Energy Performance and Major Renovation

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ABSTRACT

According to the Article 6 of the 2002/91/EC – EP *"when buildings with a total useful floor area over 1000 m^2 undergo major renovation their energy performance is upgraded in order to meet minimum requirements …."* which should be derived *"…in accordance with Article 4."*
The energy performance of existing buildings is of utmost importance due to the fact that the change of the building stock requires several decades. But renovation does not automatically mean better energy performance. *"Functionally and economically feasible"* renovation may aim at better comfort, fulfilment of functional requirements and may include e.g. change of individual stoves for central heating, implementation of mechanical ventilation, etc., accompanied by change of fuel and need for electricity. Regarding the investment for renovation the Directive says that *"It should be possible to recover additional costs…within a reasonable period of time…".* Although *this* is the question the owners and builders are interested in, it would be more plausible to ponder the complete energy balance, including operational energy saving, embodied energy for renovation and the life time of the renovated building.

KEYWORDS

Life cycle energy balance, renovation, Energy Performance of Building Directive

INTRODUCTION

According to the Article 6 of the 2002/91/EC – EP (in the followings EPBD) *"when buildings with a total useful floor area over 1000 m^2 undergo major renovation their energy performance is upgraded in order to meet minimum requirements …."* which should be derived *"…in accordance with Article 4."*

According to the suggestion of the EPBD the criteria of "major" renovation is that the cost of the measures exceeds 25% of the value of the building (without that of the building site). To this definition in the new Hungarian Building Regulation (TNM 7/2006) it isadded: "providing the measures aim at the improvement of building envelope and/or mechanical systems."

No doubt, energy performance of existing buildings is of utmost importance due to the fact that the change of the building stock requires several decades – maybe a century. Nevertheless the interpretation of the above mentioned Article is not unambiguous, some important aspects of a more complex energy balance are missed and several details should be pondered more precisely.

COMPLEXITY

"The requirements may be set either for the renovated building as a whole or for the renovated systems or components when these are part of a renovation to be carried out within a limited time period" (EPBD, 2002). In general energy performance should be expressed as a specific integrated value in primary energy, which includes all mechanical systems. This "integrated" approach cannot be applied for a component or a separate system. It is proven by experience of renovations, carried out in Germany and Hungary as well as the detailed monitoring and simulation data of the SOLANOVA demo-house project (5th Framework Program for Research& Development, No. NNE5/2001/923) that partial renovation of building components or typically *building related* mechanical systems (HVAC) does not provide adequate result, moreover, it conserves an unfavourable situation for a long time and may increase the risk of fabric damages. A set of separate requirements does not guarantee the fulfilment of the integrated energy performance requirement. Only the separate improvement of typically *user related* systems (hot water supply, lighting) may be promising. Building elements and building related mechanical systems should be renovated simultaneously in a harmonised way.

The cross effects of the renovation measures significantly increase the efficiency, in other words 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. For instance, if a building is insulated without adjusting the heating system, the energy saving will be much lower. Conversely, if controllable heating is installed and the building envelope is retrofitted only several years later, the heating system may need to be modernised again causing extra costs. The cross-effects of the added thermal insulation, heat gains and the modernisation of the heating system are analysed and proven by *(Kalmár 2005)*.

Furthermore, partial measures can result in fabric damages. Buildings with poor thermal quality construction joints are "prevented" from mould growth by the poor quality windows and the unbalanced heating systems, because the high air infiltration rate decreases the humidity content of the indoor air and the overheating increases the surface temperature of the exposed walls above the dew point temperature or even beyond the temperature limit of the capillary condensation. Therefore, installing air-tight windows and establishing individual control can increase the risk of mould growth if the quality of the joints is not improved by external thermal insulation.

Thus the design approach to the refurbishment measures (thermal insulation, exchange of windows, ventilation, etc.) should be complex and well harmonised (energy aspects, fabric protection, comfort) due to the cross effects.

DOES MAJOR RENOVATION RESULT IN LOWER ENERGY NEED?

It should be mentioned that renovation does not automatically mean better energy performance (interpreting "energy performance" as it is in the EPBD: operational energy need). *"Functionally and economically feasible"* renovation may aim at better comfort, fulfilment of functional requirements and therefore may include e.g. change of individual stoves for central heating, implementation of mechanical ventilation, etc., accompanied by change of fuel and need for electric energy. This is the case when the renovation of mechanical systems should be completed by adequate improvement of building envelope, otherwise the specific operational primary energy consumption of the renovated system will exceed the original value, possibly even if the envelope is improved,.

