Cost-Effective Climate Protection

in the Building Stock of the New EU Member States

Beyond the EU Energy Performance of Buildings Directive

Report established by ECOFYS for EURIMA

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EXECUTIVE SUMMARY

THE NEW EUROPEAN MEMBER STATES

As of 1 May 2004, the EU has grown by 10 new Member States. Next to the growth in size and population, the EU has developed into the globally largest economic single market. In order to enable this historic milestone, the new Member States had to adapt their policy and legislation to the general legal framework of the EU.
This is especially valid for climate protection issues. Although improvements in energy-efficiency have already occurred, the energy intensity in 2000 was still more than twice compared to that of the EU-15 countries. Besides energy-intensive industries, households are responsible for more than 40% of the final energy demand.

INFLUENCE OF THE EPBD ON THE BUILDING STOCK

Compared with the building stock of the long standing EU-15, the average of the building stock in the new Member States can be characterized by a lack of maintenance resulting in an urgent need for refurbishment. The development of energy consumption in the building sector is mainly influenced by the EU Energy Performance of Buildings Directive (2002/91/EC) (EPBD) which has to be implemented in national legislation by 2006. The EPBD requires fulfilment of national energy performances when large apartment buildings undergo significant retrofit.
This study analyses the impact of EPBD and possible extensions to other building types on heating-related CO_2 emissions and economics. For this, single measures and packages of measures, which are likely to become standard after implementation of the EPBD, were examined for their economics and impact on CO_2 emissions. Furthermore, the application of these measures on the building stock is shown in scenarios.

ENERGY-EFFICIENCY MEASURES

The examined energy-efficiency measures aimed at the improvement of the insulation of roofs, cellars and facades, windows and heating systems as single measures, as well as packages of measures were found to be cost effective.
With this, the study confirms that the principle of "Trias Energetica" should be applied to energy use in buildings. This states that the first requirement is that demand has to be reduced and unnecessary energy losses must be avoided. After that it is necessary to generate the remaining demand from renewable resources if possible and to use fossil fuels as efficiently as possible.
Applying the principle to the building stock implies that a good insulation standard is a pre-requisite for sustainable buildings.
In economical terms, the greatest opportunity is found to be the coupling of energy-efficiency measures with general maintenance and retrofit measures. Such an opportunity typically arises within the normal retrofit cycle only when buildings reach an age of about 30-50 years. Therefore efforts should be directed at utilizing the opportunity of combining regular retrofits with energy-saving measures.

IMPACT OF THE EPBD AND POSSIBLE EXTENSIONS

> Technical potential

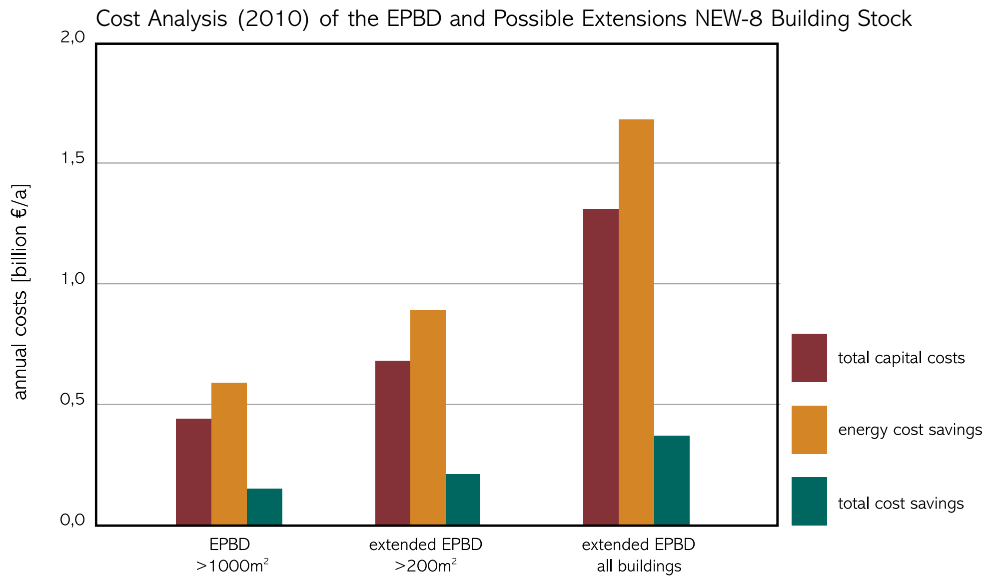
To arrive at the technical potential, all measures to comply with the EPBD and its extensions are assumed to be realized at the same time. Depending on the emission factors for district heating commonly used

for large apartment buildings, the emissions reduction potential in the NEW-8 countries for the EPBD can vary between 15 and 18 Mt/a. If the EPBD is extended to renovation of buildings >200m², the emissions reduction range from 25 to 31 Mt/a. For a further extension to all buildings, the range of emissions reduction lies between 55 and 62 Mt/a.
Comparing the technical CO_2 saving potential of the NEW-8 countries versus the EU-15 [Eco**fys** 2004] and relating the saving potential to the living area, the saving potential in the new Member States is proportionally greater than in the EU-15. (see Table 38)
The required investments to mobilize the technical potential in the building stock amount to 49 billion EURO for EPBD, 87 billion EURO for an extension of the EPBD to all buildings >200m² and 180 billion EURO for an extension of the EPBD to renovation of all buildings.

> Phased implementation

Taking into account the development factors on the building stock over time such as retrofitting, new building, demolition etc. scenarios are developed to show the development of cost and emissions induced by the EPBD and its potential extensions over time.
Additionally, it was assumed that retrofit programmes increase the retrofit rate for those buildings, which are subject to the EPBD. This results in emissions reduction of 5 Mt/a for the EPBD in 2010. For the extension to buildings >200m² and to all buildings, emissions reduction of 8 and 14 Mt/a can be effected respectively. The annual investments required to activate these emissions reduction are 2.7 billion EURO/a for EPBD, 4.3 billion EURO/a for a potential extension of the EPBD to buildings >200m² and 8.1 billion EURO/a for an extension of the EPBD to all buildings. Of these costs, roughly 40% are energy related.
Converting the energy related share of these investments into annual capital expenditure and relating them to annual cost-savings, displays the profitability of the energy-efficiency measures (s. Figure 1). The annual profit amounts to 154 million EURO/a for the EPBD in 2010 and rises to 371 million EURO/a if the scope of the EPBD were to be extended to all building-types.

Figure 1: Cost analysis EPBD and possible extensions 2010



	EPBD	Extended EPBD >200m²	Extended EPBD all buildings
total capital costs	0.44	0.68	1.31
energy cost savings	0.59	0.89	1.68
total cost savings	0.15	0.21	0.37

OUTLOOK AND RECOMMENDATIONS

In order to bring the building stock to a state of the art standard within a reasonable time, massive investment programmes would need to be launched. To meet the expectations with respect to climate protection and emission savings, these programs need to be coupled to energy-efficiency requirements. In comparison with other instruments of national and EU climate policy, the measures examined in this study for application in the building sector are highly competitive.

To accelerate the implementation of energy-efficiency measures, additional incentives could be provided in the form of revolving funds, the lowering of VAT on certain energy-saving products or the reduction of interest rates on loans for such measures.

Such programmes would also have significant effects on the employment situation. Despite the complexity of the macroeconomic factors, these large investments can be estimated to create roughly 50 to 185,000 jobs in the new Member States.

Further positive effects are in the reduction of urban air pollution and the avoidance of external costs from climate change.

CONTENT

1] INTRODUCTION

1.1 THE NEW MEMBER STATES

On the 1st of May 2004, the European Union grew from 15 to 25 countries. The new Member States include the Baltic countries (Estonia, Latvia and Lithuania), the Central European countries of Poland, Slovakia, Slovenia, the Czech Republic and Hungary, as well as the Mediterranean islands of Malta and Cyprus.
This historic enlargement will significantly influence the whole EU on many levels (see Table 1). The new members contribute an additional 34% in geographic area and 20% in population (75 million people). The economic potential of the EU increased by 5% (absolute EU GDP at current EURO prices). To join the European Union, each candidate country had to fulfil various requirements to guarantee democracy, human rights as well as a functioning market economy. Within the accession process each new Member State had to harmonize many aspects of their commercial and legal systems and adopt the common body of EU law. This includes the implementation of European Directives in the field of energy, energy efficiency and climate protection, and this causes significant reforms in the energy sector.

Although improvements in energy efficiency have already occurred since 1990 and energy related CO_2 emissions fell annually by 1.9%, the energy intensity in 2000 was still more than twice that of the 15 long-standing EU members [EC 2003]. This is primarily caused by energy-intensive industries, but since households are responsible for more than 40% of the final energy demand [EC 2003] this sector is highly relevant as well. This was confirmed at the 16th European Housing Ministers Meeting in Prague: The ministers concluded that "The refurbishment of housing and revitalization of urban quarters [...] can make a major contribution to central EU objectives, such as growth, employment and especially energy efficiency and climate protection."

To reduce the heating-related CO_2 emissions in the building stock of the new Member States, they must fulfil the requirements of the EU Energy Performance of Buildings Directive (2002/91/EC, EPBD).

Table 1: Comparison EU-15 vs. new Member States 2002 [Eurostat 2004-2; Eurostat 2005; Ecofys calculations]

Comparison EU-15 vs. new Member States 2002	Inhabitants	Buildings	Gross domestic product	Comparative price level
	million	billion m²	index	index
EU-15	378	18.0	100	100
New Member States	74.3	2.4	42-78	43-83
EU-25	452	20.4	96	96
Estonia	1.4	0.1	54	60
Latvia	2.3	0.1	49	55
Lithuania	3.5	0.2	46	53
Poland	38.2	1.1	53	57
Czech Republic	10.2	0.4	52	53
Slovakia	5.4	0.2	42	43
Hungary	10.2	0.3	53	55
Slovenia	2.0	0.1	71	73
Cyprus	0.7	0.0	78	83
Malta	0.4	0.0	69	72

1.2 THE EU ENERGY PERFORMANCE OF BUILDINGS DIRECTIVE

The EU Energy Performance of Buildings Directive came into force on 16 December 2002 and requires implementation in the legislation of the EU Member States by 4 January 2006. Four main elements define the requirements which need to be integrated into national legislation:

- Establishment of a methodology for an integrated calculation of the overall energy performance of buildings;
- Definition of minimum energy-efficiency requirements per Member State based on this methodology;
- Energy-efficiency certification of new and existing buildings;
- Regular inspection of heating and air-conditioning systems.

In addition to the aim of improving the overall energy efficiency of new buildings, large existing buildings have become a target as soon as they undergo significant renovation. Existing buildings are subject to the Directive if the total useful floor size exceeds 1,000m^2 and investment in renovation exceeds 25% of the building value (without land) or 25% of the building envelope is subject to renovation.

