ENERGETIC RETROFIT OF HISTORICAL DOWNTOWN BUILDINGS: COST EFFECTIVENESS AND FINANCING OPTIONS

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ABSTRACT

Today several energy saving measures are being taken worldwide. As a component of these, the energy efficiency of the buildings should be increased. Given the high ratio of the existing, ineffective building stock, large-scale retrofit actions are going to be needed to reduce their energy usage. The historical districts and the heritage buildings stand as special part of the above question, as several limitations increase the complexity of their retrofit.

In present paper, the authors are introducing retrofit possibilities for the traditional apartment house type, widespread in the past Austro-Hungarian downtowns. A detailed methodology for complex renovation is divided to three main aspects: energy efficiency, monument protection guidelines and feasibility. By combining the above aspects, optimized renovation scenarios and their cost efficient financing implementation are surveyed.

Results show, that the energy saving and heritage respecting solutions are not economically feasible enough to be appealing for private investors. The retrofit, however, is much needed to increase the life quality of residents, save energy, and protect the unique architectural character, now constantly endangered by demolitions.

The authors suggest solutions for the above problem by creating possible financing scenarios, which can be used as a benchmark for preliminary decision making in case of a planned retrofit.

Keywords: energy efficiency, historical building, heritage protection, energetic retrofit, decision support system, cost-benefit.

1 INTRODUCTION

1.1 Importance of the study

Presently, one of the most highlighted goals in the European Union is, to gradually reduce the energy usage in every field. The so-called Europe 2020 strategy contains targets and implementations, helping to reduce the greenhouse effect and increase energy efficiency [1]. As the buildings are consuming significant amount of energy (40% of the total primary energy) [2], it is important to deal with their retrofit.

The historical downtowns of Middle-Europe contain heritage buildings in masses, which often are in a poor energetic state. Their retrofit is a complex problem. Several monument regulations and the dense urban fabric itself hinder their renewal. However, it would be highly important to establish renovation guidelines for them, which not only protects the unique, historical architectural character, but also provides better life quality for the residents by increasing the energy efficiency and value of the property.

1.2 Previous studies

Multiple studies deal with rehabilitation methods of historical buildings. About the general methods and problems, Webb [3] and Okutan *et al.* [4] write extensively. Complex

ISSN: 2056-3272 (paper format), ISSN: 2056-3280 (online), http://www.witpress.com/journals
DOI: 10.2495/EQ-V4-N4-320-331

methodologies are introduced as an example in the European Union funded EFFESUS project (Energy Efficiency for EU Historic Districts' Sustainability) [5]. The Renewal of historical urban fabric study [6] specializes to the case study building type. In energetic questions of the case study building type, studies of Csoknyai *et al.* [7], Iyer-Raniga and Wong [8], Harrestrup and Svendsen [9] should be mentioned.

1.3 Case study area and building stock

The case study area is part of Budapest downtown (See Fig. 1), where the major architectural heritage of is the en masse of these traditional apartment buildings built around the turn of the 19th and 20th century. They are the most significant part of the cityscape, with their ornamented facade and unique forming, making the area internationally recognised as historical, cultural and architectural heritage.

The chosen area is situated in the statistical boundaries of Budapest 7th District, bordered by Király Street, Erzsébet Boulevard, Rákóczi Street and Károly Boulevard. This part of the downtown area, named Belső-Erzsébetváros (Inner-Elizabethtown), was an agricultural area until the 17th century. Today, 473 buildings are situated on 0,6 km^2. 386 units, 86% of the stock is residential. Present survey only deals with the buildings with residential function.

The most characteristic building type of the area is the above mentioned traditional multi-storey apartment house. This type is mostly built in an unbroken row along the narrow streets of the 19th century Pest, connecting to each other with firewalls on three sides.

Usually, this type has been functioning as condominium with different size and variously equipped flats. The building is built around a courtyard. The street front wing is – as usual in this type – more decorated, containing larger flats. The courtyard wings contain simpler flats, often only with a kitchen and a room, which can be entered from the hanging corridors running parallel the walls. They were constructed using similar structures and materials due to the strict regulations of the century.

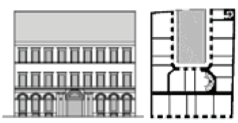
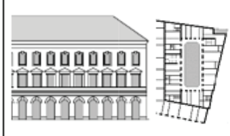
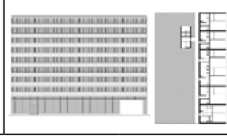
Currently, most of these buildings are in a poor condition, resulted by the lack of maintenance. Although their importance is not questioned, apart from some protected ones, most of the traditional stock is not sheltered from demolitions by law.

