ENERGIAKLUB
CLIMATE POLICY INSTITUTE
APPLIED COMMUNICATIONS

2013

COST OPTIMAL LEVELS OF MINIMUM ENERGY PERFORMANCE REQUIREMENTS OF BUILDINGS AND BUILDING ELEMENTS

The research project was led by:
Krisztina Severnyák, Energiaklub (September 2011 – May 2012)
Orsolya Fülöp, Energiaklub (November 2012 – February 2013)

Experts:
Krisztina Severnyák – dipl. arch. & building energy expert, Energiaklub
Orsolya Fülöp – economist, Energiaklub
Péter Nagy – building engineer, energy auditor

We thank Márk Somogyi for his assistance in data analysis.

The research project was supported by the Ministry of Interior and European Climate Foundation.

BM

European Climate Foundation

The data, methodology and report of the research can be found and downloaded from the website of Energiaklub Climate Policy Institute and Applied Communications: www.energiaklub.hu

The analysis is greatly based on the results of the Negajoule2020 research project (Energiaklub 2011): www.negajoule.eu

ENERGIAKLUB
CLIMATE POLICY INSTITUTE
APPLIED COMMUNICATIONS

EXECUTIVE SUMMARY

ENERGIAKLUB Climate Policy Institute was assigned by the Ministry of Interior to perform the cost optimality analysis and the draft report to be submitted to the European Commission, as defined by the Directive 2010/31/EU and Commission Delegated Regulation 244/2012/EU (hereinafter: Regulation).

The aim of the cost optimality analysis pursuant to the Directive is to ensure that minimum energy performance requirements are set in the Member States with a view to achieving cost-optimal levels for buildings, considering the economic lifecycle of building elements, investment costs as well as energy savings.

Based on the requirements of the Regulation, the analysis was divided into the following phases:

1 Establishment of reference buildings, both for existing as well as new buildings.
2 Identification of energy efficiency measures and measures based on renewable energy sources applied at each reference building.
3 Calculation of the primary energy demand resulting from the application of measures and packages of measures.
4 Calculation of the global cost in terms of net present value for each reference building.
5 Undertaking a sensitivity analysis for cost input data including energy prices and discount rates.
6 Derivation of a cost optimal level of energy performance for each reference building.
7 Comparison of results with the current requirements in Hungary.

In terms of building structures, we have examined the effect of the external insulation of the walls and slabs, replacement of windows and doors as well as the complex refurbishment of the building envelope. For all three types of measures, we have defined three different levels of requirements to building elements: at level 1, requirements were set according to the current regulation in Hungary (7/2006. TNM Decree). At level 2 and 3, the required U-values were defined according to the requirements proposed by Hungarian experts for the modification of the Decree.

Measures for improving the efficiency of building systems were in most cases examined after that the efficiency of the building envelope was improved, in order to reduce heat demand first. Certain systems (e.g. condensing boilers) were analysed at all three levels of the refurbished envelope, while some specific systems (e.g. heat-pumps, pellet boilers) were only examined only in the cases where building enclosure met the strictest requirements we have set. In some buildings, however, we also analysed the refurbishment of the building system separately, without any renovation of the building envelope.

We analysed the most efficient systems available, taking into account the more efficient use of the existing energy source as well as alternative energy sources.

According to our results, adjusting the energy efficiency of buildings to current national standards proved not cost optimal, neither in existing, nor in new buildings. However, as we have analysed a limited number of measures, the absolute optimum can not be identified to complete certainty.

The optimum of the analysed measures varies, depending on the different types of buildings, between the 'medium' and the strictest levels of the requirements set for building envelopes. This indicates, on one hand, that more stringent requirements are needed regarding the U-values, both in case of existing and new buildings. The difference is significant, whether we analyse primary energy demand or global costs. On the other hand, results indicate that the real optimum may lie somewhere between the 'medium' and the strictest level.

In conclusion, results of the cost optimality analysis pursuant to the Directive underline the need to set more stringent requirements than the current ones defined by the present regulation in Hungary. Consequently, Energiaklub suggests that at least the medium level of requirements (walls: U=0,35 W/m²K, attic slab: U=0,2 W/m²K, basement slab: U=0,3 W/m²K, windows=1,3 W/m²K) should be adopted in Hungary for existing as well as new buildings, in 2013.