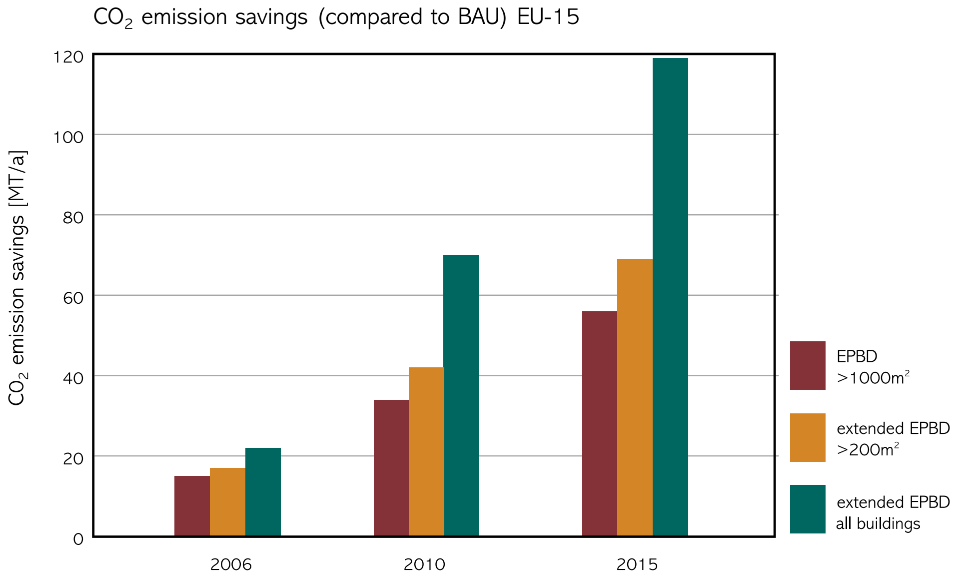
1.3 THE IMPACT OF THE EPBD ON THE EU-15 BUILDING STOCK

Two studies [Eco**fys** 2004; Eco**fys** 2005] carried out for EURIMA investigated the impact of the EPBD on the EU-15 building stock: The first study "Mitigation of CO_2 Emissions from the Building Stock" [Eco**fys** 2004] analysed the heating-related CO_2 emissions of the EU-15 building stock. Additionally, the report "cost effective Climate Protection in the EU Building Stock" quantified the investments required in energy efficiency and analysed their cost effectiveness which must be demonstrated in order to mobilise the total energy-saving potential in the EU-15 building stock.

The studies identified a significant impact of the European Directive on Energy Performance of Buildings on the heating-related CO_2 emissions of the EU-15 building stock. Compared to a business-as-usual (BAU) scenario under which common practice for energy efficiency is applied to new buildings and retrofit measures, the current EPBD leads to CO_2 emissions reduction of 34Mt/a in the year 2010 (see Figure 2). However, since single-family houses represent the largest share of buildings (45%) in the EU-15 countries, CO_2 emissions could be reduced even more significantly if the scope of the Directive were extended to include smaller buildings. Extension of the scope of the Directive to all buildings would create an additional emission-saving potential of 36 Mt/a.

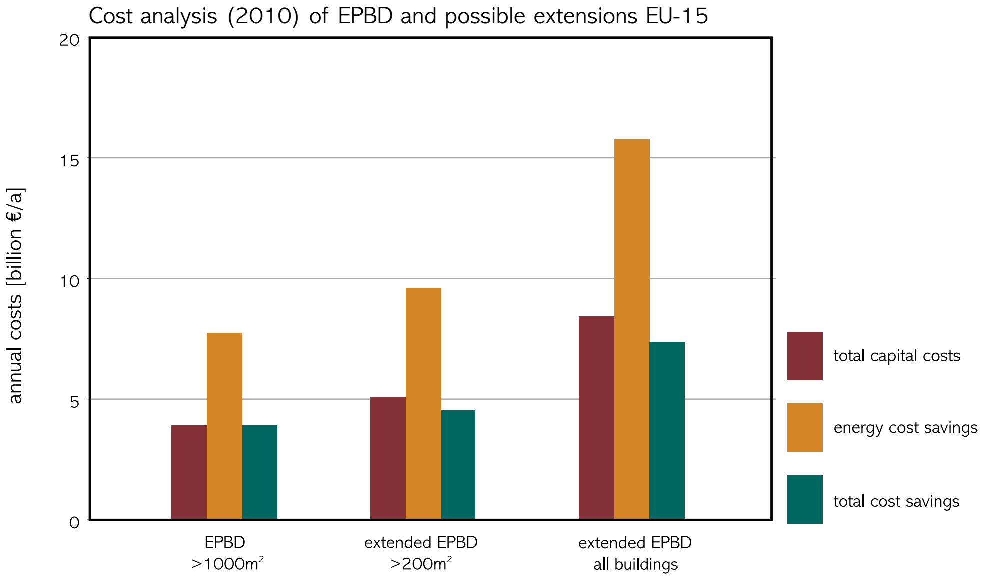
The cost analysis for the EU-15 reveals that fairly significant additional investments will be required: It is estimated that full implementation of the EPBD for new and large buildings in all countries will lead to an annual investment of nearly 10 billion EURO beginning in 2006. Extending the scope of the EPBD to all buildings, the annual investments would increase to about 25 billion EURO. However, in the context of total EU construction activities, energy-efficiency measures represent a minor share of only 1%-3% of the total turnover. In economic terms these investments would result in net annual cost reductions for national economies - making such measures profitable. Converting investments into annual capital expenditure and relating them to annual energy cost savings demonstrates the profitability of applying energy-saving measures at EU level (see Figure 3). Implementation of the EPBD would result in annual cost reductions amounting to around 4 billion EURO in the year 2010 rising to 7.5 billion EURO if the scope of the Directive were to be extended to all building-types.

Figure 2: Impact of the EPBD on the CO_2 emissions of EU-15 building stock



	2006	2010	2015
EPBD >1000m²	15	34	56
Ext. EPBD >200m²	17	42	69
Ext. EPBD all buildings	22	70	119

Figure 3: Economic impact of the EPBD on EU-15 building stock



	EPBD	Extended EPBD >200m²	Extended EPBD all buildings
total capital costs	3.9	5.1	8.4
energy cost savings	7.7	9.6	15.9
total cost savings	3.8	4.5	7.5

The European Commission has already identified this additional CO_2 saving potential. The Directorate-General for Energy and Transport has declared energy efficiency as a core objective of the European Commission energy policy from 2005 onwards. The complete package of measures to be taken across Europe remains to be finalised. However, extending the EPBD to smaller existing buildings has already been identified as one cost effective measure.

1.4 OBJECTIVES OF THIS STUDY

As shown in Section 1.1 and Table 1 the population of the EU increased with the enlargement by about 20% and the building stock by 13%. Since an urgent need for refurbishment in the building stock of the new Member States is recognised, it can be expected that the renovation can contribute significantly to the CO_2 emissions reduction targets of the EU. The dimensions of the savings potential of the new Member States should be seen in relation to the size of the building stock. Due to smaller building stock, it is obvious that the overall savings potential in absolute value is lower than in the EU-15.

The objective of this study is to analyse the impact of the EU Directive on the Energy Performance of Buildings concerning the heating-related CO_2 reduction potential and cost effectiveness in the new Member States. Thereby the following questions should be answered:

Overall energy performance improvements including better insulation, improved efficiency of heating systems and energy generation systems are key objective of the Directive.

> What is the effect of the Directive on CO_2 emissions of the new Member States' building stock?

The definition of a size threshold of 1,000m² for retrofits in existing buildings excludes a vast number of buildings and probably a significant part of the CO_2 emission saving potential.

> How large are the additional savings associated to extending the obligation for energy-efficiency retrofits towards smaller buildings?

In order to mobilise the total CO_2 emission-savings potential in the building stock of the new Member States, cost effectiveness is essential.

> Which investments are required to implement the EPBD and possible extensions in the new Member States and how cost effective are these measures?

1.5 STRUCTURE OF THE REPORT

The report is structured in the following chapters:

> The method to assess the CO_2 reduction potential and the cost effectiveness of energy-efficiency measures in the building stock of the new Member States is summarised in chapter 2.

> Chapter 3 gives a general overview of the existing building stock in the new Member States, describes the needs for refurbishment and the expected influence of the EPBD on future insulation standards of new and existing buildings.

> Chapter 4 investigates individual energy-efficiency measures focussing on insulation measures, but also taking into account heat production systems. Thereby the heating-related CO_2 reduction potential and the cost effectiveness of these measures are assessed, including the economic optimization of insulation levels.

> Out of these individual measures, suitable packages are composed in Chapter 5 which could become standard when the EPBD is implemented into national legislation.

The following chapters present aggregated results, when applying these renovation packages to the existing building stock of new Member States.

> The technical CO_2 savings potential and its economic effect is analysed in Chapter 6 making the theoretical assumption that all buildings covered by the Directive or possible extensions are retrofitted now, according to the insulation standard entering into force after the implementation of the Directive.

> The phased implementation of renovation packages under different scenarios of the implementation of the Directive and its possible extensions are assessed in Chapter 7, including the temporal development of the CO_2 emissions, the required investment, the saved energy costs and the overall economic profits.

The report ends with conclusions and policy recommendations for initiating the required investments at EU-15 level.

2] THE METHODOLOGY

In the following sections the methods to model the building stock of the new Member States, to calculate the heating-related CO_2 emission savings of individual measures and retrofit packages and the approach for economic assessment of these measures and retrofit packages are described.

2.1 MODELLING THE NEW-8 BUILDING STOCK

In order to analyze the CO_2 reduction potential and the cost effectiveness of energy-saving measures for the building stock of the new Member States, three groups with different climate conditions have been distinguished:

- The Baltic republics Latvia, Lithuania and Estonia will be reported as one group;
- Poland as the largest country will be investigated separately;
- The Central-Eastern European countries Czech Republic, Hungary, Slovakia and Slovenia are summarized as one group (hereafter called the CEEC-4).

The remaining countries, Malta and Cyprus, with approx. 1% of the household CO_2 emissions of the new Member States and marginal specific heating-related emissions will not be further investigated. The 8 new Member States investigated are hereafter referred to as the NEW-8 building stock.

The NEW-8 building stock, its CO_2 emissions, required investments for retrofit measures and energy-saving measures as well as the energy costs were calculated with the Eco**fys** BEAM model, which was developed to investigate the EU-15 building stock and was now extended to the EU-25.
Input to the model calculation is a database containing the building stock distinguished by climatic regions, building type/size, building age, insulation level, energy supply, energy carrier and emission factors. This was applied in a scenario tool used for calculating the development over time of the building stock as a function of demolition rate, new building activity, renovation and energy-efficiency measures in retrofits.
The great complexity of the building stock had to be simplified by examining five standard buildings with eight insulation standards, which are assigned to building age and renovation status (see Annex I).
Including the defined three climatic regions, this gave an array of 210 basic building types for which the heating energy demand and CO_2 emissions from heating were calculated. A detailed description of the BEAM model for the NEW-8 building stock can be found in Annex I of this report.

2.2 CALCULATION OF THE CO_2 EMISSION SAVINGS

To analyse the CO_2 emission savings of measures, the energy savings are calculated and converted by CO_2 emission factors to CO_2 emission savings as a first step. The CO_2 emission factors applied for different energy carriers are given in Table 2.

*Table 2: Emission-factors of different end-energy carriers [Gemis 2004; IEA 2002; Euroheat 2003; Eco**fys** calculations]*

Energy carrier	Emission factors [g/kWh]
Gas	202
Oil	266
Coal	338
Electricity NEW-8	610
Wood	20
District heating (Baltic Republics 2002)	237
District heating (Poland 2002)	539
District heating (CZ-HU-SL-SK 2002)	258

2.2.1 ENERGY SAVINGS OF INDIVIDUAL MEASURES

The energy-savings of different insulation measures are calculated according to the following equation:

$$\Delta E = HDH * \Delta U * 1/\eta$$

ΔE	[kWh/m²a]	Energy-savings (related to the surface area of the constructional element)
HDH	[kKh/a]	Heating Degree Hours (see Table 3)
ΔU	[W/m²K]	Difference of U-values before and after retrofit
η	[-]	Efficiency of heat generation and distribution

Table 3: Heating degree hours of different climatic zones [Ecofys 2004; STOA 1998][1]

Climatic zone	Baltic Republics	Poland	CZ, HU, SL, SK
HDH [kKh/a]	96.0	92.4	81.6
Heating degree days [Kd/a]	4000	3850	3400

2.2.2 ENERGY SAVINGS OF RETROFIT MEASURES

Energy-savings of retrofit packages assessed are calculated as the difference of the energy demands for heating of a certain house-type with different insulation levels or heat supply systems. Thereby the energy demand for heating was calculated according to the principles of the European Standard EN 832. Please note that the influence of cooling is not taken into account.