Such unprotected buildings are often destroyed to be rebuilt as contemporary apartment houses or modified to the point of losing their original values. One of the reasonings of demolitions is the poor energetic state and the sustainability problems.

The present state energetic calculation shows, that currently the building stock in the case study area consumes 274,7 GWh/a [10]. The heating energy used for the winter is particularly excessive, 2%–300% larger than today's prescribed amount [10]. As these downtown districts are the most populated parts of Hungary, the problem affects numerous residents.

Figure 1: The case study area: Budapest 7th district, and a characteristic streetscape.

Table 1: The architectural styles, their construction time and ratio in the case study area with example drawings of the street front facades and layouts.

Neo-Classicism– 8% 1811–1865	Romanticism – 2% 1845–1875	Historicism – 39% 1864–1913	Freestyle – 22% 1891–1935
			
Premodernism– 10% 1912–1942	Modernism – 1% 1954–1965	Socialist Modern – 3% 1962–1980	Contemporary – 9% 1983–2016
			

Previous study showed, that the energetic state and the architectural style of the buildings in the stock are in close connection [10], which term is already most commonly used in heritage protection guidelines. Thus, in the further part of the study, architectural style is used for grouping of the buildings.

The identification of the buildings is relatively easy depending on the style characteristics, or using the year of construction (Table 1). In brief, the Neo-Classicistic buildings are usually simple, using antique elements like tympanums. The Romantic style is taking elements from the Middle Ages, with Gothic, Byzantine or Romanesque decoration. Historicism was constructing larger buildings in masses, with Renaissance or Baroque ornaments. Freestyle buildings are using most of the plot, with waving façade surface and mixed decoration (Art Nouveau, Art deco mixed with Renaissance or Baroque). Premodernism is again simple, with undecorated façade. Modernism is using more evolved materials and free design of façade and layout, mostly with flat roof. Socialist Modernism is entirely different from the above, with its simple forming and prefabricated structures. Contemporary buildings cannot be described so simply, given the large variety of its layout and façade solution. In general, using present-day solutions in structures and materials, as well as free forming of façade with large glass surfaces might be considered as characteristics of the style.

The above styles had been identified using literature data from Hungarian studies dealing with style classification (Methodology: [10]).

2 METHODOLOGY

The authors grouped the factors into three main aspects: energy saving, heritage protection, and financial feasibility(See Fig. 2). All the three topics were thoroughly studied to find the main factors:

- Aspect 1, Energy efficiency: The energetic calculation methodology and European Union and Hungarian Decrees in force were studied to identify the possibilities of energetic interventions [11–13]. See the details in Section 2.1

- Aspect 2, Heritage protection: The heritage protection guidelines [14] and the characteristics of the case study building stock were studied to define the boundaries of renovation. See in Section 2.2.
- Aspect 3, Financing: commonly used methods for evaluating investments [15], were used as residential properties, are the biggest asset (ca. 70%) of households in Hungary [16]. Therefore, authors considered the decision of rehabilitation of this asset to have the same character as corporate financial decisions. After calculating project costs, returns and Net Present Value (NPV) were studied. Financial sources were also collected as investment needs exceeded savings of households. See in Section 2.3.

Aspects 1 and 2 were investigated first, as the protection of the architectural values and the energy savings were considered priority by the Authors. After investigating the limits and possibilities, renovation scenarios were created that both complied the heritage protection guidelines and the energetic aims on different levels. The introduction and evaluation of packages can be found in Section 3.

Results of Aspects 1 and 2 come only alive if upgrades are implemented. Therefore, financial background has to be assured based on strict calculations of both the investment and the returns of the investor. Detail can be found in Section 4.2.