TABLE OF CONTENTS

1. FRAMEWORKS OF THE ANALYSIS

ENERGIAKLUB Climate Policy Institute was assigned by the Ministry of Interior to perform the cost optimality analysis and the draft report to be submitted to the European Commission, as defined by the Directive 2010/31/EU, based on the 10/2009 Ministerial Decree and the Action Plan No. BM/3446 of the ministry. The comparative methodology framework used in our analysis was set by the Commission Delegated Regulation 244/2012/EU (hereinafter: Regulation), and its complementary guidelines (2012/C 115/01)[1].

The aim of the cost optimality analysis pursuant to the Directive is to ensure that minimum energy performance requirements are set in the Member States with a view to achieving cost-optimal levels for buildings, considering the economic lifecycle of building elements, investment costs as well as energy savings.

During the research, we organised two wide-scale consultation meetings, where the methodology and the progress of the work was presented. The key conclusions and remarks of the experts invited were taken into consideration during the work, given that the methodology set by the Regulation and the contract with the Ministry of Interior made it possible.

[1] Guidelines accompanying 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

2. ESTABLISHMENT OF REFERENCE BUILDINGS

According to the Regulation Member States are required to define reference buildings which represent the typical and average building stock in the country. The building types subject to the analysis are the following:

- single-family buildings;
- apartment blocks/multi-family buildings;
- office buildings; and
- other categories, listed in Annex I of Directive 2010/31/EU, for which specific minimum performance requirements exist.

Besides residential and office buildings, requirements only exist for educational buildings in the Hungarian legislation, thus we analysed school buildings as a fourth category.

The Regulation asks Member States to identify at least one reference building for new buildings and at least two for existing buildings subject to major renovation.

2.1. Selection criteria

2.1.1. Residential buildings

As Hungary does not have an official, up-to-date and detailed statistical database on the national building stock, we established the reference buildings based on the results of the NegaJoule2020 research project[2], conducted by Energiaklub in 2011.

The NegaJoule2020 project investigated the characteristics of residential buildings by a nation-wide, large sample, representative sampling. The data survey took place in 2000 households in 2010.

The sampling method consisted of a two-step, layered, quota-based sampling, where in the first step the sample settlement was shaped. The sample was representative on the types of settlements and on the regions set by the Central Statistical Office (KSH), bearing in mind the number of households there. During the calculation of the quota, KSH data were used. According to the specific aims of data survey the quota of the households to be questioned at the selected settlements was specified in two dimensions:

[2] Energiaklub 2011, www.negajoule.hu

- According to the ratio of occupied flats in the residential zones characteristic for the given type of settlement.
  Residential zones were as follows:
  - City-type area (terraced houses),
  - Blocks of flats,
  - Family house areas
  - Suburbs with villas,
  - Village-type areas (this differs from the family house area in that a regular agricultural activity, animal breeding and farming may take place at houses here).
- According to the ratio of the groups set up as per the number of household members.
  The household quota calculated on the basis of KSH data was as follows:
  - 1 member (20%),
  - 2 members (30%),
  - 3 members (20%),
  - 4- or more (30 %).

The interviewers selected the respondents by random walking. The household member who was asked to answer the questions was either the main earner (who contributes to the household income with the highest amount) or the main consumer (who is mostly familiar with household issues).

Data were analysed with the SPSS statistical program. Both the questionnaire and the data processed are available at www.negajoule.hu.

The results of the NegaJoule2020 research project and the data were discussed several times in 2011-2012 during expert consultations, and compared to the findings of other relevant research projects[3] as well as to data available at the Hungarian Central Statistical Office.

2.1.2. Non-residential buildings

Besides residential buildings the 7/2006 Decree defines minimum performance requirements for office and educational buildings.

As a proper statistical database on the characteristics of non-residential buildings is not available in Hungary, we defined these reference buildings based on the Hungarian State Holding Company's database of central government buildings, and Váti Hungarian Regional and Urban Development Non-Governmental Organisation's data from energy audits of municipal buildings performed within the framework of the UNDP GEF Programme during 2004-2006. The subcategories were defined by the construction material and heating system of the buildings.

We need to emphasise, however, that the above data collection cannot be considered as a representative statistical sampling.