Even in the latter case the renovation may be rational from an energy point of view. The new HVAC systems provide acceptable thermal comfort and indoor air quality (these requirements are also declared in the EPBD). Proper use of HVAC systems decreases the risk of fabric damages (capillary or surface condensation, mould growth). The same is the effect of the added thermal insulation which together with a correct external surface finishing improves the weather proofness of the exposed building elements. In case of buildings built with prefabricated sandwich panels the (further) corrosion of the welded steel elements at constructional joints will be prevented or at least slowed down.

As a consequence, on one hand the physical life time of the building may be prolonged. On the other hand, with the investment of energy for renovation (which is less than the built-in energy need of a new building) a modest improvement of the habitants' satisfaction is expected earlier, a higher level of comfort in a new building (which theoretically must be supposed) will be achieved later. If no reconstruction is done, although the high level comfort conditions will be achieved earlier, for the remaining period of the original life time no improvement, moreover worsening conditions should be considered. "Earlier" or "later" in this content mean a few decades. It again means the prolongation of the life time, which is a considerable fact if the complete life cycle energy consumption is taken into account.

Furthermore, if the life time of the building is prolonged, the tenants can use it longer with higher satisfaction, the need of demolishment will become necessary later. If the tenants are informed about such advantages of sustainable refurbishment, the willingness for retrofitting will increase. Several European projects are working on the integration of stakeholders in the retrofit process. The "E-CO-HOUSING project combines a new participation form with a life-cycle based communication and management platform and a set of confirmed design tools." (*Peuportier 2005*). The tenants were involved also in the Solanova project, the positive results of the social research are published (*Hermelink 2005*).

THE COMPLETE ENERGY BALANCE

Regarding the investment for renovation it is written in the EPBD that *"It should be possible to recover additional costs…within a reasonable period of time…".* Although *this* is the question the owners and builders are interested in, it would be more plausible to take into account all components of the life cycle disregarding the fact that the EPBD encompasses operational energy only. The life-cycle of buildings "from cradle to grave" consists of four main phases: construction, maintenance, operation and end-of-life.

Maintenance activities might reduce the operational energy demand but at the same time might increase the built-in energy content of the building. For the renovation considerable amount of energy is used. The non-renewable embodied energy of efficient external thermal insulation is between 40-80 kWh/m^2 envelope area. The production of windows with sophisticated frames and different infill gases can be extremely energy-intensive. The embodied energy content of standard double-glazed aluminium-clad windows, for example, is 282, 380 and 1150 kWh/m^2 for argon, krypton and xenon gases respectively (*Asif, Davidson, Muneer 2001*). Due to the metal elements the embodied energy of the HVAC systems is also high.

With a simplified approach one could compare the embodied energy of the renovation with the accumulated saving of operational energy calculating either a simple payback time or applying some discounting technique, e.g. net present value. In case of an old building the question can be raised whether due to the shorter remaining life time the fraction of embodied energy for one year will be higher than the saving of operational energy use. At the same time the "opposite" question may be raised, too: whether the renovation prolongs the life time of the building.

If the renovation prolongs the remaining life time of the building, the yearly fraction of the embodied energy of the renovation will be less than in the previous case. The cumulated operational energy will be obviously higher over the life span. However, the prolonged life time has other effects on the overall energy balance, too. The demolition of the existing building and the erection of a new one may be postponed. It means that the built-in energy content of the existing building will be kept for a longer period. This affects the whole building: not only the life time of elements which are in direct relationship with the operational energy use will be extended, but also the life time of other elements, such as foundation, loadbearing construction, partitions and internal floor slabs.

The energy balance of the renovation should include:

- the yearly fraction of the built-in energy content of the existing building for the prolonged period of the life time,
- the expected saving in the operational energy,
- the delay of the energy need for demolition and for the erection of a new building of similar size and use.

This balance is to be compared with the radical option:

- the life time is not prolonged,
- for the original life time the operational energy use will not change,
- the energy need of the demolition becomes actual earlier,
- a new building has to be erected earlier.

The following are some ball park figures. The embodied energy of an existing building varies between 750-1500 kWh/m^2 depending on the energy standard and construction system. Although only rough estimations are possible, the demolition of the existing building must not be forgotten. The energy requirement for demolition is 40 kWh/m^2 according to (*Adalberth 1997*). A safe value of 50-100 kWh/m^2 can be assumed. At the end of life, the existing building has to be substituted with a new one of similar size and use. The erection of the new building would then require a certain amount of energy again. The question is when the new building should be erected. On the one hand, the construction of new buildings boosts economic growth in the present. On the other hand, from an energy point of view it might be advantageous if the new building is needed later. The delay in energy use and in the related emissions alone might contribute to the mitigation of environmental problems, such as climate change. Moreover, due to improving technologies future energy production is expected to result in lower emission levels. Future buildings are also expected to have better thermal performance and consume less heating energy.