2.1 Aspect 1: Energy efficiency measures and points of interventions

Connecting to the Europe 2020 Strategy [1], which aims to reduce the energy usage, increase the efficiency and to increase the share of renewable energy usage, new European Union and Hungarian regulations introduced the 'Nearly Zero Energy Buildings' (NZEB). In correspondence with above, the Hungarian Government Decree 176/2008. (VI. 30.) [11] on the certification of energetic characteristics of buildings implemented, with the 7/2006. (V. 24.) [12] Minister Without Portfolio Decree determining the energetic characteristics of buildings, and its amending decree of Home Secretary number 20/2014. (III.7.) [13]. For new buildings, the Nearly-zero level is mandatory from 2021, but in light of the ever stricter prescriptions, it can be expected to be extended to the renovation of the existing buildings. According to the EU decrees, the NZEB 'have very high energy performance, and the low amount of energy that

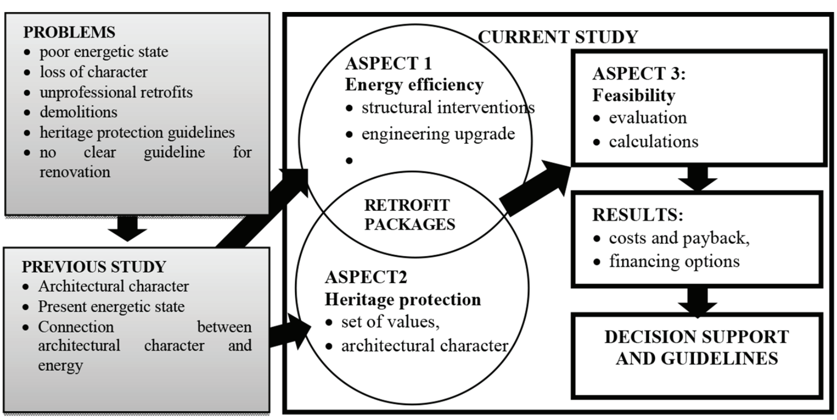


Figure 2: Structure of present study.

these buildings require comes mostly from renewable sources'. To reach the NZEB classification, all the three levels should be fulfilled. The three levels of requirement are the following:

- Compliance of structures (U, thermal transmittance value [W/m^2K]);
- Compliance of geometry (q, heat loss coefficient [W/m^3K]),
- Compliance of engineering systems (E_P, Total primary energy consumption [kWh/m^2a]). In case of residential buildings, the heating and hot water energy are considered.

Based on the above, the possible energy efficiency measures for buildings can be grouped into two main types: architectural interventions and engineering modernization (latter is mostly HVAC system).

Under architectural intervention, the two main techniques are: changes in geometry, and changes in material or structure. With these measures, the energy demand of a building can be reduced. After reducing the energy demand, the engineering modernization for heating, cooling should also be considered.

2.2 Aspect 2: Heritage protection guidelines

In Hungary, the monument protection system consists multiple levels: national monument protection, local protection, conservation area protection, and monument neighbourhood [14]. The case study area, the Old Jewish District of Pest is also protected in several ways: the district itself, with its organic fabric and built in structure, the streetscape and its scales are all protected, as well as multiple buildings have individual protection on national or local level. Most commonly, the forming of mass, space, the heights ratios in buildings, façade design with ornaments, fenestration form, indoor design and space relations are highlighted as values. The demolitions are discouraged on every level, even in case of the courtyard wings.

2.3 Aspect 3: Financial background and trends

Factors that hinder energetic refurbishments are mostly the same as in countries with the same historical background as Hungary. Price level of construction industry increased by 34% since 2010 [17], state support preferences new constructions, there is a lack in general knowledge and approach towards energy efficiency and tenders cause a lot of administrative burdens.

93% of the buildings in question are in private ownership [6]. Most commonly, each flat has its owner, the common spaces are shared ownership. Every decision on the building is based on residents' democratic voting. Refurbishment savings are not mandatory. Partially this system is responsible for the very low number of retrofits, and even less energetic rehabilitation in the stock.

Availability of affordable financial sources is crucial when it comes to rehabilitation. Top barrier of building green is high first costs [18]; thus, it is important to enumerate current possibilities in Hungary.

Taking all these into consideration authors were searching for possible financial sources to make rehabilitation feasible for all households:

Own resources can arise from residents (household savings or subsidized housing saving fund and / or refurbishment savings of communities.

Cash and deposit are the second biggest group of financial assets of Hungarian households and it shows a continuous decrease between 1995–2015 [19]. In the last 10 years, gross savings were around 11%–12% [20]. The amount that households keep in cash, deposits and short-term securities (so it can be quickly and easily used for funding reconstruction costs) is currently in average 12,630 euro per household [21]. There is no data available about average refurbishment savings of communities.