2.2. Reference buildings

2.2.1. Residential buildings

We defined the following residential reference buildings for residential buildings:

- SF-1: existing single family building, built of loam;
- SF2-2: existing single family building, built of small size (50), solid brick;
- SF-3: existing single family building, built of B30 brick;
- SF-4: existing single family building, built of 'twin-cell' brick;
- SF-5: existing single family building, built of Porotherm brick;
- SF-6: new single family building, built of Porotherm brick;
- MF-1: existing 10 storey block of flats, built of prefabricated panel blocks;
- MF-2: existing multi-storey apartment block, built of small size (50), solid brick;
- MF-3: new apartment block, built of Porotherm brick.

Parameters of the residential reference buildings can be found in detail in Annex 1, 2 and 4.

2.2.2. Non-residential buildings

We established the following six subcategories for non-residential buildings:

- S-1: existing school building, built of prefabricated panel blocks;
- S-2: existing school building, built of brick;
- S-3: new school building, built of brick;
- O-1: existing office building, built of brick;
- O-2: existing office building, built of brick, with stone cladding on the facade[4];
- O-3: new office building, built of brick.

Parameters of the reference office and school buildings can be found in detail in Annex 1, 2 and 4.

[3] Csoknyai-Talamon,-Csík-Retek (2010) Hungarian building typology and its possible applications, Hungarian Building Engineering.

[4] Due to an ornate, listed stone cladding facade, it is not possible to insulate from the outside.

3. ENERGY EFFICIENCY MEASURES/ PACKAGES

The Regulation gives flexibility to Member States in defining energy efficiency measures, along the following guidelines:

1. Energy efficiency measures / packages shall include measures necessary to meet the currently applicable minimum energy performance requirements.

2. Energy efficiency measures shall be defined for all input parameters for the calculation that have a direct or indirect impact on the energy performance of the building.

3. Member States shall also identify measures / packages using renewable energy for both new and existing buildings.

The measures and packages identified can be found in detail in Annex 4.

3.1. Refurbishment of the building envelope

In terms of the building structures, we have examined the following measures:
- replacement of windows and doors,
- external insulation of walls and slabs,
- complex refurbishment of the building envelope.

For all three types of measures, we have defined three different levels of requirements: at level 1, current requirements according to the 7/2006. Decree were set. At level 2 and 3, the required U-values were defined according to the requirements proposed by Hungarian experts for the modification of the Decree.

In new buildings, when improving the energy efficiency of walls, we found it more sensible to change the type of brick instead of adding external insulation to the walls. Contrary to existing buildings, the medium requirement level was set at 0,3 W/m²K for façade instead of 0,35, as bricks currently available in the Hungarian market are able to meet this requirement[5].

Measures are described in detail in Annex 8.

[5] Porotherm 38K: U=0,25 W/m²K, Porotherm 44K Profi: U=0,22 W/m²K (Source: Wienerberger)

3.2. Refurbishment of building systems

Measures for improving the efficiency of building systems were in most cases examined after that the efficiency of the building envelope was improved, in order to reduce heat demand first. In some buildings, however, we analysed the refurbishment of the building system separately, without any renovation of the building envelope.

Certain systems (e.g. condensing boilers) were analysed at all the three levels of the refurbished envelope, while some specific systems (e.g. heat-pumps, pellet boilers) were only examined in case the building enclosure met the strictest requirements we have set. We analysed the most efficient systems available, taking into account the more efficient use of the existing energy source as well as alternative energy sources.

In existing buildings, when installing heat-pump systems, the existing boiler was kept as well, and in new buildings an extra boiler was added, since our experience shows that in extraordinarily cold weather, heat pumps can only cover the heating needs of the building by significantly higher electricity use.

The packages and technical details can be found in Annex4, 8 and 9.

3.2.1. Residential buildings

We did not install cooling systems in residential buildings: ventilation is primarily ensured by natural methods. However, due to the expert meetings, we did calculate with heat recovery ventilation system in some buildings (SF-6, MF-1, MF-2, MF-3).

3.2.2. Non-residential buildings

In school buildings, we installed efficient boilers, heat recovery ventilation and energy efficient lighting systems. In the case of the S-2 building a separate package for refurbishing the building system was examined, without any change of the building envelope: here we did not apply heat recovery system. Due to the expert meetings, we also included packages without any measures regarding the ventilation system.

We did not install cooling systems in schools, as these buildings usually do not operate during the summer months. In office buildings, however, we did.