2.3 THE ECONOMIC ASSESSMENT METHODOLOGY

2.3.1 COSTS DURING THE LIFE CYCLE

For an economic assessment of CO_2 mitigation measures, not only investments but also the fuel, maintenance and operational cost savings realised are relevant. The methodology chosen allows the different costs over the whole life cycle of energy saving measures to be compared.

The main elements of these life cycle costs are capital costs and annual running costs which sum up the operational or energy and the maintenance costs.

2.3.1.1 CAPITAL COSTS

Capital costs result from the investment in energy-saving measures. Two different investment costs for energy-saving measures are distinguished:

> **The total investment costs**

The total investment costs for insulation and energy-efficiency measures in a retrofit implemented building project as a “stand alone” include material, labour, applicable taxes as well as overheads and profits. Here, the energy-efficiency measures are initiating the expenditure. The estimated investment costs are included for each measure in the description of the measure itself. Average values for all investigated NEW-8 states are taken into account. These are based on interviews with building experts throughout the NEW-8 states, which were carried out as part of the project. These costs are reported in the equivalent of 2002 EURO value. Compared to the costs of the EU-15 countries, the prices are generally lower. Since material costs are slightly below EU-15 levels, the differences for labour-intensive measures are more significant (see chapter 4.1).

[1] One heating degree day [Kd/a] corresponds to 0.024 heating degree hour [kKh/a]

> **energy related investment costs (energy measures coupled with general retrofit)**

Energy-saving measures may also be undertaken as part of the conventional retrofit cycle of buildings. Here they can be combined with other necessary refurbishment and replacement. When energy-saving measures are coupled with renovation, the energy related investment costs can be reduced compared with the "stand alone" scenario. For example the installation of roof insulation can be combined cost effectively with renewal of a leaky flat roof. Hence this study compares "stand alone" energy related investment costs with energy-efficiency measures applied within the renovation cycle.

In other words: the energy related investments are the total investment costs minus the investment costs for renovation without energy improvements (already existing energy-efficiency measures kept in place).

2.3.1.2 OPERATION AND MAINTENANCE COSTS

The annual operation and maintenance costs can be classified into energy costs and other operational and maintenance costs.

> **Energy costs and operation costs**

Energy costs are by far the largest component of annual operational and maintenance costs for the measures investigated. This study has calculated energy costs based on energy costs and the assumed respective increase rates displayed in Table 4. Average values for all NEW-8 states investigated are taken into account. Due to the variation of energy prices in different countries results may differ for specific national circumstances. Thereby the annual rate of price increase is related to the equivalent monetary EURO value in 2002. In reality, the energy tariffs might rise faster due to inflation.

Table 4: Energy rates for different end-energy carriers [derived from EC 2003; Eurostat 2002; IEA 2002; Enquete 2002]

	Energy tariff 2002	Annual rate of increase	Average value 2002-2032
	[€/kWh]		[€/kWh]
Gas	0.025	1.50%	0.032
Oil	0.036	1.50%	0.046
Coal	0.017	1.50%	0.022
Electricit	0.085	1.50%	0.188
District heating	0.035	1.50%	0.045
Wood	0.017	1.00%	0.020

> **Other Operational and Maintenance Costs**

Within the standard retrofit cycle, the operational and maintenance costs for insulation is negligible. The maintenance cost for technical equipment such as gas boilers can be seen as constant and remains approximately 1% of the investments [VDI 2067]. However, in the assessment of energy-saving measures, results are usually compared with a reference having the same maintenance costs, as long as no fuel switching takes place. Therefore the maintenance costs have no influence on the economic assessment and no non-energy operational and maintenance costs are considered.

2.3.2 ASSESSMENT CRITERIA FOR LIFE CYCLE COSTS

The annual operation and maintenance costs can be classified into energy costs and other operational and maintenance costs.

2.3.2.1 AMORTISATION

The amortisation period is a transparent criterion for the assessment of the economic viability of energy-saving measures. It indicates the time span after which the investments are recovered from the energy cost savings, expressed on an annual basis. It has the disadvantage that the costs of financing are not taken into account.

2.3.2.2 TOTAL EQUIVALENT ANNUAL COSTS

To account for the costs of financing and compare alternative measures with different life spans, the total equivalent annual costs are commonly used. The total equivalent annual costs are calculated as the sum of annual operational and maintenance costs, plus annualized capital costs.
Therefore the investments are converted into constant annual capital costs. The investment costs are multiplied by the equivalent annual cost factor or annuity factor, which is based on the lifetime of the measure and an interest rate:

$$a=\frac{(1+i)^{n} * i}{(1+i)^{n}-1}$$

a ➡ Annuity factor
i ➡ Interest rate
n ➡ Service Lifetime

Table 4 lists the values chosen for the cost assessment. These are consistent with the previous study on the cost effectiveness of energy-efficiency measures in the EU-15 building stock [Ecofys 2005] and other EU studies which have evaluated the cost effectiveness of various climate change mitigation options such as EU DG Environment's "Economic Evaluation of Sectoral Greenhouse Gas Emission Reduction Objectives" [Ecofys 2001]. Compared to [Ecofys 2005] the interest rate was adapted due to higher costs for capital in the NEW-8 states. Since the interest rates for short-term and long-term investments are about 2% higher [WKO 2004; Eurostat 2004-3] this percentage was taken into account and the assumed interest rate was increased from 4% for the long standing EU members to 6% for the NEW-8 states. It is however important to note that these default societal interest rates can differ significantly from capital costs or expected returns on investment for companies or individuals, i.e. the cost optimum for society is often different from an investor's optimum. Public policy however usually attempts to minimise costs to society.
Additionally, it is important to note that the values used for economic lifetime are derived from other studies [VDI 2067; Ecofys 2001; IWU 1994]. The actual technical lifetime of the products and its technical applications may exceed the economic lifetime, thus increasing the economic benefits.

Table 5: Assumptions for calculation of annual capital costs [Ecofys 2001; VDI 2067; WKO 2004; Eurostat 2004-3]

Interest rate	6%
Service lifetime insulation	30 yrs
Annuity factor insulation	0.0726
Service lifetime technical equipment	20 yrs
Annuity factor technical equipment	0.0872

2.3.3 EMISSION MITIGATION COSTS

EU climate policy aims to avoid future economic damage and risks by reducing greenhouse emissions at minimum costs to society. Most policies and measures to mitigate climate change are expected to lead to some additional cost for end users, companies and governments.

For decisions on policies and measures at EU level, the mitigation costs expressed as annualised EURO per ton of CO_2 avoided are used as the economic criterion. Mitigation costs refer to the last unit and thus most expensive unit to achieve the agreed target.

Measures can be prioritised according to their positive mitigation costs. Positive mitigation costs result from a cost benefit analysis: it costs a certain amount of money to save CO_2 emissions. Negative mitigation costs indicate just that the measure is cost effective. The measure results in two benefits which might not be directly connected[2].

Table 6 presents an overview of indicative marginal mitigation costs. These costs are not taken into consideration in the economic assessment of the measures investigated but are meant for benchmarking the mitigation costs of the calculated measures (see chapter 7).

Table 6: Estimates of EU and national marginal mitigation costs [Friedrich 2001]

Source	Assumptions	Marginal mitigation costs
Blok, Jager et all. (2001)	Calculated for the EU-15 to achieve its Kyoto target domestically using all six greenhouse gases and sectors	$20€_{1999}$/tonne CO_2e[3]
Criqui and Viguir (2000)	Calculated for the European Union (EU-15) to achieve its Kyoto target provided full flexibility is assumed and all sectors are included	37US$/tonne CO_2e
Capros and Manzos (2000)	Calculated for achieving the EU Kyoto target allowing free trade of emission certificates globally	$19€_{1999}$/tonne CO_2
Fahl (1999)	Calculated for Germany to achieve its Kyoto target	19€/tonne CO_2e
Maibach et al. (2000)	Calculated for a 50% reduction of CO_2 for 2030 compared to 1990 values	$135€_{2000}$/tonne CO_2

[2] Prioritising measures according to their negative mitigation costs might lead to wrong conclusions. Example:
measure 1: costs: -10 EURO/a, CO_2-savings: 10t/a: mitigation costs: -1 EURO/t
measure 2: costs: -10 EURO/a, CO_2-savings: 1t/a: mitigation costs: -10 EURO/t
measure 3: costs: -1 EURO/a, CO_2-savings: 10t/a: mitigation costs: -0.10 EURO/t
For measure 1 both benefits are maximal. Using the mitigation costs as indicator measure 2 would be optimal.

[3] This figure must be interpreted to achieve the target in the most effective manner and includes all Kyoto gases. It was assumed the target could be achieved without global emissions trade but with full flexibility. Full flexibility refers to a European wide implementation of least cost measures in different sectors independent of the EU Bubble.

It is widely accepted within the EU and its Member States that 20€$_{2000}$/tCO_2e represents an indicative limit of acceptable mitigation costs in the near term – considering the current economic potential for emissions reduction balanced against the likely range of future damage and some ancillary benefits.
This report shows the cost effectiveness of energy-efficiency measures (see chapter 4 and 5) expressed in mitigation costs and the costs or financial benefits per saved energy unit. Negative values mean cost effectiveness. The average cost of energy has been used in the report.
Remark: Actual energy prices in any particular country should be taken into account to establish the national or local effectiveness of energy-saving measures. A higher or lower national energy price can be considered in the "cost saved energy" values in the tables "economic assessment of retrofit measures" in the chapters 4 and 5 by adjusting the price difference[4]. If the new value is negative, the measure is cost effective.
Figure 4 summarises the calculation principles for the economic assessment of energy-saving measures in the building stock.

Figure 4: Calculation principles for the economic assessment

Calculation Principles		
Total investment costs	IC_{total}	(€/m²)
- related to surface area of constructional element for individual measures (chapter 4) - related to heated floor area of investigated house for retrofit packages (chapter 5)		
Energy related investment costs	$IC_{energy\ related}$	(€/m²)
When coupling the energy measures with the regular retrofit cycle, the energy related costs are the total investment costs minus the investment costs for regular preservation measures without energy improvements (see 2.3.1)		
Annual investment costs	$IC_{annual} = IC_{total/energy\ related} * a$	(€/m²a)
Investment costs converted to annual capital costs; a = annuity (see 2.3.2)		
Saved energy costs	$\Delta EC = \Delta E * EP$	(€/m²a)
ΔE = energy-savings [kWh/m²a] (see 2.3.1); EP = Energy price (€/kWh)		
Total cost-savings	$TC_{annual} = IC_{annual} - \Delta EC$	(€/m²a)
Related to constructional area (individual measures) or heated floor area (packages)		

Decision Criteria		
Cost Effectiveness		Policy Decision
Amortisation (Pay Back Time) $A = IC_{total} / \Delta EC$ [a]	**Cost saved Energy** $C_{\Delta E} = TC_{annual} / \Delta E$ [€/kWh$_{avoided}$]	**Mitigation Costs** $MC = TC_{annual} / \Delta CO_2$ [€/tCO_{2e}]

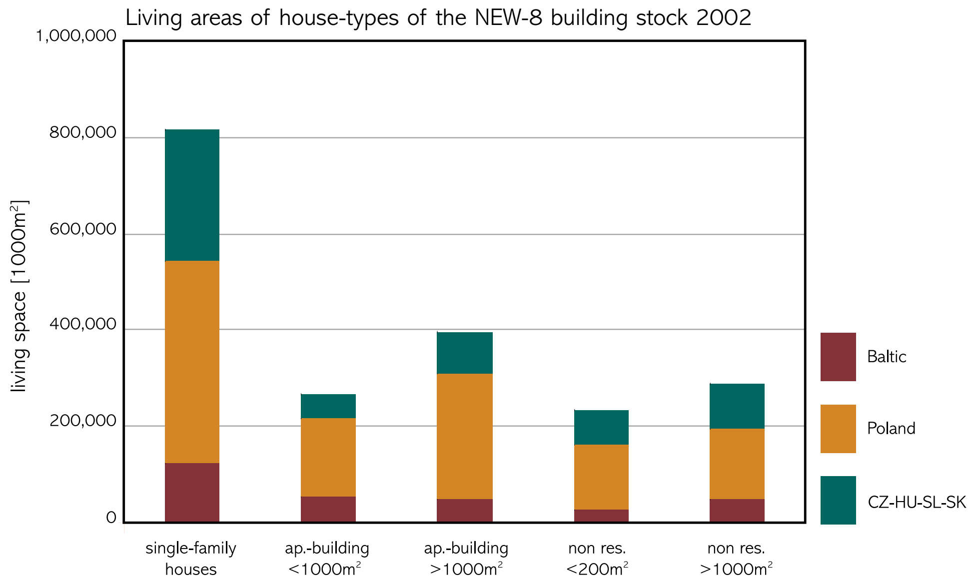
[4] Example: The report calculates with the average zone price for energy in Table 8. If the local price is 1 cent above this value then the "cost saved energy coupled" for instance in Table 10 should be adjusted from -1.8 to -2.8 cent/kWh in the Baltic Republics.