Normal bank loans could also be considered. The average amount of housing loans (APR between 4–10%) is 8,600 euro, but these are generally used less and less for modernization (ca. 5%) [22]. Rapidly increasing ratio of loans raised for purchasing new flats are clearly driven by CSOK (Funding for Dwellings of Families, a Hungarian support for family housing). Unfortunately, energetic features of newly built flats do not reach cutting edge solutions.

The government also realized the problem of fund for energetic renewal. The Warmth of a Home program is announced every year for different purposes. In 2019, change of convectors was the goal of the grant. Disadvantage of the program is that the goal is not foreseeable and the total amount of the grant is low; thus, many households miss the opportunity.

Different supports are available for energy saving projects financed by the state and there are some examples of ESCO (Energy Service Company) model also.

To sum up the above, the households and common condominium management do not have real planning options for large-scale retrofit of these houses, they receive no foreseeable funding and guidelines to help the decisions and the reconstruction itself. The result is, that mostly individual smaller retrofits are made, and the much-needed complex retrofits are rare.

3 RETROFIT SCENARIOS

The main problem with the retrofit is, that the monument protection boundaries and the energy retrofit possibilities are controversary. The architectural intervention points mentioned above are intruding the same surfaces that the guidelines aim to protect. The retrofit measures should consider the character of a building, to avoid the loss of values. Figure 3 shows retrofits without respecting the architectural character. The enveloping structures possible solutions are detailed in the author's previous study [23].

To avoid the mistakes shown on Fig. 3, the limits of the retrofit should be included. These include the problems of the dense urban fabric, and also the monument protection guidelines, which should be applied to maintain the architectural values and character.

When creating the renovation scenarios, the authors thus considered two limiting data: the retrofit should be complying the heritage protection guidelines, and the retrofitted building should reach the nearly zero energy level.

Three scenarios, the original state, and two retrofit versions were considered and compared to each other. The scenarios are named based on the architectural intervention and engineering upgrades included. The first part of the abbreviation shows the code for the architectural

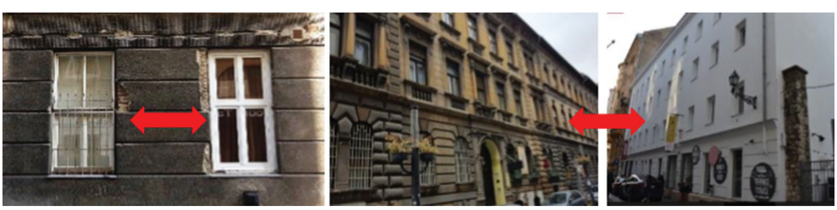


Figure 3: Energetic retrofit with no consideration to heritage value. The original ratios and ornaments are destroyed.

intervention type, the second part is for engineering. The scenarios are combinations of architectural interventions and engineering upgrades:

- OR_OR: Original structure with original HVAC system, basically the present state of the buildings. This scenario is used for baseline of comparisons.
- OR_CH: Original structure with upgraded HVAC system, where the heating is provided by modern condensation heater. This is a common upgrade option of the houses.
- LI_HP: Least invasive structural upgrade with heat pump. This scenario is the most optimal renovation solution complying all the heritage protection guidelines and the nearly zero energy requirements.

Concerning the architectural interventions, OR and LI methods are introduced below:

The 'Original Structure' (OR) contains the data of the original structures based on a typology created using literature sources. Fortunately, in the surveyed time range, clear information can be found in various sources detailing the used building structures. The most characteristic period of the stock, the turn of the 19th and 20th century, is especially well documented. For the detailed methodology of the typology, see [10]. The advantage of this version is, that there is no intervention, but it is not decreasing the energy demand either.

In case of the 'Least Invasive (LI)' component, the heritage protection guidelines are fully complied but only the necessary, less visible, valuable surfaces were insulated. The decorated façade walls, cellar walls, arcades are left intact. The roof and cellar slabs were insulated as well as the not-covered firewalls. The preferred material is mineral wool, because of its advantageous vapor characteristics. The windows are upgraded with the full heritage compatible solution (fitting and exchange of the glass to low-e glazing) [23]. The upgraded surfaces were calculated with sufficient insulation to reach the nearly zero U value requirement level [11–13]. The advantage here is, that intervention happens only on less-visible surfaces, or mainly not decorated surfaces.

Similar to the architectural interventions, the engineering solutions are: 'Original heating system (OR)', 'Condensation Heater (CH)', 'Heat Pump (HP)'.