As non-residential buildings have rather high electricity demand, we applied photovoltaic systems, which, through the installation of solar inverters, can generate energy in the summer months that can be used in the winter months.

In every building type, we installed building automation and control systems.

Variations can be found in Annex 4, 8 and 9.

4. CALCULATION OF THE PRIMARY ENERGY DEMAND OF THE REFERENCE BUILDINGS

4.1.1. Relevant legislation

The calculations were carried out based on the parameters, requirements and the simplified calculation method pursuant to the 7/2006. Decree. All our technical calculations were carried out by professional energy auditors, with WinWatt energy engineering software.

4.1.2. Calculation period

According to the requirements set by the Regulation, the calculation period is 30 years for residential buildings, and 20 years for non-residential buildings.

4.1.3. Conversion factors

According to the current national legislation conversion factors are the following:

	Energy source	**e**
-	electricity	2,50
-	off peak electricity	1,80
-	gas	1,00
-	fuel	1,00
-	coal	0,95
-	district heating (heating plant)	1,20
-	district heating (co-generation)	1,12
-	firewood, biomass	0,60
-	renewable energy	0,00

4.1.4. Delivered energy specified by source

See Annex 5.

4.1.5. Results of the energy performance assessments

Results of the calculations can be found in Annex 4.

5. CALCULATION OF GLOBAL COSTS

The Regulation asks Member States to calculate the global costs of energy efficiency measures in terms of net present value for each reference building they have established, along the following guidelines.

5.1. Life cycle

According to the Regulation and the guidelines set by Annex A we used the EN 15459 standard for estimating the life cycle of building elements.

5.2. Categories of cost

In line with the Regulation, Member States shall establish the following separate cost categories to be used:
- initial investment costs;
- annual costs (energy costs, replacement costs, maintenance costs); and
- disposal costs (if applicable).

For the calculation at macroeconomic level, Member States shall in addition establish the cost category of greenhouse gas emissions.

According to the Regulation, the following costs may be excluded from the calculation when calculating the global costs of a measure or package:
- costs that are the same for all measures / packages; and
- costs related to building elements which do not have an influence on the energy performance of the building.

5.2.1. Initial investment costs

When calculating the initial investment costs, we relied on the following data sources:
- Guidance on the methodology for carrying out Cost-Benefit Analysis [6] and
- the Collection of Building Norms.

In cases where the two databases above did not contain sufficient information, we collected additional data from the market. In case of new buildings, we used the cost calculations carried out by Wienerberger in 2011, which were provided to us by the company.

In the case of non-residential buildings we also took into account the data of the "Refurbishment of central governmental buildings – Preparatory study", compiled by ÉMI Non-profit Ltd for Quality Control and Innovation in Building in April 2012. We also used price offers made by contractors in order to define average investment costs.

The cost of chimney lining was only considered in buildings (SF-3, MF-2) where the chimney was not used by the initial building system (convectors / electric or gas storage boilers). In these cases the cost of the chimney lining is obviously connected to the refurbishment of the buildings system and does not appear in the initial state or renovations of the building envelope. In other cases, where the chimney has been in use before, the costs of (re)lining (might) appear apart from the refurbishments as well, due to the 'normal' deterioration of the building and its elements, i.e. in every package. Therefore, in these buildings this cost category was not taken into account – the Regulation allows such simplifications.

We would like to note that in case of the currently less used technologies in Hungary (e.g photovoltaic systems, heat recovery ventilation, heat pumps, etc.) information on the average investment costs was rather difficult to obtain, as costs vary in a broad range. In these cases, further calculations might be necessary.

Initial investment costs used in our analysis can be found in Annex 10.

Depending on the economic life cycle of the building elements and the calculation period, residual value shall be calculated for building elements. According to the Regulation, the residual value of a building at the end of the calculation period can be calculated from the straight-line depreciation and the initial investment cost or the replacement cost of a given building element, discounted to the beginning of the calculating period.

5.2.2. Annual costs

In Hungary, an official energy price prognosis is not available, nor did we find any international price forecasts referring to or referable to Hungary (including the Regulation). Therefore, we prepared a

[6] Published yearly by the Hungarian Chamber of Commerce and Industry, the National Federation of Hungarian Contractors, the Chamber of Hungarian Architects, The Chamber of Hungarian Engineers, and the Association of Hungarian Consulting Engineers and Architects.

new prognosis based on several data and information sources[7].

