CONSIDERATION ABOUT THE COST OPTIMAL METHODOLOGY TO DETERMINE ENERGY PERFORMANCE REQUIREMENTS FOR BUILDINGS

Jerzy KWIATKOWSKI
Warsaw University of Technology, Faculty of Environmental Engineering, Poland, jerzy.kwiatkowski@is.pw.edu.pl

Aleksander PANEK
Warsaw University of Technology, Faculty of Environmental Engineering, Poland, aleksander.panek@is.pw.edu.pl

Alexander LEHMDEN
Wienerberger AG, Austria, Alexander.Lehmden@wienerberger.com

Clemens UNGER
Wienerberger AG, Austria, Clemens.Unger@wienerberger.com

Summary

European regulatory efforts, towards increasing energy efficiency of buildings, are focusing on a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements, which has been published as a European regulation 244/2012.

The framework methodology requires that many parameters have to be decided on national level. The paper describes influences of parameters and the change on final requirements. In different examples of the cost optimal method indications coming from guidelines accompanying Commission Delegated Regulation (EU) No 244/2012 (2012/C 115/01) and standard CEN EN 15459 “Standard economic evaluation procedure for energy systems in buildings” will be taken into account.

In the paper the results obtained using the framework for two different assumptions in order to define the energy performance requirements for building are presented. The aim of the paper is opening the discussion on cost optimal methodology and turning on the attention for the needs for further harmonisation of the approach.

The presented considerations reflect the works of the IEE project on Market Transformation Towards Nearly Zero Energy Buildings Through Widespread Use of Integrated Energy Design.

Keywords: Cost optimal methodology, energy requirements, LCC.

1 Introduction

The Recast of the Directive on the Energy Performance of Buildings (the EPB Directive) came into force on 9 June 2010. EU member states should have published the relevant laws and administrative regulations which are necessary to implement its provisions, until 9 June 2012.

The new provisions of directive states, among others, are that the minimum requirements of the energy performance of buildings, such as the maximum heat transfer coefficients of the envelope element (U-value) and the primary energy coefficient (EP), should be set by using the cost-optimal calculation. The Directive defines this concept, and the European Commission (EC) determines by regulation a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements.

The basis of the methodology for calculating cost-optimal levels of energy performance of buildings are:

- Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (OJ L 153, 18.06.2010),
- Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements.

The recast of the EPB Directive in the preamble says that Member States are responsible for determining the minimum requirements for the energy performance of buildings and building elements, and these requirements "should be defined so as to achieve the cost-optimal balance between the investments and the energy costs saved throughout the cycle life of the building."

In accordance with Article 5 of the Directive, Member States shall calculate cost-optimal levels of minimum energy performance requirements using the comparative methodology framework defined by delegated acts by the Commission in accordance with Annex III of the Directive and taking into account relevant parameters, such as climatic conditions and the availability of energy infrastructure. The comparative methodology framework distinguishes between new and existing buildings and between different categories of buildings.

The Directive requires then comparing the calculated optimal levels of cost with the minimum requirements for the energy with respect to the appropriate category of building.

After calculating the optimal level of requirements in terms of cost to the macroeconomic and financial perspective, Member States shall decide which of these perspectives will be used as a national benchmark.

Member States should use the results of this comparison in order to ensure that minimum energy performance requirements are set in order to achieve optimal levels of costs in accordance with Article. 4, paragraph. 1 of Directive 2010/31/EU. It is recommended that Member States are linking tax and financial incentives to ensure compliance with the calculation of the optimal result in terms of cost in relation to the same reference building. The framework of methodology requires that many parameters have to be decided on national level.

The paper describes the results of using a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for two variations of building elements: single-layer and double-layer wall. Beside the financial and macroeconomic calculations there are calculations for two variants of external envelopes and three different types of fuels. The aim of the paper is not to define the requirements but to contribute to the discussion on cost optimal methodology. Presented methodology of cost-optimal calculation is important both for industrial sector and institutions interested in building energy efficiency. This article is a result of work of both groups.

The cost optimal methodology is not only important for estimation of building requirements but can be also used for integrated energy design as an analysis of best solution searching in order to obtain low energy building.

2 Methodology

According to the Regulation No 244/2012, the decision of the Member States include the following issues:

- Whether the national benchmark used as the final outcome of the cost-optimal calculations is the one calculated for a macro-economic perspective (looking at the costs and benefits of energy efficiency investments for the society as a whole) or a strictly financial viewpoint (looking only at the investment itself).
- Determine the estimated economic lifecycle of a building or building component, the corresponding energy, products, systems and maintenance costs, operating costs and labor costs, primary energy conversion factors and the evolution of energy prices.
- Determining the discount rate to be used in the calculation of macroeconomic and financial calculations after performing sensitivity analysis for at least two discount rates for each count.

Methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements is presented in Annex 1 to the Regulation No 244/2012. General principles for the calculation of costs include:

- Member States may use the forecasts of the evolution of energy prices for crude oil, natural gas, coal and electricity, that is given in the regulation. Member States should establish national projections in relation to other energy sources used on the regional/local level. Annex II of the Regulation contains a reference to information relating to the estimated evolution of energy prices in the long term, which can be used for calculations. These data can be extrapolated beyond the year 2030.
- Cost data shall be market-based and shall be coherent as regards location and time. Costs should be expressed as real costs excluding inflation. Costs shall be assessed at country level.
- When determining the global cost of a measure/package/variant, the following may be omitted: costs that are the same for all assessed measures/packages/variants; costs related to building elements which have no influence on the energy performance of a building.
- The residual value shall be determined by a straight-line depreciation of the initial investment or replacement cost of a given building element until the end of the calculation period discounted to the beginning of the calculation period. The depreciation time is determined by the economic lifetime of a building or building element.
- Member States shall use a calculation period of 30 years for residential and public buildings, and a calculation period of 20 years for commercial, non-residential buildings.
- Member States are encouraged to use Annex A to EN 15459 on economical data for building elements when defining estimated economic lifetimes for those building elements.

In the next two paragraphs the formulas used for financial and macroeconomic calculation are given.

2.1 Calculation of global costs for a financial calculation

When determining the global cost of a measure/package/variant for the financial calculation, the relevant prices to be taken into account are the prices paid by the customer including all applicable taxes including VAT and charges. Global costs for buildings and building elements shall be calculated by summing the different types of costs and applying to these the discount rate by means of a discount factor so as to express them in terms of value in the starting year, plus the discounted residual value as follows:

$$C_g(\tau) = C_I + \sum_j \left[\sum_{i=1}^{\tau} \left(C_{a,i}(j) \times R_d(i) \right) - V_{f,\tau}(j) \right] \tag{1}$$

where: τ means the calculation period
$C_g(\tau)$ means global cost (referred to starting year τ_0) over the calculation period
C_I means initial investment costs for measure or set of measures j
$C_{a,i}(j)$ means annual cost during year i for measure or set of measures j
$V_{f,\tau}(j)$ means residual value of measure or set of measures j at the end of the calculation period (discounted to the starting year τ_0)
$R_d(i)$ means discount factor for year i based on discount rate r to be calculated according to (2)

$$R_d(p) = \left(\frac{1}{1 + r/100} \right)^p \tag{2}$$

where: p means the number of years from the starting period and
r means the real discount rate.

2.2 Calculation of global costs for the macroeconomic calculation

When determining the global cost for the macroeconomic calculation of a measure/package/variant, the relevant prices to be taken into account are the prices excluding all applicable taxes, VAT, charges and subsidies. When determining the global cost at macroeconomic level a new cost category: cost of greenhouse gas emissions is to be included so that the adjusted global cost methodology reads as:

$$C_g(\tau) = C_I + \sum_j \left[\sum_{i=1}^{\tau} \left(C_{a,i}(j) \times R_d(i) + C_{c,i}(j) \right) - V_{f,\tau}(j) \right] \tag{3}$$

where: $C_{c,i}(j)$ means carbon cost for measure or set of measures j during year i.

It is stated that Member States shall calculate the cumulated carbon cost of measures/packages/variants over the calculation period by taking the sum of the annual greenhouse gas emissions multiplied by the expected prices per tonne CO_2 equivalent of greenhouse gas emission allowances in every year issued, using as a minimum lower bound initially at least EUR 20 per tonne of CO_2 equivalent until 2025, EUR 35 until 2030 and EUR 50 beyond 2030.

3 Calculation

In this paper the presented methodology of global cost analysis has been used for calculation of cost-optimal level of U-value for external wall in residential building located in Poland. The calculation has been done using both methodologies: for financial and macroeconomic calculation using building life time of 30 years. In the Table 1 and 2 the different variants of external wall has been presented for single-layer and double-layer wall. The variants differ in insulation thickness for double-layer wall, and the thickness or construction for single-layer wall.