The 'Original heating system (OR)' of the buildings is based on the Hungarian Central Statistical Office database was used on assuming the presently used heating systems of the traditional apartment houses. Most of the traditional buildings are not centrally heated, but with room-by-room devices. These are mostly equipped with convectors for heating and gas boiler for domestic hot water.

The 'Condensation Heater (CH)' uses gas and heats through hot water-filled radiators. The domestic hot water is produced via the same device and stored centrally. This is a common solution for retrofit, which is included in the study, because the practice shows, that it is a common choice for retrofit.

The 'Heat Pump (HP)' is, as the name shows, using the device to absorb heat from outside air and releases it inside the building. Its advantage is, that the same system can be reversed in summer, cooling the indoor temperature. The empty attic or the cellar can provide enough space for the system. The pipe systems with radiators should be reconstructed in the whole building.

The above scenarios were used to calculate the original and the retrofitted versions' original and upgraded energy usage. All 386 buildings of the case study area were included, there annual energy consumption were compared in case of every scenarios.

4 RESULTS AND DISCUSSION

4.1 Calculations, values used for evaluation

In the methodology section, it was mentioned, that three aspects were considered in this study. The energetic (Aspect 1) and heritage protection (Aspect 2) were used combined to create the retrofit options by limiting the usable technical solutions. Aspect 3, financing was used to evaluate and compare the scenarios.

For the energetic calculation, the European Union, Energy Performance of Buildings Directive (EPBD) conform Hungarian calculation system was used (See section 2.1). The value used for evaluation from this aspects are: E_P, Total primary energy consumption [kWh/a]) and $E_{\Delta P}$ energy saved [kWh/a].

Project costs for each building for each scenario were calculated with help of TERC VIP Gold software [24], which is a cost calculating tool Hungarian construction industry mostly uses. Both material and labour costs were included into the amount. This amount was divided by the number of flats the building contains to enable a household level study.

Currently, costs of electricity and gas are laid down by the state since 2010 in Hungary because of socio-political reasons. Therefore utility cost calculation of households after energetic refurbishment were counted with current prices without estimating inflation and price volatility of energy on the worldwide market. Saving of households due to decreased energy consumption (lower utility costs) was considered as positive cash flow (CF) of the project. CF was discounted with the interest rate of long-term Hungarian treasury bonds [25], as authors regarded risks of energetic retrofit as almost 0 like in case of Hungarian treasury bonds. NPV was calculated for 20 years with project cost as starting expenditure (negative CF) and savings of households (positive CF, discounted).

4.2 Evaluation of retrofit scenarios

As Table 2 shows, the optimal choice for Aspect 1 would be to use LI_HP scenario. In OR_OR scenario, the present energetic state is averagely bad ($\sum E_P$ = 274,7 GWh/a). Using OR_CH would only partially help (20%–40% average energy saving, $\sum E_{\Delta P}$ = 69,9 GWh/a), increasing the energy efficiency only a little. LI_HP would result averagely 70-80% energy saving ($\sum E_{\Delta P}$ = 204 GWh/a).

As for Aspect 2, OR_OR and OR_CH would only maintain the present, slowly deteriorating state. In case of Socialist Modernism and Contemporary styles, the buildings and structures are not yet old. LI_HP would comply all the heritage protection guidelines.

Aspect 3 shows the payback period of the scenarios. In case of OR_OR, it is not applicable. OR_CH have short (5–15 years), LI_HP have quite long (20–40 years) payback period.

To summarize, including all aspects, OR_CH would be a fast payback period, but moderately energy saving retrofit, which is not upgrading the building structures, thus leaving them to further deterioration. LI_HP is the best choice from energetic and heritage protection point of view, but on the other hand, the upgrade is expensive and hardly pays back within reasonable time.

The authors nevertheless suggests to use LI_HP scenario, based on the below reasons:

- Energy efficiency is a key question today, and saving most of the energy is an obligation.
- Protecting and maintaining our built heritage should not be measured only in cost-efficiency. These buildings are highly regarded as cityscape, historical and architectural value,

Table 2: Comparison of scenarios, based on aspects, by architectural style.

Aspects	Scenarios	Classicism	Romatisicm	Historicism	Freestyle	Premodernism	Modernism	Socialist Modernism	Contemporary
ASPECT 1 Energetics (Energy usage per year)	OR_OR								
	OR_CH								
	LI_HP								
ASPECT 2 Heritage Protection (Is it protecting heritage respecting?)	OR_OR								
	OR_CH								
	LI_HP								
ASPECT 3 Financing (Feasibility and payback period)	OR_OR								
	OR_CH								
	LI_HP								

thus should be saved. Using standardized guidelines would stop the individual modifications of the buildings, which are currently problematic (see above)

- Large number of residents lives in these buildings, which underlines the need of renovation to improve their life quality.