For the gas and electricity price prognosis we used the tariffs regulated and published by the Hungarian Energy Office in 2012, both in case of residential as well as non-residential buildings, as data on prices in liberalised energy markets are scarce in Hungary. We used the forecast of GKI Energy Research and Consulting Ltd as well.[8]

Regarding district heating, we created a national average price level based on the current tariffs of 18 Hungarian towns, collected by the Association of Hungarian District Heat Suppliers[9]. We applied the same rate of growth for district heating as for gas prices, as most of the district heating plants are fuelled by natural gas in Hungary.

In case of firewood and pellet, we have based the forecast on data we have collected ourselves, as well as data from *the '2009-2020 biomass price prognosis'* published by KPMG-essrg[10].

The different price forecasts can be found in Annex11.

Replacement costs were taken into account depending on the life cycle of a given building element – primarily in case of heating and other building systems, as their life cycle is typically shorter than the calculation period required by the Regulation. We considered replacement costs equal to investment costs, due to the joint effect of inflation and reducing prices caused by technology development.

Yearly maintenance cost was considered only in cases, where it is significantly higher than at usual building systems, i.e. heat recovery ventilation system (filter), solar thermal collectors (antifreeze liquid), photovoltaic systems (inverter). These costs can also be found in Annex 10.

5.2.3. Costs of greenhouse gas emissions

When calculating the cost of greenhouse gas emissions, we used the reference carbon price scenario projected by the European Commission, as shown in the Annex of the Regulation.

5.2.4. Discount rates

The Regulation gives flexibility to Member States in establishing discount rates to be used in the macroeconomic and financial calculations, after performing a sensitivity analysis of at least two rates for each calculation. One of the rates shall be 3% expressed in real terms.

In Hungary, Government Decree No 161/2005 defines the calculation method for net present value, and the discount rates to be applied. At the beginning of our calculations, the prognosed yearly rates varied between 6,5-7,5%. For expressing the rates in real terms, the above mentioned Government Decree requires the use of a 35 year yield-curve, published by the Government Debt Management Agency on the website of the Ministry of Finance. It varies around 2,5% on average.

Based on all this, we set the second discount rate at 5% expressed in real terms, both in the financial and the macroeconomic calculation.

[7] Hungarian Economic Research Institute (GKI) (2010)
[8] According to the agreement the index line may not be published.
[9]www.mataszsz.hu/doc/2011.11.18_Kozzetett_dokumentumok/Tavhodijak.2011.marcius.31/tavhodijak_osszehasonlitasa_6000-nel.tobb.lakas.pdf
[10] KPMG-essrg (2010) 2009-2020 biomass price prognosis; Macroeconomic analysis and prognosis, with special attention to financial indicators and energy prices (2008-2030) http://ec.europa.eu/energy/observatory/trends_2030/index_en.htm

5.3. Method of calculation

According to the Regulation, global costs shall be calculated in the financial calculation as follows:

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

where:

- τ means the calculation period;
- C g (τ) means global cost (referred to starting year τ o) 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,τ (j) means residual value of measure or set of measures j at the end of the calculation period (discounted to the starting year τ o).

R d (i) means discount factor for year i based on discount rate *r* to be calculated
as:

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

where:

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

When determining the global cost at macroeconomic level, in addition to the cost categories listed above, a new cost category – the cost of greenhouse gas emissions - is to be included, so that the adjusted global cost methodology reads as:

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

where:

- C c, i(j) means carbon costs for measures j during year i.

The relevant prices to be taken into account in the macroeconomic calculation are the prices excluding all applicable taxes, VAT, charges and subsidies.

6. UNDERTAKING A SENSITIVITY ANALYSIS FOR COST INPUT DATA

As required by the Regulation, Member States shall perform a sensitivity analysis on the discount rates using at least two discount rates for the macroeconomic calculation, and two rates for the financial calculation, each expressed in real terms. In addition, they shall perform a sensitivity analysis on the energy price development scenarios for all energy carriers used to a significant extent in buildings in their national context.

Results for both calculation methods can be found in Annex 4. We found that changes in energy prices and discount rates do not result in significant changes in terms of cost optimality.

