# 480: Risks and solutions in the practice of building retrofit

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**Abstract**

In addition to energy considerations, the concept of a renovation project is affected by many other practical aspects: available budget, preconceived ideas, non-energetic purposes (aesthetic issues, acoustics, fabric protection, maintenance, etc.). The outcome is often a partial renovation, in which only some building elements are upgraded. It can result in unexpected negative impacts: fabric damages, overheating, less energy saving than foreseen, discomfort and unexpected extra costs. This paper analyses the most relevant renovation measures, focusing on the possible risks and the parallel measures necessary to avoid the problems and to improve the outcome of the project. Additionally, possible risks of properly elaborated complex retrofit projects are also presented regarding user behaviour, improper exploitation of results and marketing issues.

Keywords: building retrofit, complex renovation, effects and side effects, green investment scheme, supporting schemes

## 1. Introduction

In the recent years significant efforts were made on the retrofit of buildings in order to decrease the heating energy use and $CO_2$ emission of the Hungarian building stock. Most of the projects were partial renovations, e.g. replacement of windows or insulation of one **or** two facades **or** modernisation of the heating systems. The reason was the lack of financial resources, but in many cases also the lack of professionalism. In a significant part of the projects the result was disappointing: mould growth on the inner surface of the facades, less energy saving than expected, noisy heating system, etc. In order to realize a successful project the effects and side effects, the interactions and synergic effects of the renovation measures have to be considered and a complex approach should be followed. These interactions, risks and solutions will be discussed in the following chapters. Not all measures will be analysed (e.g. the realisation of controllable heating systems, application of renewable systems are missing) only a random selection of them.

## 2. Replacement of windows and doors

### 2.1. Contribution of windows to the energy balance of the building

There are two kinds of energy losses in relation with windows:

- The transmission flow through the structure: the glazing and the frame, but here should be mentioned the thermal bridge losses at the junction of the frame and the facade wall;
- Infiltration and exfiltration through the air leakages at the window sills and the frame-wing contours are responsible for a major part of the ventilation losses in a building unless the building envelope is airtight.

When calculating energy efficiency, not only the improvement of the U-value, but also thermal bridge losses, the lower ventilation losses and the solar gains should be taken into account. The energy saving strongly depends on the geometry and the original structure.

### 2.2 Other advantages of replacing windows and external doors:

- Better air tightness and lower ventilation heat losses,
- More stable air change in the different rooms of the building, resulting in easier control of the heating system,
- Significantly higher energy efficiency of a potential balanced ventilation system with heat recovery,
- Better acoustic comfort,
- Better thermal comfort owing to the warmer internal surface of the glass.

### 2.3 Risks of replacing windows and external doors:

- The decreased ACH (air change rate) can result in fabric damages (mould growth, unless added thermal insulation of walls is provided),
- In case of open burner in the flat the decreased ACH can result in accident,
- In case of inappropriate positioning and installation of the new windows the decrease of thermal bridge losses does not meet the expectations and eventual mould growth is possible around the window reveal.

### 2.4 Arguments for complex renovation:

- New windows are airtight, thus a significant drop of the ACH is expected. Lower ACH results in higher relative humidity in the room air unless measures for efficient ventilation are made. The higher humidity can result in fabric damages and mould growth at cold internal surfaces, especially at structural joints. The problem can be avoided when external added thermal insulation is applied.

- Thermal bridge free installation can be achieved if the added thermal insulation covers the external surface of the frame. It leads to further energy savings and minimises the risk of mould growth around the window inner surfaces. For the correct installation construction plans are recommended.
- The calculated energy saving cannot be achieved if the heating system is not controllable and not adjusted to the lower heat demand. In case of an uncontrollable heating system, the renovated building will be overheated or the tenants will open the windows too often.
- Solar gains through the glazing can be responsible for most of the cooling load. Construction costs can be decreased if summer protection measures and window replacement are established jointly.

### 2.5 Recommended joint measures:

- Realisation of a controllable heating system
- Thermal insulation of the building envelope, particularly the facades, but in certain construction types the insulation of other elements may have priority
- Solar protection measures, particularly in case of combined systems (integrated shading device between the glasses, special protective glasses and solar protective foils that decrease the shading coefficient of the glazing (g-value) with at least 25% (see chapter ”Solar protection)
- Window fittings that keep the open window in a fix position are eligible, because it is useful for natural cooling in summer nights. Mosquito nets are in certain cases necessary to be able to keep the windows open at night.

