ASSESSMENT OF ENERGY PERFORMANCE IMPROVEMENTS IN ALREADY-BUILT BUILDINGS

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Summary

The environmental impact of buildings has become an increasing concern in the construction industry ever since the growth in public awareness of the potential threat brought by climate change. More demanding energy performance requirements have led to the development of new technical systems for buildings with the introduction of renewable sources. It is, however, difficult to define clearly the extent to which building refurbishment or energy saving measures are efficient. By means of clear energy use presentation, the potential of energy saving measures in a building can be reliably estimated. The quantification of energy performance improvements presents in this case a decisive factor in the realization of such measures. The paper discusses variants of quantification and assessment of energy savings in an already-built dwelling house. The assessment can be used as a tool for estimating the efficiency of measures, related to the energy performance of a building.

Keywords: assessment, energy saving step, already-built building

1 Introduction

Greenhouse gas emissions and the energy demand of buildings can be reduced by the use of renewable energy sources and better quality thermal insulation. It is, however, difficult to define clearly the extent to which building refurbishment or energy saving measures are efficient.

More demanding energy performance requirements [1] have led to the development of new technical systems for buildings with the introduction of renewable sources such as solar and geothermal energy.

Generally, an improved thermal insulation gives a greater flexibility in option of heating and hot water warming systems. The lower the energy demand is, then the easier it is to integrate a system of renewable energy sources [2].

The lower becomes the transmission heat loss (through construction) of a building, the more an important role is played by heat loss through ventilation. Installation of mechanical ventilation is reasonable in this case (depending on the target value of energy demand and thermal insulation level), because by minor ventilation heat losses the heating can be reduced.

2 Assessment of energy performance improvements

With a refurbishment/project improvement of one or several construction parts, the calculation of transfer heat demand has to be performed [3]. One of the methods is the assessment of energy demand Q_H with the help of heat transfer coefficient U in the current and the new state. The difference between the energy demand in the "is" and "new" construction state will define the quantity of energy which will be saved:

$$\Delta Q_E = \Delta Q_{H,con.part} \cdot e = (Q_{H,con.part,IS} - Q_{H,con.part,NEW}) \cdot e \tag{1}$$

where Q_E energy demand of building,
$Q_{H,con.part}$ is annual energy demand for heating and hot water warming by a given construction state,
e – energy loss coefficient.

Energy savings resulting from technical measures can be assessed by the difference in energy loss coefficient of the technical system. In this case the difference in energy demand can be defined as follows:

$$\Delta Q_E = Q_H \cdot \Delta e = Q_H \cdot e_{is} - Q_H \cdot e_{new} \tag{2}$$

2.1 Fuel savings and cost savings

Calculation of the difference in demand for fuel through different energy demand can give us a clearer conception of the energy savings that can be attained. It can be performed according to the energy value of the given fuel. Fuel savings in this case are estimated in much the same way as energy savings:

$$\Delta F = (Q_{E,IS} - Q_{E,NEW}) / f \tag{3}$$

where ΔF is the difference in fuel demand,
f is the energy value of the used fuel.

According to the difference in the fuel demand before and after energy saving measures, cost savings can be assessed in accordance with the fuel costs.

Tab. 1 *Energy value and fuel costs for different energy carriers (rough values) [4]*

Energy carrier	**Energy value *f***	**Fuel costs *c* (EUR/kWh)**
Brown coal	6 kWh/kg	0.05
Black coal	8 kWh/kg	0.05
Wood	4 kWh/kg	0.02
Natural gas	10 kWh/m^3	0.04
Fuel oil	10 kWh/l	0.04
Electricity	1	0.06
Distant heat	1	0.05

Fuel costs for different energy carriers, shown in table 1, can serve as the estimation of cost savings:

$$\Delta C = (Q_{E,IS} - Q_{E,NEW}) \cdot c \tag{4}$$

where ΔC is cost savings,
c is fuel costs.