According to the Regulation, Member States shall decide whether they take the macroeconomic or the financial calculation as national benchmark. After consulting with the Minsitry of Interior that is responsible for implementing the Directive 2010/31/EU in Hungary, we decided to fill in Table 7 of the reporting template according to the financial calculation method, with a discount rate of 5% expressed in real terms, and using energy price prognosis 2. Table 7 can be found in Annex 7.

7. DERIVATION OF A COST OPTIMAL LEVEL OF ENERGY PERFORMANCE FOR EACH REFERENCE BUILDING

According to the Regulation, for each reference building Member States shall compare the global costs calculated for different energy efficiency measures with their existing national requirements (after deciding whether their national benchmark will be calculated by a macroeconomic or a financial method).

If measures or packages have the same or very similar global costs, the one with the lower primary energy use should, if possible, guide the definition of the cost-optimum level. The current requirements at Member State level shall be compared to the calculated cost-optimal level. In line with Directive 2010/31/EU, a significant discrepancy between the outcome of the cost optimal calculation and the minimum requirements currently in force in the Member State exists if the latter are 15% lower than the cost optimum.

As we were certainly unable to extend our calculations to every reference point of the cost-'curve', our results do not, in fact, develop a curve but rather a 'cloud of reference points'. Consequently, we cannot conclude with absolute certainty where the optimum is: in our view, the 'cloud of reference points' can only indicate which packages of measures produce the best results in terms of cost optimality among the measures examined.

Nevertheless, we can conclude that it is necessary to set more stringent minimum energy efficiency requirements than the current ones, for both existing and new buildings, as they produce significantly better results in terms of cost optimality in almost every case.

We can also conclude that, in the majority of existing buildings, global costs are the highest when the building is not renovated (marked as measure '0' in the Tables of Annex 4).

Results can be found in Annex 4.

7.1. Residential buildings

In residential reference buildings, refurbishment of building structures to higher standards produce better results in terms of cost optimality than those renovated to current standards, both in existing and new buildings. However, there are slight differences among the different types of buildings: in some reference buildings, renovations to the medium level of requirements, whereas in other buildings renovations to the highest level of standards produce the cost optimal solution.

In terms of building systems, heat pumps and pellet boilers cannot be considered as cost optimal investment at present. However, the installation of solar collectors for hot water generation produced promising results.

7.1.1. Existing single family building, built of loam (SF-1)

In existing single family buildings built of loam, renovation package 11 produced the best results. Package 11 contains the refurbishment of the front walls to an U-value of 0,35 W/m²K, 0,2 W/m²K for attic slab, 1,3 W/m²K for windows and doors, as well as the replacement of inefficient wood stoves and electric boilers to wood gasification boilers (a detailed description can be found in Annex 4, 8 and 9).

In case of renovation of the building structure only (without changing the initial heating and hot water system), i.e. packages 4-6 and 7-9, refurbishment to the medium level of requirements (packages 5 and 8) produced the best results in terms of cost optimality.

7.1.2. Existing single family building, built of small-size brick (SF-2)

In this reference building, renovation package 14 produced the best results in terms of cost optimality. This package includes the external insulation of the building envelope to higher than the existing standards, (U-value=0,35 W/m²K for the facade and 0,2 W/m²K for the attic slab), and instalment of a wood gasification boiler.

It is important to note that, in case of this reference building, packages to refurbish the building system contained the replacement of the original wood-burning boilers to condensing boilers, thus, a switch from wood to natural gas was involved. These packages had higher global costs than the firewood-based heating.

7.1.3. Existing single family building, built of B30 brick (SF-3)

In this very typical reference building in Hungary, renovation package 20 proved cost optimal. The measure included the refurbishment of the building structure to the highest requirements (U=1,0 instead of 0,8 for windows), as well as the installation of wood gasification boiler for heating and generating hot water. Similarly to the previous reference building type, a fuel switch was involved, but conversely: from a less efficient gas heating to a more efficient wood-burning boiler.

The chart in Annex 4 clearly shows that among the measures for improving the efficiency of building systems, conversion to pellet boilers (package 14) produced the highest global costs.

7.1.4. Existing single family building, built of 'twin-cell' brick (SF-4)

In this reference building, renovation package 11 has the lowest global costs, which includes the external insulation of the building structure to the medium level of requirements, as well as installing more efficient heating system.

7.1.5. Existing single family building, built of Porotherm brick (SF-5)

In this reference building, renovation package 21 gives the lowest global costs, involving changes only in the building system. The reason for this is that this building is already quite efficient in its initial state: the parameters of the walls and windows hardly lag behind the current requirements.