## 3. Improvement of the thermal envelope

### 3.1 Energy losses and saving potential

The main energy saving potential from the insulation of the thermal envelope is due to the reduction of transmission losses and the related heating energy demand. In multi-storey buildings facades are the responsible for most of the losses, but in low-rise buildings the roof and the floor on the ground or over the cellar have more significance. With additional insulation, not only the thermal transmittance of plane surfaces is reduced, but also the effect of thermal bridges (construction joints at slabs, window perimeters, wall corners etc.) decreases significantly. Depending on the building type, this can account for a considerable fraction of the total losses. The analysis of buildings made with prefabricated sandwich panels (dominating the building industry in the 70's and 80's in Eastern-Europe) proved that 20-30% saving could be realised through additional insulation, from which more than half was due to the reduction of thermal bridge losses. In other types of buildings, thermal bridges are usually less significant. Another effect of additional insulation is the shortening of the heating period, which further increases the potential energy saving.

According to the Energy Performance Building Directive (EPBD) only buildings with a total useful floor area over 1000 $m^2$ undergoing major renovation have to meet the minimum requirements of the building code. “Major” is the renovation if the cost of the measures exceeds 25% of the value of the building (without that of the building site).

In general, additional insulation is the most economical if the building element is in bad condition and needs renovation anyway. In this case, only the measures directly connected to the insulation should be taken into account in a financial analysis considering that the price of the insulation material itself is only a fraction of the total investment costs.

### 3.2 Advantages of additional insulation (external insulation):

- Effect of thermal bridges is reduced: fabric damages are prevented, mould growth is eliminated.
- Better thermal comfort for the inhabitants: higher internal surface temperatures, air temperature can be lower.
- Heat capacity of the structure is increased: more stable internal temperatures (lower temperature peaks in summer), better utilisation of solar gains in winter.
- Protection of the load-bearing structure: risk of frost and driving rain damages is decreased. In panel buildings corrosion of steel elements at constructional joints is prevented or slowed down.
- Smaller built-in capacities are required: heating system with a lower output is enough, smaller radiators are satisfactory.
- Life time of the building is increased.
- Satisfaction of users is higher.
- Increase of aesthetic value.
- Increase in the market value of real estate.

### 3.3 Risks:

- Thermal bridge effect might be increased at special joints where insulation is difficult, e.g. balcony slabs.
- In certain cases, mostly if internal insulation is not correctly applied, vapour diffusion problems might arise, risk of condensation and fabric damages, mould growth but this risk can easily be avoided if the design and execution is professional.
- Internal insulation reduces the heat capacity of the building.
- The application of internal façade insulation has to be justified. It can only be accepted if expert calculations prove that there is no condensation risk in the structure. The effect of thermal bridges has to be calculated in a detailed way, preferably with finite element software tools.

### 3.4 Arguments for complex renovation:

- Building elements can be renovated separately, but to minimize the effect of thermal bridges, the best is to apply the additional insulation on all elements at the same time, or at least to prepare for it with careful planning.

- If windows are replaced at the same time, a thermal bridge free installation can be realized if the façade insulation overlaps the external surface of the frame.
- The calculated energy saving cannot be achieved if the heating system is not controllable and not adjusted to the lower heat demand. In case of an uncontrollable heating system, the renovated building will be overheated or the tenants will open the windows too often. Conversely, if controllable heating is installed and the building envelope is retrofitted only several years later, the heating system may need to be modernized again, causing extra costs. The same level of energy saving can be achieved only with higher labour input and extra costs if the measures are not done at the same time in an integrated way.

**3.5 Recommended joint measures:**

- Realization of a controllable heating system.
- Exchange of windows and external doors.
- If original radiators remain, replacement of atmospheric boilers with condensing boilers.

## 4. Condensing boilers

**4.1 Energy saving and environmental impacts**

The energy efficiency of gas boilers can be higher than 88% only in condensing operation. The latent heat content of natural gas is 11%, which means that a condensing boiler has a nominal efficiency at least 11% higher than that of an atmospheric boiler. In reality the energy saving can be significantly higher as the efficiency of condensing boilers remains high at low-performance partial load e.g. during mid-season (moderate external temperature). This is not the case for atmospheric boilers. In general the choice of a condensing boiler instead of a good quality new atmospheric boiler would save 15-20% energy and the corresponding $CO_2$ emission. In case of exchanging an old boiler to a condensing new one the saving can be up to 30%.