3] THE NEW-8 BUILDING STOCK

3.1 LIVING AREAS

Figure 5 shows the distribution of living areas of the current building stock for the 8 new Member States investigated (hereafter called the NEW-8 building stock). Buildings larger than 1,000 m², which are subject to the EPBD represent some 34% of the total area of the building stock. The group of single-family houses represents the largest share of buildings (41%). Apartment houses cover 33% of the total building stock, non-residential buildings 26%. A detailed overview of the NEW-8 building stock and its age distribution is given in Table 44, Table 48 and Table 52 of Annex I.

Figure 5: Living areas of building-types of the NEW-8 building stock 2002

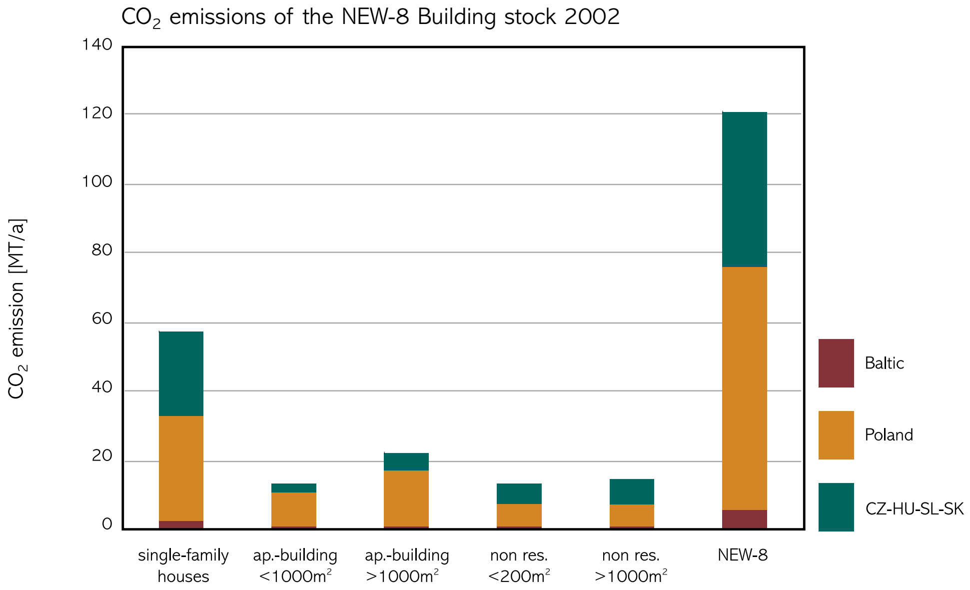


3.2 CO_2 EMISSIONS NEW-8 BUILDING STOCK

The extent to which the investigated groups and different house-types contribute to the CO_2 emissions of the current building stock of 121 Mt/a is addressed in Figure 6. Thereby the CO_2 emissions were calculated with the Eco**fys** BEAM model (see chapter 2.1 and Annex I).

As can be seen in Figure 6, the CO_2 emissions from the group of single–family houses are analogous to their share of living space (see Figure 5). Even though their external surface relative to living space is larger than that of compact apartment blocks resulting in greater specific heating energy consumption, this effect is counterbalanced by the high emission-factor of district heating, which is the predominant heat supply system in high-rise apartment buildings. This is caused on the one hand by relatively high losses due to old district heating networks and on the other hand by the use of coal, especially in Poland.

Figure 6: CO_2 emissions of the NEW-8 building stock 2002 [Mt/a]



	Single family houses	Ap.-building <1000m²	Ap.-building >1000m²	Non res. <200m²	Non res. >1000m²	NEW-8
NEW-8	57	13	22	13	15	121

3.3 RECENT DEVELOPMENTS IN THE NEW-8 BUILDING STOCK

The governments of the new Member States report the highest level of need for refurbishment in the EU. The study [PRC 2004] concludes that "the large part of the stock in EU10 ... is in urgent need for maintenance and repair. [...] Whereas in EU-15 (in general) programmes are in place to support refurbishment of the housing stock since decades, these programmes are quite recent, and in terms of available budget, also quite modest (or even lacking) in the EU-10. Due to considerable under investment in maintenance of the housing stock in the EU-10, the need for investments will even increase. The conclusion must be that for the new Member States [...] there is an urgent need for a considerable intensification of refurbishment programmes."
A large share of the residential buildings in the NEW-8, which are covered by the Directive, were built after the second World War as high-rise apartment buildings with prefabricated panels. Due to the mass production in a relative short time span and due to the homogeneity in technology, a large number of buildings need to be refurbished at the same time across one country and even across the whole region. [Environ 2004] quantifies the need for partial renewal of local government-owned, social-rented dwellings in Hungary to about 40%, while 24% of the apartments are in expressively poor condition and require comprehensive refurbishment.

The need for refurbishment is already recognized by the European and national governments: the 16th European Housing Ministers Meeting held in Prague in March 2005 dealt with "Sustainable Refurbishment of High-Rise Residential Buildings and Restructuring of the Surrounding Areas". The Ministers concluded [Czech 2005]:

> that it is important to adopt a sustainability perspective when refurbishing high-rise residential buildings [...].

> that emphasis should be given on integrated strategies involving housing management, maintenance employment, energy-saving measures, urban development and social policy approaches in the refurbishment of large, high-rise housing estates in the new Member States [...].

> that refurbishment is a major financial issue requiring significant investment, particularly in new Member States and accession countries, that is primarily a domestic concern, which demands clear political choices and policies, [...].

Some countries e.g. Czech Republic, Slovakia and Poland have already experiences with programs to support refurbishment. For example, the goal of the thermomodernisation fund in Poland is the decrease in energy use for heating in housing and public buildings sector. But the urgent need for maintenance and repair requires considerable intensification of refurbishment programs in the new Member States.

3.4 FUTURE NATIONAL INSULATION STANDARDS

The Directive does not give minimum levels for energy performance or thermal insulation. Therefore the impact of the EPBD on thermal insulation was assessed by interviews with building authorities and experts throughout Europe. This has resulted in forecasts for thermal insulation levels in the three climatic zones by the time the EPBD is implemented in national legislation. In the following, these values will be referred to as the "**expert forecast EPB-standard**".

Table 7: U-values according to the expert forecast EPB-standard

U-values [W/m²K]	Expert forecast EPB-standard new buildings	Expert forecast EPB-standard retrofit
Baltic Republics		
Roof	0.17	0.20
Façade	0.26	0.26
Floor	0.29	0.29
Windows	1.66	1.66
Poland		
Roof	0.23	0.23
Façade	0.30	0.25
Floor	0.60	0.60
Windows	2.00	2.00
Central Eastern European Countries CZ, HU, SL, SK		
Roof	0.23	0.23
Façade	0.34	0.35
Floor	0.44	0.46
Windows	1.65	1.70

In general the U-values for new buildings are in almost all cases identical or slightly better than for retrofit. One curious exception is the expected U-value for the façade in Poland: Due to the above-mentioned subsidy programme in Poland with minimum insulation levels for the façade, the Polish experts predicted a better standard for retrofit. This proves the effectiveness of subsidy programmes.

4] THE ASSESSED MITIGATION MEASURES

As described in Chapter 2, this chapter focuses on heating-related CO_2 emission-saving potential and the economics of individual energy-efficiency measures on CO_2 emissions. Cooling is not a focus of this study. The measures assessed address the building envelope and the energy supply system of buildings:

- Building envelope; reduced transmission loss by:
  - Increased insulation of walls;
  - Increased insulation of roof;
  - Increased insulation of cellar/ground floor;
  - Improved windows with lower U-value.

- Renewal of energy supply

For the calculation of the results of retrofit measures on the building envelope (insulation and windows) the following situations are compared:

> Situation before retrofit:

The economic viability of insulation measures is strongly dependent on the energy efficiency of the building before start of the retrofit measure. In our model calculations, the general energy efficiency status of buildings in the NEW-8 countries built before 1975 and not yet renovated is taken into account.

> Situation after retrofit:

The measures are analyzed for insulation levels according to expert forecast EPB-standard (see chapter 3.4). Additional calculations have been made by varying the possible levels of building insulation in order to determine an economic optimum.

To assess the benefit of measures to improve the thermal resistance of the building envelope, a uniform average energy price and CO_2 emission factor including all energy carriers (gas, oil, electricity etc.) have been calculated for the respective zones (Table 8).

Table 8: Characteristics of assumed energy mix in the three climatic zones [IEA 2002; Eurostat 2004; Ecofys calculations]

Climatic zone	Average CO_2 emission factor	Average energy costs (30 years)
	[kg/kWh]	[€/kWh]
Baltic Republics	0.130	0.042
Poland	0.293	0.042
CZ-HU-SL-SK	0.220	0.045

4.1 INSULATION OF EXTERNAL WALLS

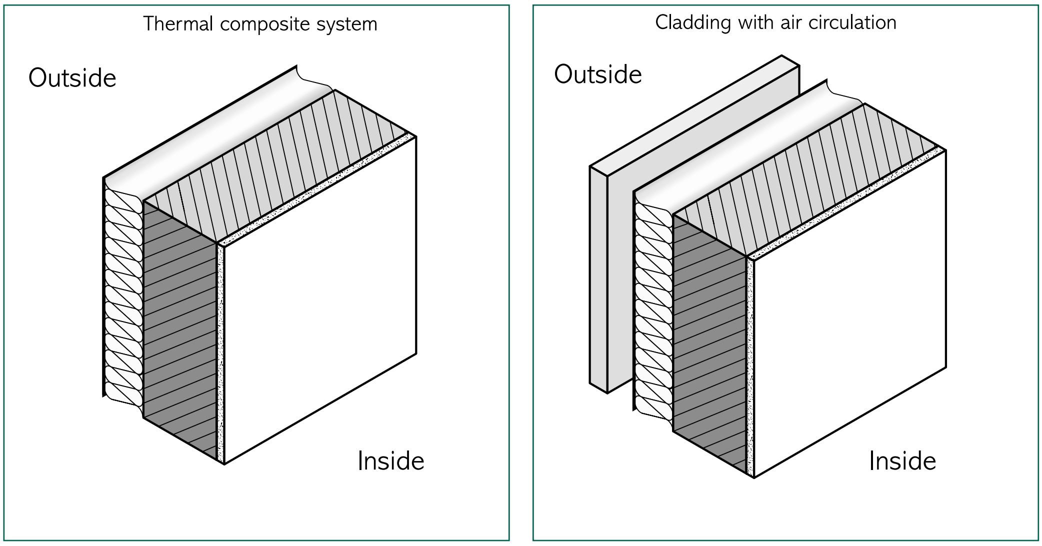
The methods for insulating external walls when applying energy-efficiency measures during the retrofit of a building depend on the particular structure of the outer walls. Three different types can be distinguished: external insulation, cavity insulation and interior insulation (dry lining). Hereinafter the method of external insulation is assessed as being by far the most common method for insulation of outer walls in the NEW-8 states.