Tab. 1 *U-value and investment cost for different variants of double-layer external wall*

Variant	Insulation thickness (m)	U-value (W/m^2K)	Investment cost (including VAT) (PLN/m^2)
P25_S10	0.10	0.287	302.53
P25_S12	0.12	0.251	311.46
P25_S15	0.15	0.211	323.31
P25_S18	0.18	0.182	339.75
P25_S20	0.20	0.167	346.76
P25_S25	0.25	0.138	386.54

Tab. 2 *U-value and investment cost for different variants of single-layer external wall*

Variant	Construction thickness (m)	U-value (W/m^2K)	Investment cost (including VAT) (PLN/m^2)
P_38	0.38	0.350	193.31
P_44	0.44	0.300	223.48
P_44_E	0.44	0.220	285.28

In the calculation of double-layer wall one construction material (ceramic wall of 25 cm) and different thickness of insulation layer (extruded polystyrene) was assumed. The lower U-value and thicker insulation layer the higher total investment cost (construction and insulation material). The single-layer wall differs in thickness and constructions solution but the same ceramic material was used. The variants were chosen in order to find the optimal U-value using the cost-optimal methodology.

It can be noticed that the investment cost for the same U-value of single-layer wall is lower than the double-layer wall. This can provide to higher cost-optimal U-value as the other parameters in calculation are the same.

As the discount rate should be determined at national level it is important to choose the correct value. A higher discount rate – typically higher than 4 % excluding inflation and possibly differentiated for non-residential and residential buildings – will reflect a purely commercial, short-term approach to the valuation of investments. A lower rate – typically ranging from 2 % to 4 % excluding inflation – will more closely reflect the benefits that energy efficiency investments bring to building occupants over the entire invest-ment's lifetime. For this analysis the discount rate of 4% was used as it is recommended by guidelines to Regulation no 244/2012.

In order to verify the influence of fuel price on cost optimal level three heat sources were used: gas boiler, coal boiler and heat pump. In the Table 3 the characteristic of each heat source is given.

Tab. 3 U-value and investment cost for different variants of single-layer external wall

Heat source (fuel)	Fuel price (including VAT) (PLN/kWh)	Total system efficiency (-)	Primary resource factor (-)	CO_2 emission factor (kg CO_2/GJ)
Gas boiler (gas)	0.20	0.82	1.1	55.82
Coal boiler (coal)	0.10	0.70	1.1	94.58
Heat pump (electricity)	0.59	3.11	3.0	94.13

It can be noticed that the price for each fuel is different, and the coal is six times cheaper than electricity. For the other side the total efficiency of the system for the heat pump is the highest. In order to calculate cost of greenhouse gas emission the Primary Resource Factor (PRF) [1] and CO_2 emission factor [2] were given. The evolution of energy prices was done according to Annex II of the Regulation 224/2012 [3]. The increase of fuel prices has been extrapolated for 30 years of calculation and it is equal to 3.9 % for gas, 3.5 % for coal and 4.1 % for electricity.

4 Result

The calculations were performed for four main variants: financial and macroeconomic calculation for single and double layer wall. In the calculation the discount rate of 4 % was used. In each variant three heat source has been taken into consideration. For each of external wall described in Table 1 and 2 the global cost in 30 years was estimated. It was assumed that for double-layer wall the economic lifetime of insulation layer is 30 years and of construction material 60 years (lifetime of a building). In case of single-layer wall the economic lifetime of entire envelope of 60 years was assumed.

The global cost of each solution is presented in following figures. In Figure 1 the global cost for financial calculation and double-layer wall is presented. In Figure 2 the results for macroeconomic calculations and double-layer wall are given. The Figure 3 and 4 shows the results of single-layer wall for financial and macroeconomic calculation respectively.