Figure 1 shows an example for two scenarios: one with major renovation and prolonged life time, and one without major renovation and earlier demolition. The total energy balance is influenced by many parameters, therefore the relationship between the lines can be different. The diagram shows one of the realistic options.

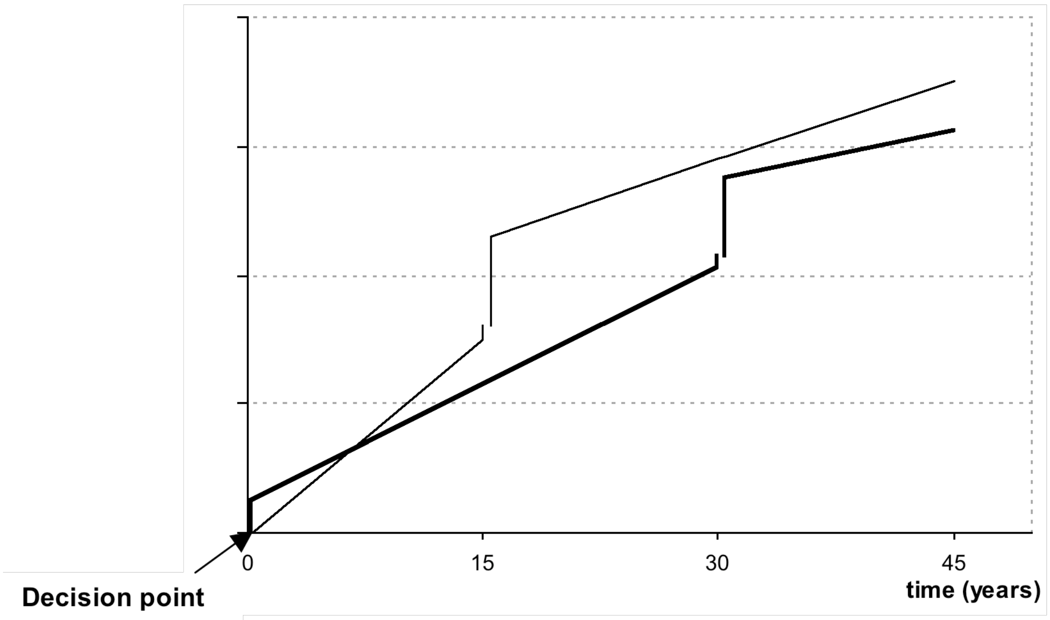

Figure 1: Energy balance for two scenarios (thin line: no major renovation at the decision point, earlier demolition; thick line: major renovation prolongs the life time of the building, demolition later)

In the evaluation of a major renovation, all the above aspects have to be considered. To include the effect of time and to compare activities due at different points in time, discounting techniques can be applied. There is no general solution: the right decision will be different from case to case.

CASE STUDY

In the already mentioned Solanova project the decision making on the final design concept was supported by eco-efficient optimisation. As (*Hübner 2005*) says "the realized optimizing measures led to significantly reduced environmental effects without reducing the insulation level or increasing the investment costs. The mass of the building was increased by the refurbishing measures by 1,8% with an input of primary energy of 580 MWh and related climate gas emissions (GWP) of 28 t. With the achieved saving an amortisation of primary energy of one year and a settled GWP-balance to one and half years were obtained. The advantage of refurbishment

strategies of panel construction from the point of view of sustainability is the preservation of the resource input of the existing buildings, the comparatively low efforts of refurbishment and the high environmental relief in the period of utilization. For the tenants it means a long-term preservation of value in a high quality dwelling."
According to the preliminary evaluation of the monitoring data in the first year after the refurbishment 85% energy saving has been achieved and better comfort conditions have been proven by the interviews with the tenants.

CONCLUSIONS

With regard to sustainability and due to the slow change of the existing building stock energy conscious retrofit of existing buildings is of utmost importance.

According to the EPBD national regulations must include energy performance requirements if buildings beyond a certain floor area are subjects of major renovation. Nevertheless, this requirement relates to the operational energy need only.

In a more complex approach other components of life cycle energy balance are to be taken into account The major renovation may prolong the life time of the building and this fact may considerably change the total energy need for a life span of 30 – 60 years.

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