> Description of the measure

The insulation is attached on the outer surface of the external wall (see Figure 7). In this, two different types can be distinguished:

- In a thermal composite system, the insulation material is attached to the wall and coated by a final layer. This method is widely employed in retrofit projects in Eastern Europe.
- A cladding with air circulation consists of insulation material, an air gap of approx 3 cm and a weatherproof layer (wood, metal sheets, ceramic plates etc.).

Figure 7: Visuals of external insulation



> Investment and Cost Analysis

As described in Chapter 0 two different investment costs are taken into account:

- **Coupled realisation:** If the insulation is included in the framework of general renovation measures of the façade (e.g. a renewal of the surface) only the "additional investment" or "energy related investment costs" for insulation material and associated labour costs are taken into account as energy related costs.

- **Independent realisation:** If the insulation measure is carried out without any other maintenance measures which are carried out anyway, the total costs of the measure have to be taken into account.

Costs and characteristics of external insulation measures ("coupled" and "independent") are described in Table 9 for the 3 different zones according to the desired level of the expert forecast EPB standards (see introduction in chapter 4). The basis for the cost calculations for the insulation measures in this study is a heat transmission coefficient (λ-value) of 0.04 W/mK[5]. An average price has been assumed representing the mix of most representative insulation materials usually used in retrofit projects in Eastern Europe. The values mentioned are normalized to one square meter of insulated wall.

[5] A normalised λ-value of 0.04 W/mK also includes the influence of thermal bridges for fixations, etc.

Table 9: Characteristics and investment cost external insulation in three climatic zones

Façade: investment external insulation		Baltic Republics	Poland	CZ-HU-SL-SK
U-value before retrofit	[W/m²K]	0.90	1.20	1.50
U-value after retrofit	[W/m²K]	0.26	0.25	0.35
Total investment costs (independent)	[€/m²]	44	46	42
Additional investment (coupled)	[€/m²]	26	28	24

It is clear to see that the U-values before retrofit show increasing values from the Baltic Republics to the CEEC4 being linked to the different climatic conditions. The U-values after retrofit follow this trend, whereby in Poland a governmental subsidy programme encourages investors to reach a value of 0.25 W/m²K, which is already quite advanced (see Chapter 3.4).

Assuming similar material costs and labour costs in the different climatic zones, the total investment and additional costs for external insulation vary only slightly due to different insulation thicknesses. As described in Chapter 0 the costs for insulation measures in the Eastern European countries are lower compared to the EU-15 countries (see [Eco**fys** 2004]) due to lower labour costs.

Table 10 displays the energy savings and the economic assessment of retrofitting the façade with external insulation according to the expert forecast EPB standard for three climatic zones.

Table 10: Economic assessment of external insulation in three climatic zones

Façade: investment external insulation		Baltic Republics	Poland	CZ-HU-SL-SK
End-energy savings	[kWh/m²a]	76	100	107
CO_2 emission savings	[kg/m²a]	10	30	24
Mitigation costs (independent)	[€/tCO_2]	-3	-28	-75
Mitigation costs (coupled)	[€/tCO_2]	-131	-71	-129
Cost-saved energy (independent)	[cent/kWh]	0.0	-0.8	-1.7
Cost-saved energy (coupled)	[cent/kWh]	-1.8	-2.1	-2.9
Amortisation (independent)	[a]	14	11	9
Amortisation (coupled)	[a]	8	7	5

The end energy savings depend on the improvement of the U-value and the climatic conditions. In this case, the improvement of the U-value is dominating, leading to increasing savings from the Baltic Republics to the CEEC4.

Concerning the CO_2 savings, the influence of the relatively high emission factor in Poland (see Table 2) is clear to see.

Mitigation cost and amortisation of increasing the external insulation of the façade to the expert forecast EPB standard decrease from the Northern (Baltic Republics) to the Southern Countries (CEEC4). The reason for this is the relatively better energy efficiency of the building stock in Northern countries. Due to relatively low labour costs in the new Member States, an independent retrofit is still feasible (with a break even in the Baltic Republics) but the conclusion is that it is imperative to strongly recommend that external insulation measures are coupled with maintenance of the façade in all climatic zones to obtain optimal cost effectiveness.

> Economic optimum

Figure 8 demonstrates the effects on the U-value and CO_2 emissions and the financial implications (for independent and coupled measures) of external insulation of façades depending on the thickness of additional insulation.

The graphs in the left column represent the resulting new U-value of the improved wall related to the additional insulation thickness. The insulation property (existing U-value) of the structures before the retrofit is taken into account in the calculation. The red line in the graphs marks the estimated retrofit level according to the expert forecast EPB standard.

The graphs of the financial implications (middle and right column) display the annual overall costs resulting from the sum of annual capital costs and annual energy costs. If the thickness of insulation is increased, all graphs show a minimum for the annual overall costs, representing the optimal insulation level. Due to the relatively flat minimum, a wide range of insulation thicknesses leads to almost similar economic outcomes.

Analysing the results shows that for the Baltic Republics, external insulation is cost effective as a stand-alone measure between U-values of 0.20 and 0.30 W/m^2K. Below and above this level a retrofit is not cost effective. As a coupled measure, the external insulation is always cost effective. An economic optimum can be reached between U-values of 0.20 and 0.35 W/m^2K.

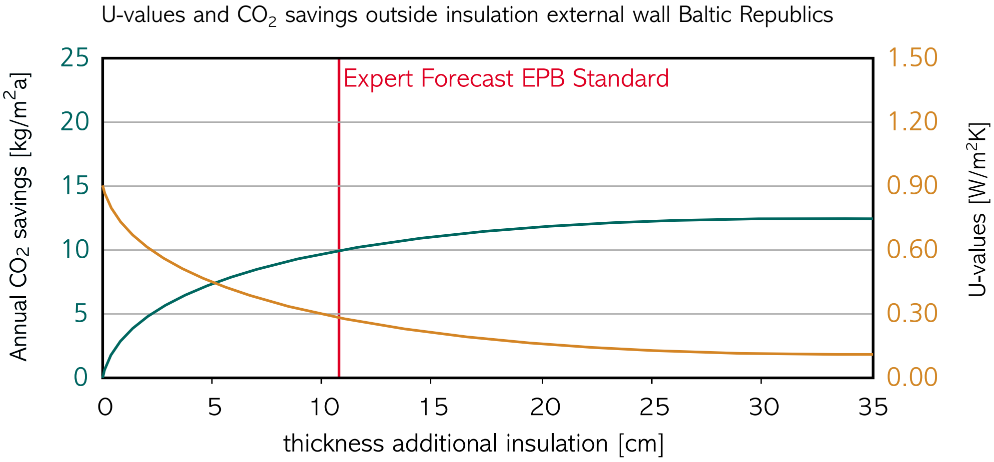
In Poland, independent insulation measures are cost effective, with an optimum between 0.20 – 0.40 W/m^2K. Above this insulation level, a retrofit is generally not cost effective. When looking at coupled measures in Poland it becomes evident that a financial benefit can be realised with an optimum between U-values of 0.20 – 0.40 W/m^2K.

In the CEEC4, the lower thermal resistance of the average building envelope makes stand-alone and coupled insulation measures economically feasible. For this the economic optimum is near a U-value of approx 0.20 to 0.40 W/m^2K.

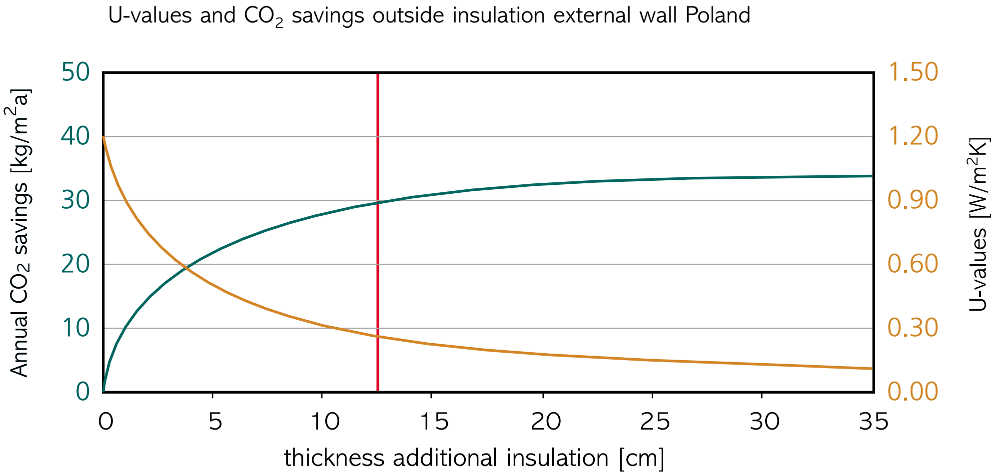
For all three climatic areas, the top of the cost efficient range of U-values is beyond the values given in the expert forecast EPB standard. This indicates that additional emissions reduction potential can be made available without extra cost by increasing the ambition level of the legislation.

Figure 8a: U-values and CO_2 savings

Baltic Republics



Poland



CZ-HU-SL-SK

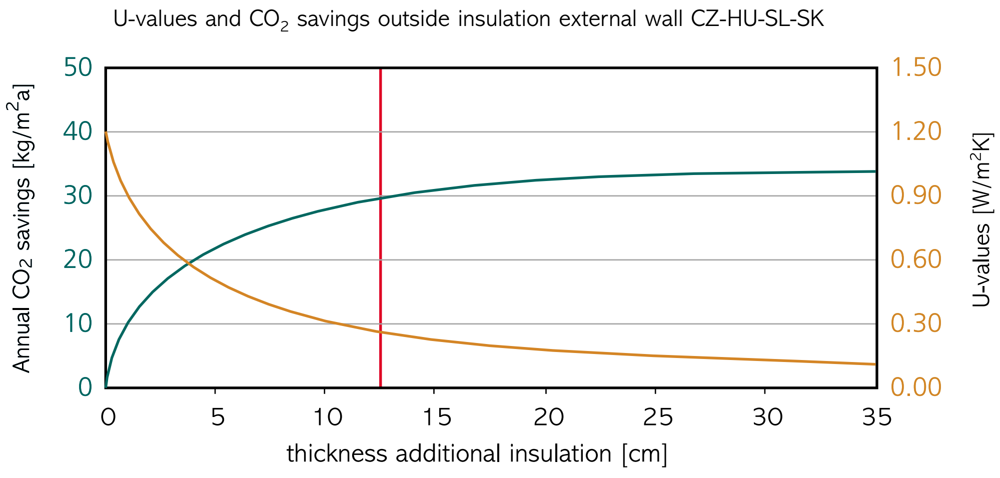
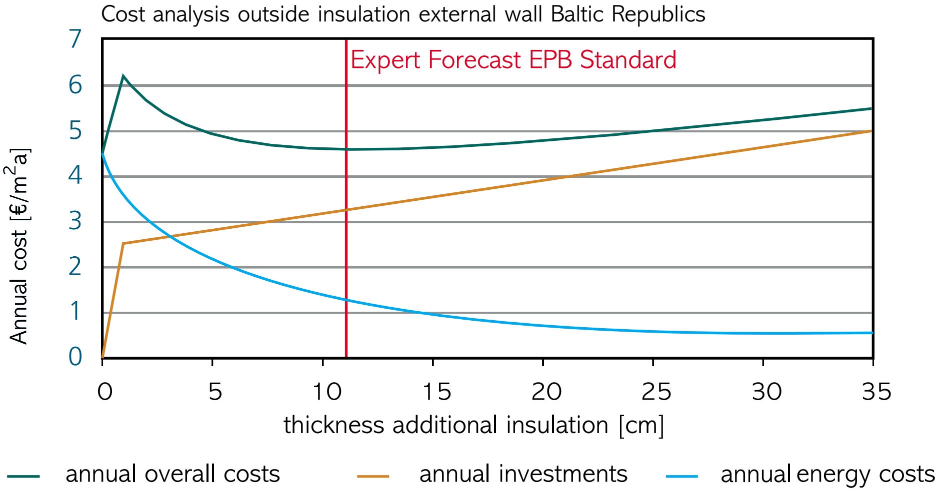
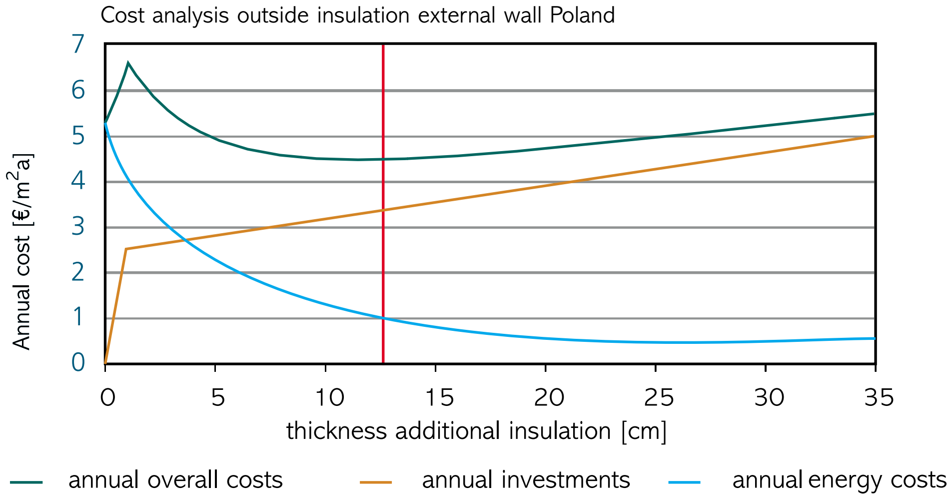