In addition to the saving of energy and of the $CO_2$ emission, the $NO_x$ emission of condensing boilers is less than 50% of that of the best atmospheric boilers. CO emission is also significantly lower.

**4.2 Technical requirements**

Boilers should be designed for operating in the range of 30%-100% nominal output during the major part of the heating season. Therefore, if the heat demand of the building (or building part) heated by the boiler is below 10 kW, priority should be given to boilers having a nominal output below 15 kW. These types of boilers usually require a DHW-storage tank, unless the boiler provides heat only for heating and not for domestic hot water.

Heating systems should be designed for a return-flow temperature under 45 $^oC$. Low-temperature heating systems have larger radiating surfaces than usually that may increase the investment costs in a new building. Wall heating and floor heating are ideal options.

In the frame of a retrofit project when the building envelope is upgraded, the original radiator surfaces may be ideal for a low-temperature heating. It should be taken into consideration in the planning of the retrofit measures.

**4.3 Recommended joint measures**

- Realization of a controllable heating system.
- Ideal for surface heating systems (wall heating, floor heating)
- Replacement of original radiators with larger ones if the heat demand is not decreased with upgrading the building envelope

## 5. Solar protection

The EPBD gives priority to strategies that enhance the thermal performance of buildings during the summer period with a special attention to passive cooling techniques. The application of passive solar protection measures decreases the cooling demand and the necessary installed capacity of the air-conditioning systems resulting is significant energy and $CO_2$ emission saving. From the point of view of $CO_2$ mitigation the substitution of AC (air-conditionning) systems with passive cooling techniques is particularly significant, as most AC systems are driven by electricity, which has a primary energy factor of 2,5-3,0. It means that $CO_2$ mitigation caused by 1 kWh saved cooling energy is equivalent of mitigation caused by 3 kWh saved heating energy (in Hungary).

Summer comfort is particularly problematic in offices where temperatures above 28 $^oC$ strongly decrease the working productivity. Furthermore, office equipments (photocopies, computers, printers, faxes) produce significant internal heat load above solar gains. An efficient solar protection can decrease the cooling load up to 60-70 %, but the concrete value is determined by the ratio of solar gains and internal gains. The effectiveness of the solar protection can be improved with night ventilation, particularly in buildings of massive construction.

It is hard to estimate precisely the energy saving and $CO_2$ mitigation potential of solar protection devices on national level, because in many cases they don't explicitly substitute the AC-system, but improve the summer indoor comfort. However, as AC-systems have an intensively growing market they will be responsible of future, presently non existing $CO_2$ emission. Passive cooling devices could hinder this future trend. In other terms solar protection is a measure to prevent a self-generating process of wide spreading of AC.

The more AC are in use the more intensive is the anthropogenic heat output and as a consequence the urban heat island effect. The increasing temperature in urban areas results in intolerable overheating and further wide spreading of AC systems.

### 5.1 Other considerations

Most external shading devices decrease the U-value of the glazing at night during winter, which results in secondary savings in the energy consumption and $CO_2$ emission. This effect is particularly important for old windows.

There are several solutions on the market that decrease the solar gains in a building: fix overhangs, venetian blinds, roller blinds, shutters, louvres, reflexive coatings, protective foils, etc. Their influence on the cooling load is different. In general devices on the outside are more efficient than on the inside of the glazing, but they may cause extra thermal bridge losses.

Installation of solar protection devices can be supported as an independent measure, but it is recommended to consider their combination with the replacement of windows, because several combined solutions can be found on the market (integrated shading device between the glasses, special protective glasses).

### 5.2 Risks

Some solar protection systems may influence the appearance of the buildings significantly and building permission is needed.

## 6. Balanced ventilation systems with heat recovery

In single family houses and small buildings the significance of ventilation losses is app. 20-40% of the total heat loss, but in large existing buildings it can be above 50%. A part of the ventilation losses (the spontaneous filtration through the air leakages) can be eliminated by creating air-tight building envelope (see windows section), but the fresh air needed for human respiration has to be provided in any case. Also a minimum air change rate needs to be kept in order to avoid fabric damages caused by mould growth. The necessary fresh air can provided by simply opening the windows or by using mechanical ventilation. The exchange of air results in inevitable energy waste that can be decreased by a balanced ventilation system with heat recovery. In such a system the leaving warm used air warms up the cold fresh air in a heat recovery unit. This way the ventilation losses can be decreased with 50-90%. The concrete value depends on the efficiency of the installed unit and the air-tightness of the building envelope.