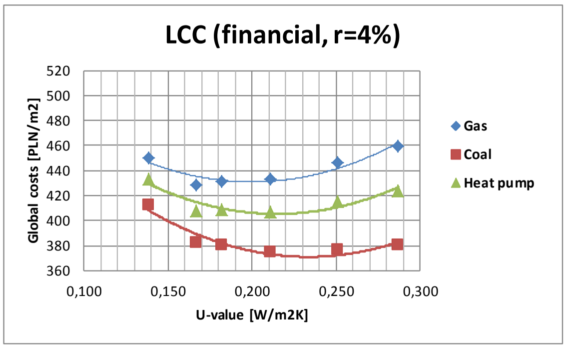

Fig. 1 Global cost of financial calculation for double-layer wall

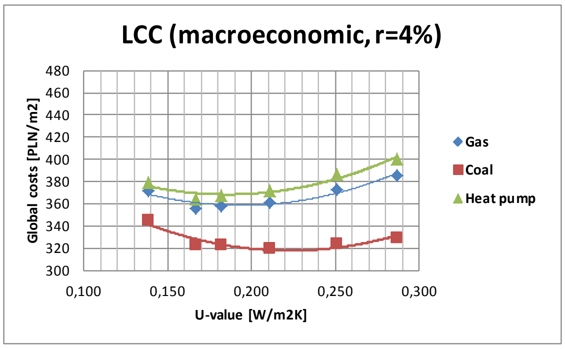

Fig. 2 Global cost of macroeconomic calculation for double-layer wall

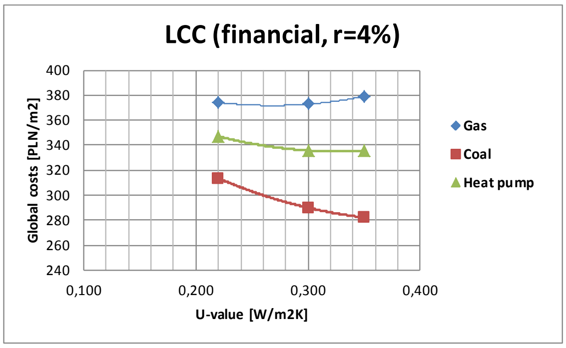

Fig. 3 *Global cost of financial calculation for single-layer wall*

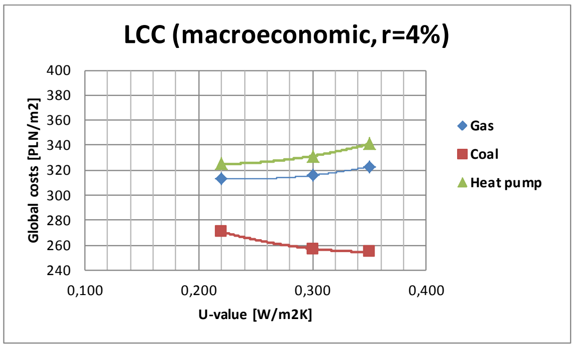

Fig. 4 *Global cost of macroeconomic calculation for single-layer wall*

The optimum value for each variant can be found. In the financial calculation the analysis with gas boilers gives highest values of global cost (as it is most expensive fuel when both fuel price and system efficiency is taken into account). In the macroeconomic calculation the heat pump generates highest global cost. In this case the cost of greenhouse gas emission was included, and as electricity in Poland provides high emission the total cost is high. For all cases the lowest global cost has been obtained for coal boiler, as the coal price is the lowest.

It can be noticed that the global cost for single-layer wall is lower than for double-layer construction. This difference is mainly a result of lower investment cost in case of single-layer wall ate the same U-value. The other reason might be connected with residual value. As for the double-layer wall it was assumed that economical lifetime of insulation layer is 30 years, the residual value of insulation after 30 years is 0. Thus, residual value for both variants of walls depends only on construction material and the investment cost of construction layer is higher for single-layer wall.

For each variant and fuel the optimal U-value has been estimated. In the Table 3 the results are given.

Tab. 4 *Optimal U-value [W/m^{2}K] for different variants of calculation*

Heat source	Financial Double-layer	Financial Single-layer	Macroeconomic Double-layer	Macroeconomic Single-layer
Gas boiler	0.200	0.268	0.193	0.244
Coal boiler	0.233	0.396	0.223	0.355
Heat pump	0.215	0.325	0.186	0.214

The results are different between each variant. For both calculation methodologies higher U-value is obtained for single-layer wall, and the difference is between 15 and 40 %.

For each heat source and the same wall construction the U-value is lower for macroeconomic calculation, as the cost of CO_2 emission was taken into account.

Of course for the cheaper fuel the U-value is higher, as the energy savings cannot cover an extra investment of insulation layer.

It can be also found that using macroeconomic calculation and the heat pump as heat source in building the requirements of envelope must be higher than for gas boiler. The inverse situation was for financial calculation.

The results show that there are many parameters that have to be considered using cost-optimal calculation for setting building requirements. An adoption of one from calculation methodologies may prefer high emission sources but with cheap fuel or high system efficiency. It can be seen that different values of requirements are obtained for single and double-layer walls.

5 Conclusion

The presented example of application of the comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements suggested by EC for the use by Member States can help to justify any requested value. The range of new U-values defined in different countries in Europe is between 0.3–0.15 W/m^{2}K. Assuming that these values have been estimated using the fore mentioned methodology the range is significant and cannot be associated only to climate influence.

Thus, the methodology should be amendment by the examples of determination of the requirements to guide MS trough the procedure.

There are more parameters influencing LCC which were not discussed in the paper: e.g. estimation of residual value, life cycle of the elements and the building, sensitivity on energy prices and investment outlays.

Important remark that can be drawn from the analysis is necessity of consideration of incremental criteria instead of LCC. As the LCC itself can guide us to conclusion that the existing requirements are good enough and there are no needs for their improvements. This is especially important in application of comparative methodology in integrated design process e.g. MATRID project.

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