Figure 8b: Cost independent measures

Baltic Republics



Poland



CZ-HU-SL-SK

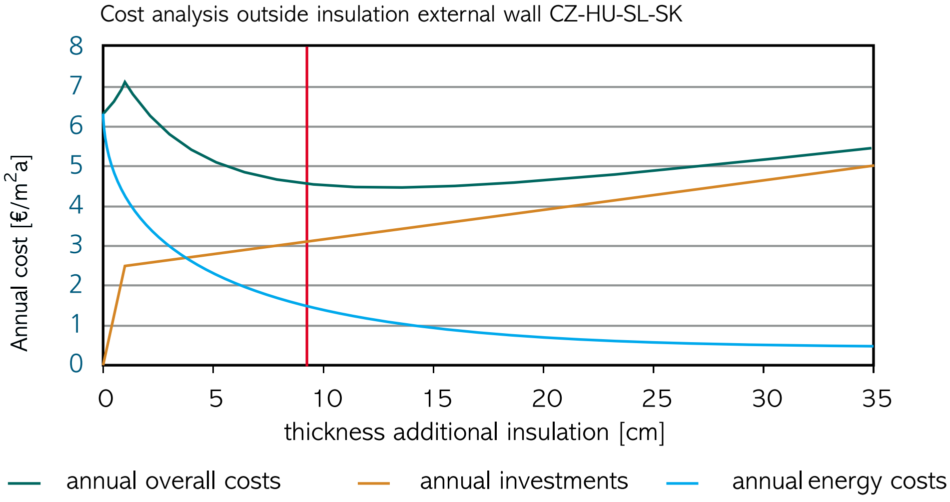
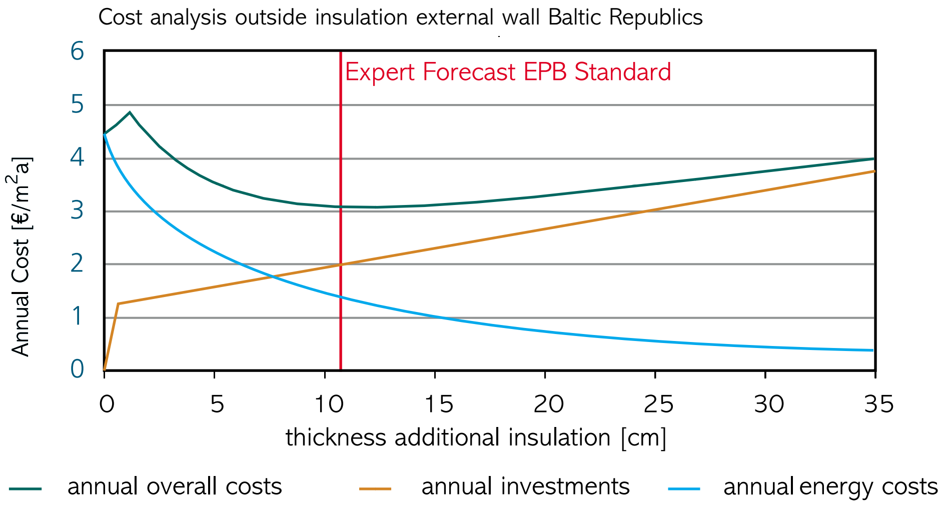
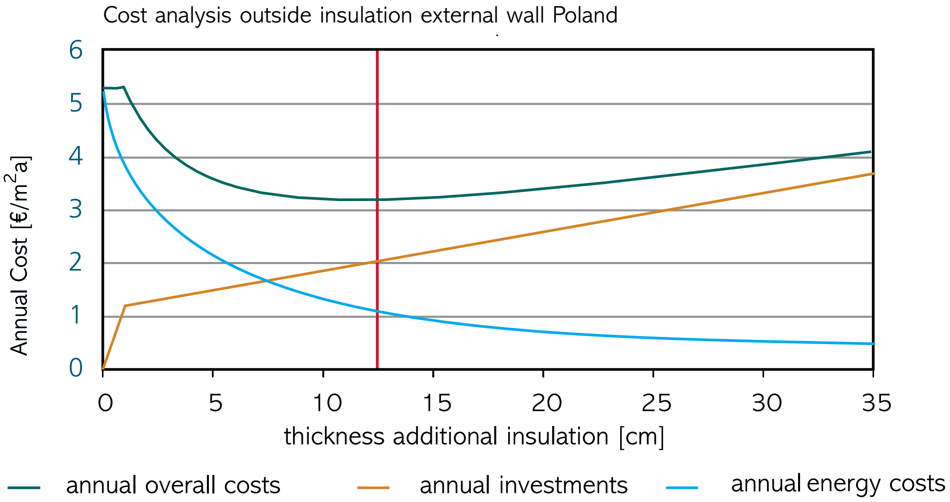


Figure 8c: Cost coupled measures

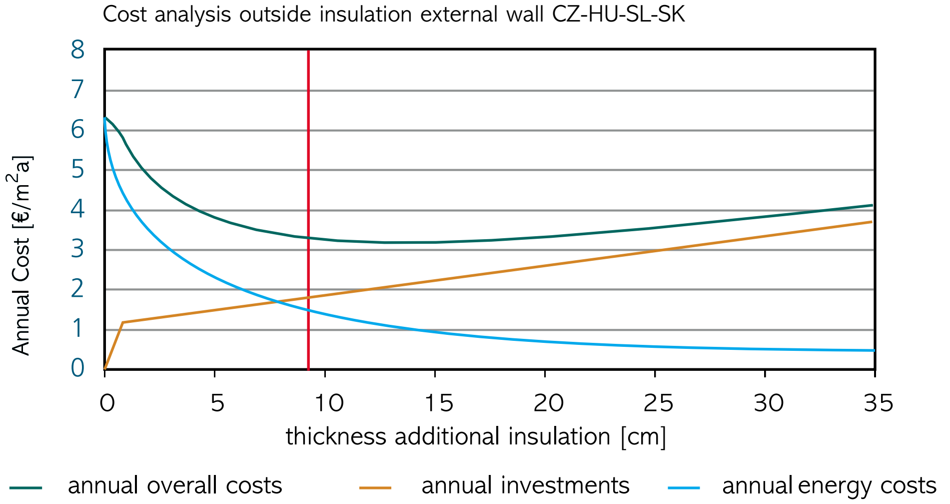
Baltic Republics



Poland



CZ-HU-SL-SK



4.2 INSULATION OF ROOFS

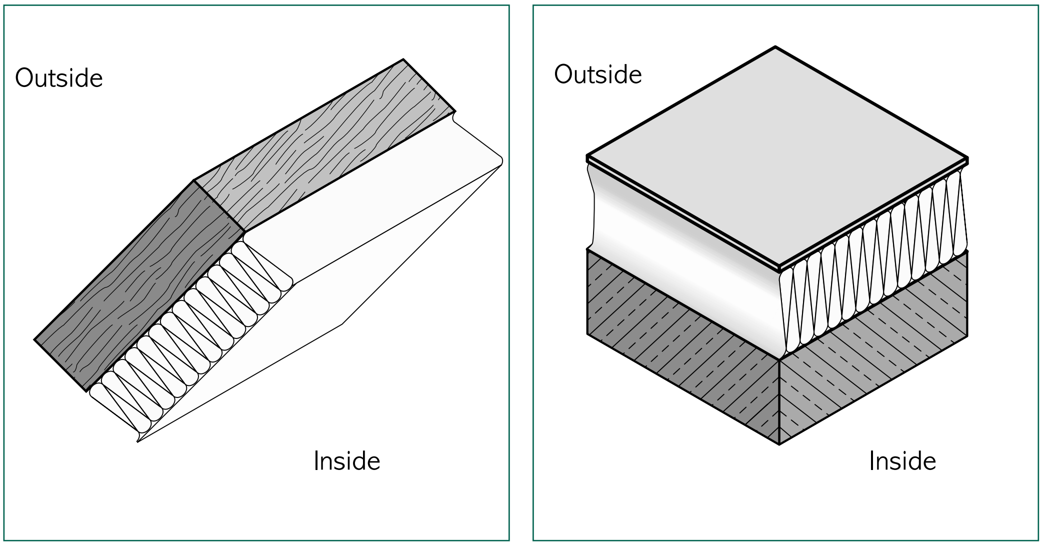
> Description of the measure

When considering insulation of roofs during the thermal retrofit of buildings, two different types of roofs can be distinguished (see Figure 9).

- pitched roof: the additional insulation is usually added on the inside surface of the roof between rafters and, if the insulation thickness has to be further increased, beneath the rafters. Insulation of the roof is often combined with the conversion of the attic (or loft) to living space which might increase the overall economic performance of the project. In other cases the attic is insulated horizontally between the ceiling joists ("cold roofs").

- flat roof: the insulation is applied to the exterior surface of the roof and is covered by a waterproof layer.

Figure 9: Visuals of insulation methods for pitched and flat roofs



> Investment costs

In the Eastern European building stock, single-family houses are mainly covered with pitched or sloping roofs, whereas multi-family dwellings (flats, apartments) usually have flat roofs. In the following calculations, additional insulation between the rafters for pitched roofs is investigated. In this case it is not possible to reduce the additional investment costs by coupling the insulation measures with maintenance measures. The total investment has to be regarded as energy related. However, other solutions, e.g. the installation of prefabricated sandwich elements with integrated insulation, might lead to reduced energy related costs when applied as part of the conventional retrofit cycle.

The cost and impact on U-values of insulation of the roof to achieve the expert forecast EPB standard in the 3 different zones are detailed in Table 11. The costs are quoted for a section of one square meter of the insulated roof.

Table 11: Characteristics and investment costs of additional roof insulation in three climatic zones

Pitched roof: insulation investment		Baltic Republics	Poland	CZ-HU-SL-SK
U-value before retrofit	[W/m²K]	0.70	0.90	1.40
U-value after retrofit	[W/m²K]	0.20	0.23	0.23
Investment costs	[€/m²]	26	26	27

Table 12 displays the results of the economic assessment for retrofitting the pitched roof to the levels of the expert forecast EPB standard for three climatic zones.