The pay-off period of non-recurrent investment is equal then to the ratio between the costs of refurbishment/amount of investment and expected savings ΔC.

Costs of a refurbishment include the amount of expenditure for construction and technical energy saving measures [5]. Refurbishment measures that will happen anyway, for example replacement of a faulty window or boiler, are not included in this case into investment in energy savings. In a pay-off assessment an investment in better heat insulation or a more efficient technical system will be included.

Taking into account a 4% interest rate for a loan and a 1% cost rate (energy price increase) adjusted for inflation, the pay-off period can be estimated by the method of capital value.

3 Results and Discussion

3.1 Case 1: window renovation

Case 1 consists in the replacement of old single-glazed windows with new warm protective windows. The U_w-value of old windows (eastern/western orientation) is 3.72 W/(m^{2}K), the U_w-value of new windows (eastern/western orientation) is 0.44 W/(m^{2}K).

For one square meter of window area the heating demand is the following:

$Q_{H,window,IS} = 84 \cdot 1 \cdot 3.72 \cdot 1 \cdot 0.9 = 281$ kWh/a, and

$Q_{H,window,NEW} = 84 \cdot 1 \cdot 0.44 \cdot 1 \cdot 0.9 = 33$ kWh/a. [6]

In the case where the heating system in a house is a low temperature boiler operated with fuel oil or gas (energy loss coefficient e = 1.16) [4], the energy savings ΔQ_E per one square meter of window is about 288 kWh annually. For an average one-family house with about 25 m^2 of window area, this means an annual energy saving ΔQ_E of about 7 200 kWh or an annual fuel saving ΔF of 720 liters of fuel oil or 720 m^3 of natural gas. The cost of this measure is approximately 7 900 EUR.

3.2 Case 2: Boiler replacement

In case 2, a refurbishment measure involving replacement of an old oil boiler (energy loss coefficient e =1.85) [4] with a low temperature oil boiler (energy loss coefficient e =1.16) can be assessed in the following way. Where the heating demand of the building is not known, a comparable typical building can be considered. For a dwelling house standing separate from another building and built in 1949–57 a rough value of 253 kWh/(m^{2}a) can be used in the calculation [6]. For the assessment of the technical system with combined household water warming the value of energy demand for the hot water preparation will be added – it amounts to 12.5 kWh/(m^{2}a) [6]. The usable floor area of the building is 130 m^2.

The energy demand of the current building can be given as:

$$Q_{E,IS} = (Q_h + Q_w) \cdot e \tag{5}$$

where Q_h is annual energy demand for heating,

Q_w – energy demand for household water warming,

e – energy loss coefficient.

$Q_{E,IS}$ in our example, including the energy demand for hot water warming, is

$(263+12.5)\cdot 130\cdot 1.85=63{,}853$ kWh/a.

After the boiler replacement $Q_{E,NEW}$ amounts to $(263+12.5)\cdot 130\cdot 1.16=40{,}037$ kWh/a.

The measure leads to an annual energy saving ΔQ_E of about 23,800 kWh, or an annual fuel saving ΔF of 2 380 liters of fuel oil. The cost of the measure including installation is approximately 6000 – 7000 EUR. The pay-off period of the step is about 7 years.

By the combined realization of several measures at once the total pay-off period decreases and the realization of several energy saving steps brings the highest efficiency [7].

4 Conclusion

The growing trend in building energy use has made energy efficiency strategy the main concern for energy policies which then involve developing new building regulations and certification processes. By means of such indicators as heat loss and energy demand, the energy performance of a building can be reliably estimated. In the paper there were proposed and evaluated several possibilities for reduction in energy demand, which means an increase in environmental efficiency of energy use in the building. The methodology adopted could be used as a quick tool for estimating the pay-back of the proposed changes in a project or some refurbishment steps, related to the energy performance of a building. Estimation involving more case-studies will provide an efficient tool for an investor or a builder to make a well-grounded decision about steps which offer potential realization of increased energy efficiency.

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