We examined the switch from constant temperature gas boiler to wood gasification boiler as an independent measure: the joint effect of wood based heating together with improving the building envelope was not analysed in this building type. Thus, in this case we do not know if the complex refurbishment would bring better results than the renovation of the building system only.

7.1.6. New single family building, built of Porotherm brick (SF-6)

In this reference building, package 6 gives cost optimal results. This involves constructing the building envelope to higher standards than the ones in force (U-value of 0,22 W/m^2K for the facade, 0,14 W/m^2K for the attic slab, 0,22 W/m^2K for basement slab, and 1,3 W/m^2K for windows and doors). It also includes installing a condensing boiler for heating and hot water generation.

Regarding efficient building systems, installing condensing boilers produces better results than installing low-temperature boilers in all cases. Converting to a heat pump system or pellet boilers lags behind the cost optimum.

7.1.7. Existing multi-family house, blocks of panel (MF-1)

In this reference building, renovation package 6 produced the best results in terms of cost optimality, i.e. external insulation of walls to the strictest level of requirements. However, we need to mention that renovation package 12 with higher standards had only slightly higher global costs, while the primary energy need is significantly lower. Therefore, it is suggested to regard package 12 as optimum. Our suggestion is underpinned by the fact, that most cases of the sensitivity analysis indicate package 12 as optimal. However, in Table7 package 6 is indicated as the optimum.

It is to note again, that our calculations have been carried out according to the May 2012 status of the 7/2006 TNM Decree; the modification in July 2012 might affect the results.

7.1.8. Existing multi-storey apartment block, built of small-size brick (MF-2)

Similarly to panel buildings, renovation package 9 produced the best results in terms of cost optimality. The reason for the complex packages not being optimal might lie in the high extra cost of the chimney lining (see chapter 5.2.1 and Annex 10).

7.1.9. New apartment block, built of Porotherm brick (MF-3)

As in new single-family buildings, package 6 proved cost optimal in new apartment blocks as well, i.e. the construction meeting higher requirements than the existing ones.

7.2. Non-residential buildings

Similarly to residential buildings, more stringent requirements produce better results in terms of cost optimality in non-residential buildings.

7.2.1. Existing school building, made of prefabricated blocks of panel (S-1)

In this reference building, renovation package 11 produced cost optimal level of refurbishment. It involved the medium standards in terms of the building structure as well as the refurbishment of the building system.

Detailed parameters can be found in Annex 4, 8 and 9.

7.2.2. Existing school building, built of brick (S-2)

In this reference building, renovation package 5 produced the best results in terms of cost optimality. However, the global costs of renovation package 11, which includes the replacement of windows as well, is close to the cost of package 5 – while the primary energy need is significantly lower. Thus, we suggest that package 11 should be regarded as cost optimal. Nevertheless, we filled in the relevant cells of Table 7 according to the data of package 5.

7.2.3. New school building, built of brick (S-3)

Similarly to existing school buildings built of panel blocks, renovation package 11 can be considered cost optimal. It includes measures meeting higher requirements than the existing ones (U=0,3 W/m²K for front walls, 0,2 W/m²K for attic slab, 0,3 W/m²K for basement slab, and 1,3 W/m²K for windows and doors), as well as the installation of a control system, and a more efficient lighting and heat recovery system.

It is important to note, that we have also examined the cost optimality of installing a heat pump system in this reference building (in case the building envelope met the highest standards), but this solution is far from optimal in terms of global costs.

7.2.4. Existing office building, built of brick (O-1)

In this reference building, renovation package 6 gives the best results in terms of cost optimality.

7.2.5. Existing office building, built of brick, with stone cladding on the facade (O-2)

In this reference building, the facade cannot be insulated externally, which means that renovation is restricted to the attic slab, and windows and doors. Similarly to O-1 reference building, renovation package 6 is cost optimal.

7.2.6. New office building, built of brick (O-3)

In this reference building, the optimum is at renovation package 11.

7.3. Comparison with existing national requirements

According to the Regulation, the current minimum requirements need to be compared to the cost-optimal levels of the calculations. The difference between cost optimal levels and existing requirements can be calculated by comparing the average of all existing energy efficiency minimum requirements, and the average of all cost optimality levels from all reference buildings that can be examined in one group.