**Advantages**

A properly designed, installed, operated and maintained balanced ventilation system with heat recovery has several positive features:

- 50-90% of the ventilation heat losses and the corresponding $CO_2$ emissions can be eliminated. It represents approximately 15-50% of the total energy consumption of a building.
- The air change rate can be adjusted to the needs using a control panel (e.g. if the tenants are cooking it can be turned up, if they are not at home it can be turned down). After heat recovery the remaining ventilation losses can be kept minimal. Also the electricity consumption of the ventilators can be decreased in case of intelligent usage.
- The indoor air quality is better, because the incoming fresh air is cleaned by an efficient filter. It has a positive impact on the health and the working productivity of the occupants.
- As the air change rate is not allowed to be higher than necessary the desiccation of indoor air can be decreased, which has another positive health impact.
- Since fresh air is provided by a mechanical system there is no need to open the windows in winter. It is particularly favourable if the building site is noisy and the outdoor air is polluted. Drought is also avoided this way.

**Risks**

If a system is not properly designed, installed, operated or maintained the following problems may occur:

- Energy efficient ventilators should be selected, otherwise the primary energy saved in heating would be significantly decreased by the consumption of the ventilators.
- Condensation and frost between the heat recovery unit and the air outside. It can be avoided with thermal insulation of pipes and/or other frost (pre-heating, by-pass) protection methods.
- If the filters are not regularly replaced the ducts can get dirty decreasing the indoor air quality.
- If condensed water is not correctly removed legionella bacteria can proliferate resulting in legionella disease. The problem can be avoided by proper installation.
- If the speed of the fresh air in front of the air inlet is too high it can cause discomfort. The optimal speed depends on the location of the inlets in the room, but in a dwelling air speed under 0,2 m/s is a safe solution.
- If the air speed in the ducts is too high and/or the silencer is not properly designed or installed the noise level can be disturbing.
- Selection of the materials used in the system should take into account their health impact (e.g. mineral fibres in a silencer can cause cancer).

## 7. Sunspaces – additional glazing of existing loggias and balconies

### 7.1 Energy losses and saving potential

Glazed loggias or balconies are acting as sunspaces/greenhouses or they can be regarded as a special form of double-skin facades. The advantages of this solution are the extension of the inhabitable space – the sunspace might be used up to 5000-6000 hours per year, on the one hand, and the potential heating energy saving, on the other hand. The energy balance of the sunspace is determined by complex energetic processes. Incoming solar radiation is “trapped” in the sunspace due to the greenhouse effect. The absorbed heat warms up the air and elements in the sunspace and enters the room behind the sunspace by conduction and

ventilation. The transmission losses of the interior are reduced as the sunspace acts as a buffer between the external environment and the interior. The most considerable saving is usually from the reduction of ventilation losses if the interior is ventilated through the sunspace by the air preheated in the sunspace.
Different design strategies should be applied if the goal is to maximise the number of inhabitable hours in the sunspace or to maximise the heating energy saving.

### 7.2 Advantages

- Additional insulation of the façade becomes easier: if the loggias have side walls, only the external surface of side walls adjacent to the exterior, the edges of the side walls and of the balcony slabs and the bottom horizontal surface of the lowest balcony slab should be insulated. As the sunspace temperature is higher than the exterior, this insulation can be thinner than the average. The loggia on the top floor can be covered with a transparent covering.
- Improved acoustics: noise from the external environment is considerably reduced in the interior.
- Protection of the façade against rain.
- The sunspace acts as a dust settling chamber, ventilation air through the sunspace will be free from larger particles.
- Security of the dwelling is improved against burglary.

### 7.3 Risks

- Aesthetics: glazing of loggias one by one, by different executors and using different systems will result in an aesthetically undesirable appearance. On the other hand a well designed, professionally installed solar protection device can increase the aesthetic value of the façade. Single glazing without frame can be, for example, an elegant solution.
- Inappropriate use of the loggia, for example as a storage room will also negatively influence the overall appearance.
- In the winter, direct solar gains and day lighting levels are slightly decreased due to the additional glass pane.
- In the winter, vapour might condense on the internal surface of the loggia glazing. This can be avoided if there are small dilatation gaps between the panes or lamellas; however this reduces the insulation capacity.
- The risk of summer overheating might be higher due to sunspace unless the movable shadowing devices and openable glazing are correctly used.