Table 12: Economic assessment of roof insulation in three climatic zones

Pitched roof: results insulation		Baltic Republics	Poland	CZ-HU-SL-SK
End-energy savings	[kWh/m²a]	59	70	109
CO_2 emission savings	[kg/m²a]	8	21	24
Mitigation costs	[€/tCO_2]	-74	-51	-121
Cost-saved energy	[cent/kWh]	-1.0	-1.5	-2.7
Amortisation	[a]	11	9	6

The increasing step of improvement of the U-value is again leading to increasing savings from the Baltic Republics to the CEEC4. Looking at the CO_2 emission savings, the influence of the relatively high emission-factor in Poland becomes evident.
Additional insulation to expert forecast EPB standard is cost effective in all climatic zones. This is due to the relatively low investment required and the resulting large energy savings.

> Economic optimum

In the Baltic Republics, insulation of the roof is economic within an optimum at a U-value of 0.13 to 0.25 W/m²K (see Figure 10).

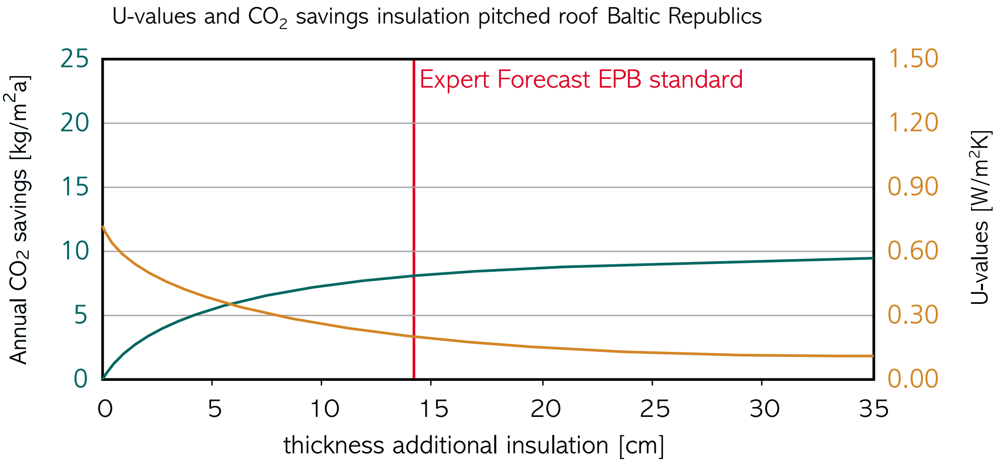
In Poland a thermal retrofit of the roof is always cost effective. The economic optimum can be reached with U-values of between 0.15 and 0.35 W/m²K.

The economic optimum in the CEEC4 can be reached with U-values of between 0.15 and 0.40 W/m²K.

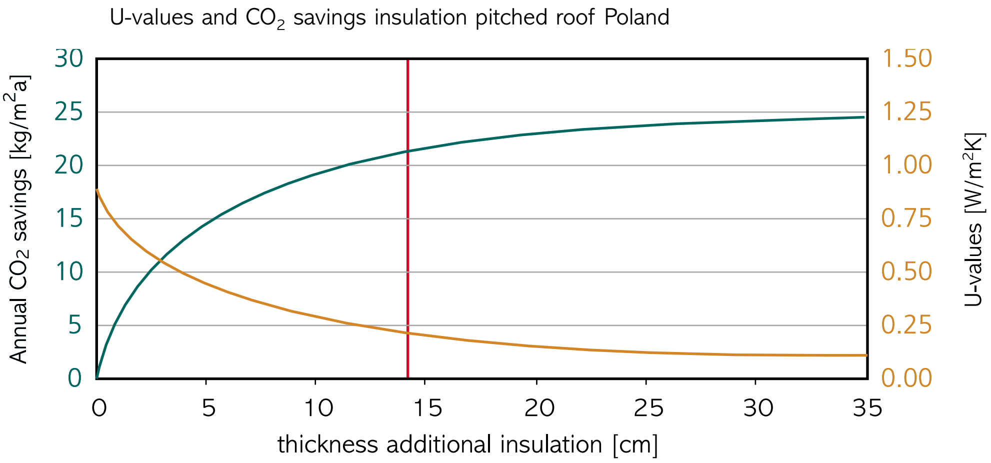
Similar to facades, the top of the cost-efficient range of U-values is beyond the values given in the expert forecast EPB-standard for insulation of roofs in all three climatic zones. This indicates that additional emission reduction potentials can be made available without extra cost by increasing the ambition level of the anticipated legislation.

Figure 10a: U-values, CO_2 savings and economic optimum of additional roof insulation

Baltic Republics



Poland



CZ-HU-SL-SK

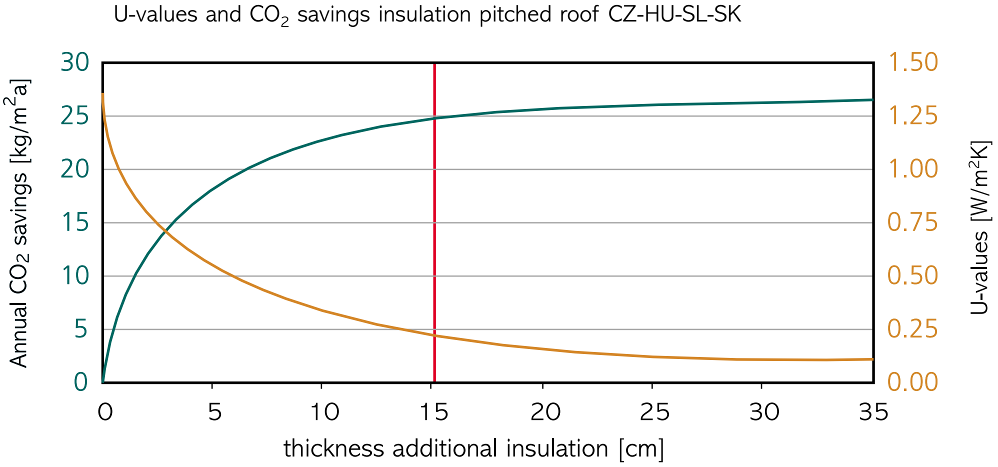
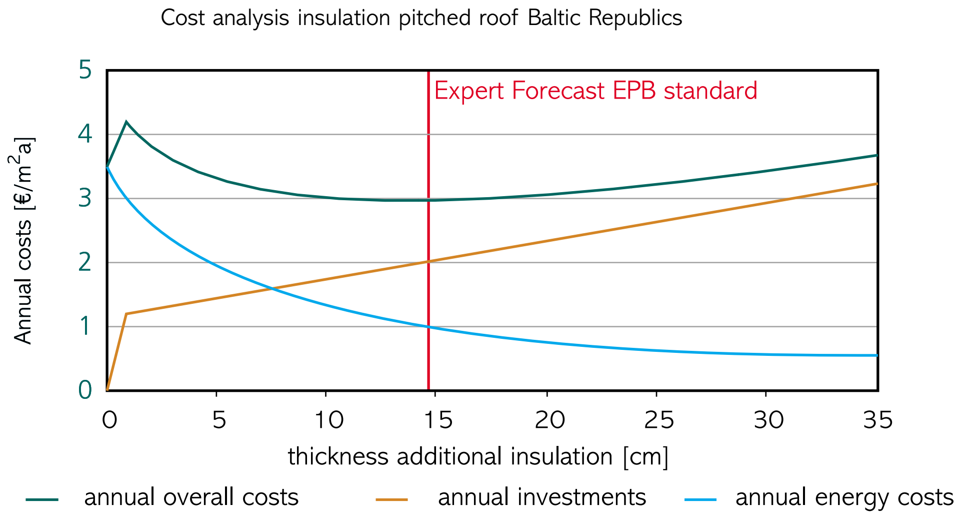
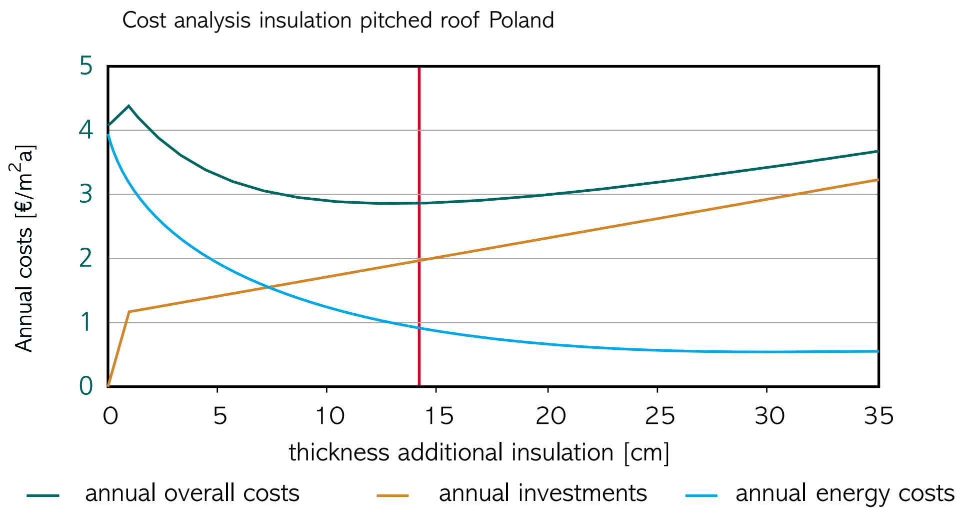


Figure 10b: U-values, CO_2 savings and economic optimum of additional roof insulation

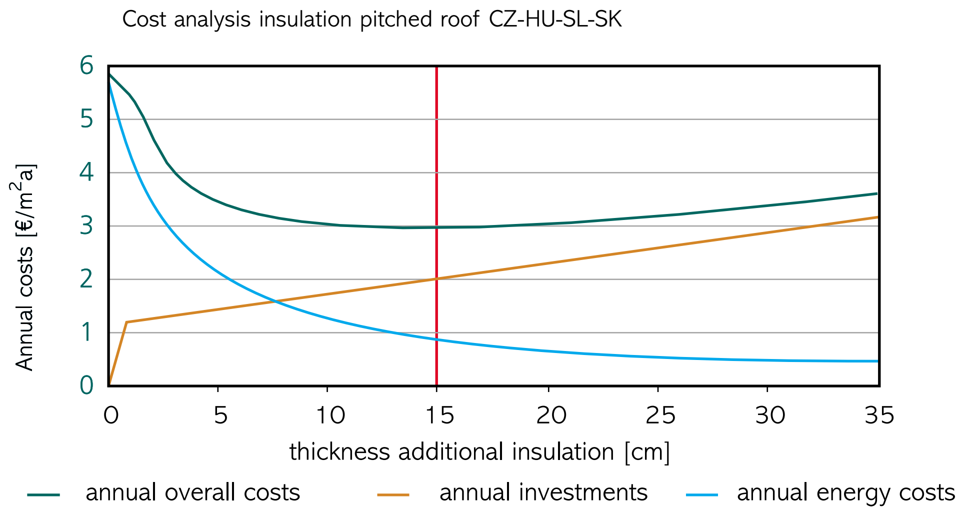
Baltic Republics



Poland



CZ-HU-SL-SK



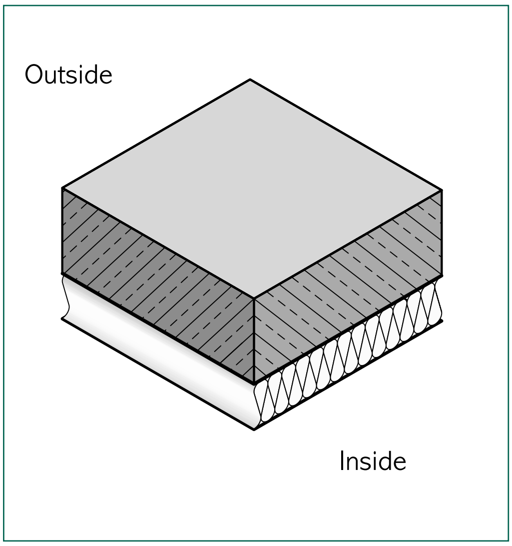
4.3 INSULATION OF GROUND FLOORS/CELLAR CEILINGS

> Description of the measure

The method of insulating the ground floor of a building during an insulation retrofit depends heavily upon whether the building has a cellar or not.

