in planning and implementation of energy saving measures in the Czech Republic during the last 15 years. Projects consider more options, new materials and technologies are used and energy audits are not only employed to identify potential energy savings, but also to quantify the effectiveness of the project.

However, there are still improvements to be made in operational phase. Energy monitoring, the management tool for maintaining an appropriate level of energy consumption, is primarily applied to large projects (large administrative buildings, hospitals, schools and other objects of civil amenities). However, for smaller projects, e.g. implementation of energy saving measures on panel buildings, energy monitoring is not implemented automatically and therefore important data for routine control of energy consumption in relation to outside temperature conditions are missing.

Therefore, the energy potential identified in the energy audit is not achieved in practice, the payback period is extended and project becomes less efficient. Causes for failing to achieve the potential savings can only be detected by means of high quality energy monitoring. They can be ascribed either to the fact that the contractor's works were poorly performed (which can be claimed during the guarantee period), to poor regulation of heating system or to the customary behaviour of residents (overheating of rooms and excessive ventilation in winter).

Energy savings projects on residential buildings generally (not just panel houses) pose two specific obstacles – psychological and legal. Firstly, residents in blocks of flats pay considerably less attention to the control of implemented measures than owners of family houses. Individual residents participate in total investment costs only proportionally according to the share of their flat in the total flooring of the whole building and unit costs per 1 m^2 are lower, while a similar project on family house burdens just the house owner who carefully watches the rentability of their investment.

Secondly, there is a legal issue especially in block of flats where particular flats are in ownership of individual residents. The number of such houses is rising in connection with the privatization of municipal housing stock and sale of housing association stock towards individuals. In these cases, residents are often unable to agree on a common solution. Only one dissenting resident can complicate, delay or even completely block the revitalization of the building. Czech law requires that the community of owners of flat units must approve of the proposal unanimously. Consequently, residents implement to realize partial energy saving measures individually (e.g. window replacement) on their own.

Despite all mentioned problems, constantly rising prices of energy, global change of climate, requirements for reducing emissions and rising intensity of energy consumption (e.g. newly implemented air-conditioning of inside premises) will force people to ensure the efficient operation of their buildings and thus deal with energy monitoring in the future.

7 References

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