The main disadvantage of the LI_HP scenario is undeniably, the cost (averagely 347 000 Euro per house). Not surprisingly, NPV calculation showed negative numbers; thus, an inadequate result as a business case for any profit oriented organisation. Payback period for the most expensive scenario would be 64 years. We must keep in mind that positive CF was calculated with current utility costs, which is a clear underestimation but might be reality because of socio-political reasons. If we would have counted with inflation and price increase of energy, household saving would have been bigger, thus CF per period and as a result NPV would be higher.

Although as a business opportunity, no one would catch for energy saving rehabilitation, there are other factors that provide justification for such investments. Heritage protection and obligations to energy saving are reasons enough to search for funds that can finance the projects.

The amount of the investment required for the retrofit is impossible to be covered by households themselves as these surpass own savings (see Section 2.3) by far. Therefore, additional fund is to be collected.

One possible solution is the Energy Efficiency Loan Scheme for Residents, which can be raised by condominiums also. Financial institutions offer credits especially for refurbishments and even free-use credits could be source. The most advantageous conditions (0% interest) are offered be the state owned Magyar Fejlesztési Bank (Hungarian Development Bank) as Energy Efficiency Loan Scheme for Residents. The loan can be raised by individuals (max. 30,800 euro) and condominiums (max 21,540 euro per flat) for energy efficient retrofit and/or renewable energy resource usage of dwellings [26]. Calculations show that retrofit scenarios advised by authors can be almost fully financed by household savings on utility costs as these cover repayment for the duration (20 years).

In case of less than 10% of the houses (37 out of 386, mainly Historicism and Classicism style) when additional fund is needed. For these cases, authors suggest combination of the following existing possibilities:

- own savings of households and / or condominium
- housing loan with low interest rate
- subsidized housing savings account of residents

Funding for projects could also be household savings in subsidized housing saving fund, which was a commonly used tool for home-savings accounts. It had the advantage of government support until end of 2018, since then serves as own source of households. Average level of this source (rounded up in 6–9 years) can reach approximately 13,850 euro. Although purpose of use is change of fenestration and insulation according to a representative research of one of the biggest actors in the country, amount planned for reconstructions is only 5,540 euro. Those living in the central region with high-level education this amount reaches 7,080 euro [27].

Additionally, authors found that CSOK (see above) is possible to raise for retrofit but currently only in case of houses situated in small villages. An extension towards energy efficient rehabilitation everywhere in the country is essential to support the goals highlighted in the article. It would not be an unprecedented support as prefabricated Social Modernist buildings already received this possibility some years ago.

Another solution would be Energy Efficient Mortgages launched currently by the EU or an example from Great Britain. The latter [28] is a service provided to owners including a consultation about the most efficient retrofit and pre-financing of the project. Repayment of the loan is based on the previous utility costs (it cannot exceed those) and is connected to the bills thus also tenants can pay it. In case of selling the flat, the loan is transferred automatically to the new owner.

5 CONCLUSIONS

Based on the above results, the energy saving and heritage respecting solutions for retrofit are not economically feasible enough to be appealing for private investors. The renewal of these buildings are, however, much needed to increase the life quality of residents, save energy, and protect the unique architectural character, now constantly endangered by demolitions.

The results also show that large amount of energy (70%–80%) can be saved by renewing these buildings. The costs of a complex rehabilitation that complies to energy efficiency aims and heritage protection guidelines are relatively high. The residents usually do not have the funds and need professional help to deal with the retrofit on building level. Only small, individual upgrades are made currently which frequently damage the architectural character.

The solution can be to offer technical guidelines for the complex, building-scale retrofit. These large-scale upgrades should not be dealt as standard cost-efficiency based investments, but as a way to reach the energy saving goals and support the sustainable protection of our heritage. The financing thus should be supported by the government by upholding and extending the presently available options.

Beyond serving energy efficiency and protection of our built heritage, refurbishment of these buildings creates positive externality: renewed streetscapes, better comfort of life and last but not least, the apartments become much more valuable for the long term.

ACKNOWLEDGEMENTS

Supported by the National Cultural Fund of Hungary (http://www.nka.hu/).

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