This shall be calculated as follows:
Difference (%, on the level of the reference building) = (cost optimality level [kWh/m 2 year] – existing minimum requirements for energy efficiency [kWh/m 2 year]) / cost optimality level [kWh/m 2 year]) × 100 %.

For building elements, it is calculated according to the following equation:
Difference (%, for building elements) = (cost-optimal level [unit of performance indicator[11]] – current minimum performance requirements [unit of performance indicator]) / cost-optimal level [unit of performance indicator]) x 100%.

As in Hungary the legislation contains a triple-set of requirements (U-value, Ep and q), we had to perform both calculation methods. Results are shown in Annex 7. (Examining the q values were outside the scope of our work, we did, however, indicate q values related to the cost optimal packages in Annex 7.)

According to the calculations, there is significant difference between the current requirements and the cost optimal levels. In case of the building elements, cost optimum is achieved when more

[11] E.g. U-value (W/m²K)

stringent requirements are applied, in all building types. The energy performance indicator (Ep) connected to cost optimal packages, however, lags behind the requirements set for a new building in some cases, even if the building elements meet the stricter requirements. The reason for this is that in these cases, cost optimality can be reached by partial refurbishments, i.e. renovation of only 1 or 2 building elements.

According to the results, applying cost optimal requirements for building elements, the energy performance indicator of existing single family buildings can be improved to 104-138 kWh/m^{2}a, in multi-family buildings to 115-175 kWh/m^{2}a. For new residential buildings, the Ep value related to the cost optimal level of building elements is 133-134 kWh/m^{2}a.

Ep value of existing school buildings can be reduced to 69-219 kWh/m^{2}a by the refurbishments – it is to note here that if we choose package 11 for optimum in the case of S-2 (as indicated in chapter 7.2) the Ep level related to the optimum would be 111 instead of 219 kWh/m^{2}a. In the new school building, the energy performance indicator related to the optimal building elements is 63 kWh/m^{2}a.

The Ep value of existing office buildings can go down to 156-227 kWh/m^{2}a due to refurbishments to cost optimum levels of building elements' requirements. In case of new office buildings, the energy performance indicator is significantly lower: 84 kWh/m^{2}a.

The results of our calculations can be found in Annex 7.

7.4. Conclusions

The optimum of the analysed measures varies, depending on the different types of buildings, between the 'medium' and the strictest level of the requirements set for buildings envelopes. This indicates, on one hand, that more stringent requirements are needed regarding the U-values, both in case of existing and new buildings. The difference is significant, whether we analyse primary energy demand or global costs.

On the other hand, results indicate that the real optimum may lie somewhere between the 'medium' and the strictest level. As we have analysed a limited number of measures, the absolute optimum can not be identified to complete certainty.

The results of the cost optimality analysis pursuant to the Directive underline the need to set more stringent requirements than the current ones defined by the 7/2006. Decree. Consequently, Energiaklub suggests that at least the medium level of requirements (walls: U=0,35 W/m^{2}K, attic slab: U=0,2 W/m^{2}K, basement slab: U=0,3 W/m^{2}K, windows=1,3 W/m^{2}K) should be adopted in Hungary for existing as well as new buildings, in 2013.

ANNEXES

Annex 1.
Table 1: Reference buildings for existing buildings

Annex 2.
Table 2: Reference buildings for new buildings

Annex 3.
Table 3: Sample of the reporting table for energy performance related data

Annex 4.
Table 4: Summary tables presenting measures defined, by different types of reference buildings

Annex 5.
Table 5: Energy demand calculation output table

Annex 6.
Table 6: Output data and global cost calculations

Annex 7.
Table 7: Comparison table for both new and existing buildings

Annex 8.
Renovation packages for building structures

Annex 9.
Renovation packages for building systems

Annex 10.
Investment costs

Annex 11.
Energy price prognosis

RESEARCH COMMUNICATION TRAINING

FOR DECISION-MAKERS, STATE ADMINISTRATION, COMPANIES AND HOUSEHOLDS

ABOUT HUNGARIAN AND INTERNATIONAL CLIMATE AND ENERGY POLICIES, ENERGY-EFFICIENCY AND RENEWABLE ENERGY SOURCES

ENERGIAKLUB
CLIMATE POLICY INSTITUTE
APPLIED COMMUNICATIONS

www.energiaklub.hu