**Recommended joint measures**

- Realization of a controllable heating system.

**Design considerations**

- If additional insulation of the façade is also foreseen, the glazing and the insulation should be designed and preferably executed at the same time for the most optimal technical solution.
- Only unheated loggias, separable from the interior can be supported. It is not allowed to install heating device in the sunspace.
- In order to maximise solar gains in the winter, orientations close to South (SW-SE) should be preferred. However, other orientations might also be supported if the saving potential is justified. In this case, the saving from the sunspace should be compared with the potential saving if additional insulation is applied.
- In the summer, the risk of overheating should be minimised by installing effective shading devices and providing appropriate ventilation of the sunspace. Suitably sized and located openings are necessary, the most favourable option is if the glazing can be totally removed (sliding panes, rotating lamellas etc.).

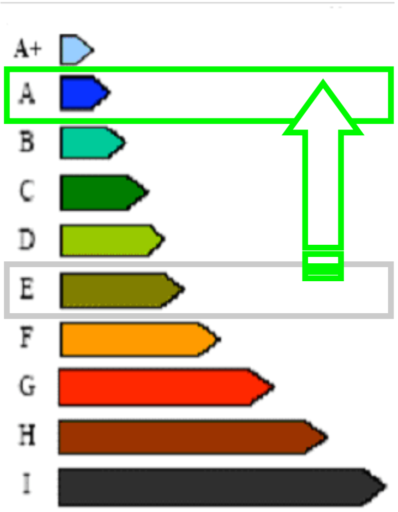
## 8. Other arguments for complex renovations

- Renewable systems were not discussed in details, but one point should be mentionned: the investment cost of such systems is usually higher than that of the energy efficiency measures. Therefore it is usually recommended to apply renewable systems when the energy efficiency measures are already accomplished. Thus, a much smaller renewable system will be enough, which is more economical than installing a large renewable system in an inefficient building.
- From the point of view of the construction process, complex measures are more effective than a series of individual measures realized in several stages taking more years. Repetitions of actions can be avoided: scaffolding, taking the site, surface finishing, etc. Realization of structural joints is easier. Inconveniencies caused to the building occupants are less. Finally, the total cost of the investment is lower for the complex renovation than for the sum of the individual measures.
- Regarding the supporting schemes complex projects are easier to handle. The paperwork is much less, because if individual measures are supported the number of projects are much higher and all bills and invoices must be collected and checked. In countries with significant black market this can provoke 'invoice production', thus growth of the black market.

## 9. Conclusion and recommendation for subsidy systems

This paper has illustrated the advantages of complex renovation projects to the individual measures from the point of view of fabric protection, energy saving and environment protection, technical feasibility, disturbance on the occupants and the investment costs in long term. In spite of the many advantages, most projects (in Hungary) are focusing on individual measures, because they are much cheaper, at least in short term. It results in problems that should be handled.
Complex projects could be stimulated by significantly higher supporting intensity than that

for individual measures. The optimal form of support (cheap loans, non-refundable grants, lower taxes, etc.) is not discussed here, because it strongly depends on the economical, social environment of the country.
However, the EPBD provides a possibility for a common approach for establishing state support programs based on the certification system with the following idea: No matter what the renovation measures are, the only important questions are the starting and the end point of the renovation in the scale of the certification system. The amount or intensity of support is calculated from the difference between the energy performance level of the original and the renovated state. For example if a building was originally in category H and it was upgraded to category C, this category "jump" will determine the support. If the target category is A or A+, the support will be certainly higher. The concrete grants and support intensities can be determined considering the scale of the national certification system, the economical environment, cultural background and the priorities. However, it is recommended to apply a progressive scale: the better the target category is the support should increase progressively. Only a progressive scale motivates building owners to choose the more efficient, complex approach.




This scheme has great advantages. The amount of the grant doesn't have to be in proportion with the investment costs. Since only the original and target energy performance count, the beneficiaries are motivated to choose the cheapest but most energy efficient solutions. In a mature system the market will choose the optimal combination of measures for each project. In addition, the administration can be simplified as bills and invoices are not necessary. If complex projects are subsidised, the demonstration effect is much higher, because buildings renovated in a complex way look much more attractive.

This idea is being implemented in the Hungarian Green Investment Scheme that is planned to be introduced during autumn 2008.