- In buildings with a cellar, the insulation can be applied under the cellar ceiling (see Figure 11) or, with more complex technical implications, on top of the ground floor.
- In buildings without a cellar, it is sometimes possible to use cavities in the structure (i.e. in wooden houses) or underneath the ground-floor for additional insulation.

Figure 11: Visual of insulation of the cellar ceiling



> Investment costs

The following economic analysis is calculated for insulation of the cellar ceiling, which is the method most frequently applied if insulation of the lower side of the building is realised during a retrofit. It should be noted that insulation of the lower side of buildings is not very common in the new Member States.
It is not possible to couple the insulation with maintenance measures because the cellar ceiling is normally not subject to maintenance activities. The total investment of the measure has therefore to be regarded as energy related.

Cost and impact on U-values of insulation of the ground floor to the levels of the expert forecast EPB standard in the 3 different zones are shown in Table 13. The costs are quoted for a one square meter section of the insulated floor.

Table 13: Characteristics and investment costs of insulation cellar ceiling in three climatic zones

Cellar ceiling: investment insulation		Baltic Republics	Poland	CZ-HU-SL-SK
U-value before retrofit	[W/m²K]	0.70	1.20	1.40
U-value after retrofit	[W/m²K]	0.29	0.60	0.46
Investment costs	[€/m²]	20	17	18

Measures taken and the resulting costs can be compared to an insulation of a pitched roof.
Table 14 displays the economic assessment of insulating the cellar ceiling to the levels of the expert forecast EPB standard for three climatic zones.

Table 14: Economic assessment of insulation of cellar ceiling in three climatic zones

Pitched roof: results insulation		Baltic Republics	Poland	CZ-HU-SL-SK
End-energy savings	[kWh/m²a]	24	34	44
CO_2 emission savings	[kg/m²a]	3	10	10
Mitigation costs	[€/tCO_2]	130	-20	-66
Cost-saved energy	[cent/kWh]	1.8	0.6	-1.5
Amortisation	[a]	19	12	9

Due to the existing higher insulation standard in the Baltic Republics before retrofit, insulation of the ground floor to the levels of the expert forecast EPB standard is not cost effective. In Poland and the CEEC4, the additional insulation results in an economic benefit.

> Economic optimum

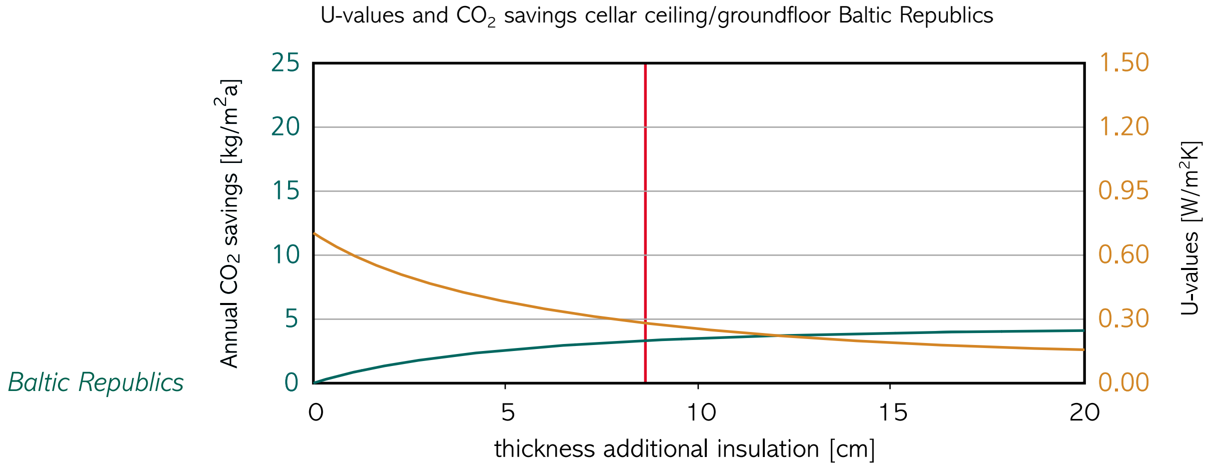
Due to the existing high insulation standard in the Baltic Republics additional insulation of the cellar ceiling is usually not cost effective (see Figure 12).

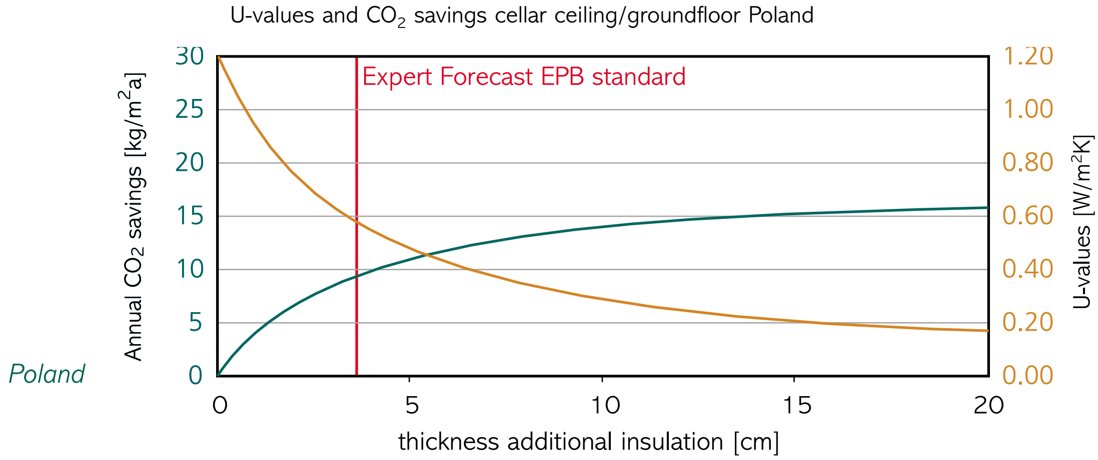
In Poland, retrofitted insulation of the cellar is cost effective within an optimum range of approx 0.22 to 0.48 W/m²K.

In the CEEC4 floor insulation is economically feasible with an optimum U-value range between approx 0.22 to 0.50 W/m²K.

For the Baltic States, the anticipated legislation according to the expert forecast EPB standard is already sufficiently ambitious, so that further cost effective improvements cannot be achieved by more stringent standards. In the other states examined, the top of the cost-efficient range of U-values is beyond the values given in the expert forecast EPB standard. This indicates that in those states, additional emissions reduction potential can be made available without extra cost by increasing the ambition level of the legislation.

Figure 12a: U-values, CO_2 savings and economic optimum of additional insulation the cellar ceiling





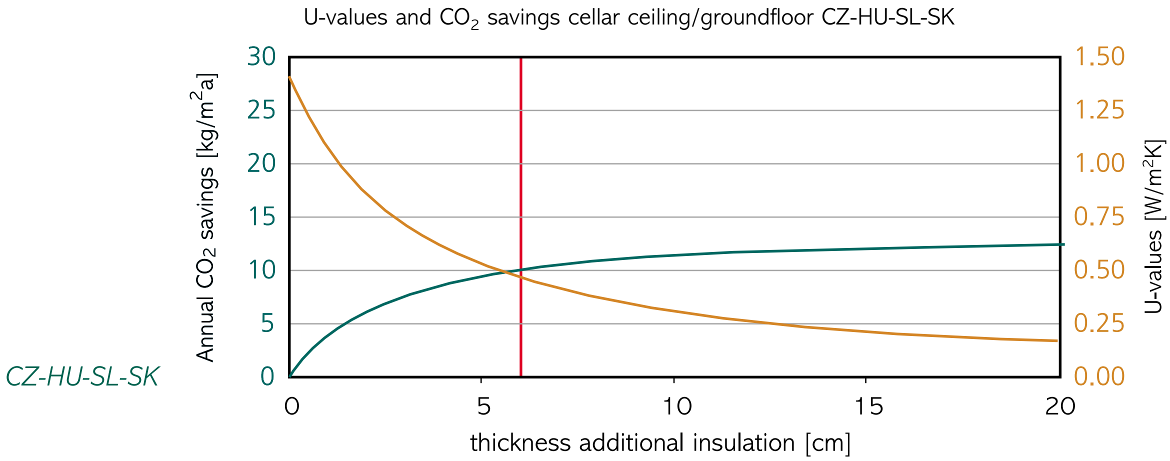
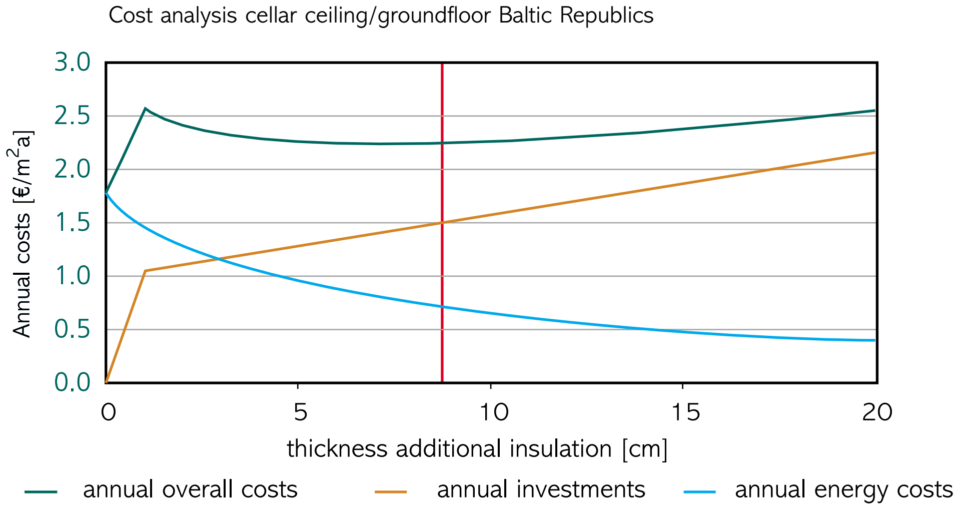
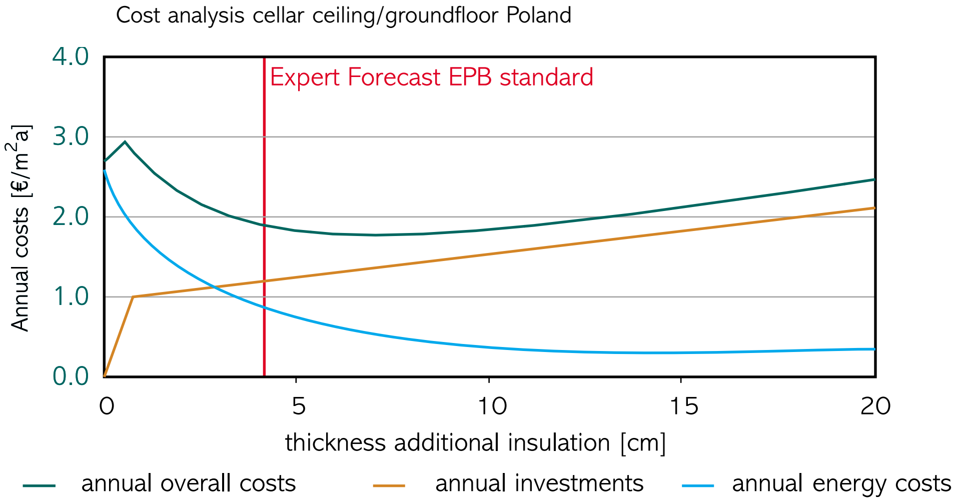


Figure 12b: CO_2 savings and economic optimum of additional insulation in the cellar ceiling

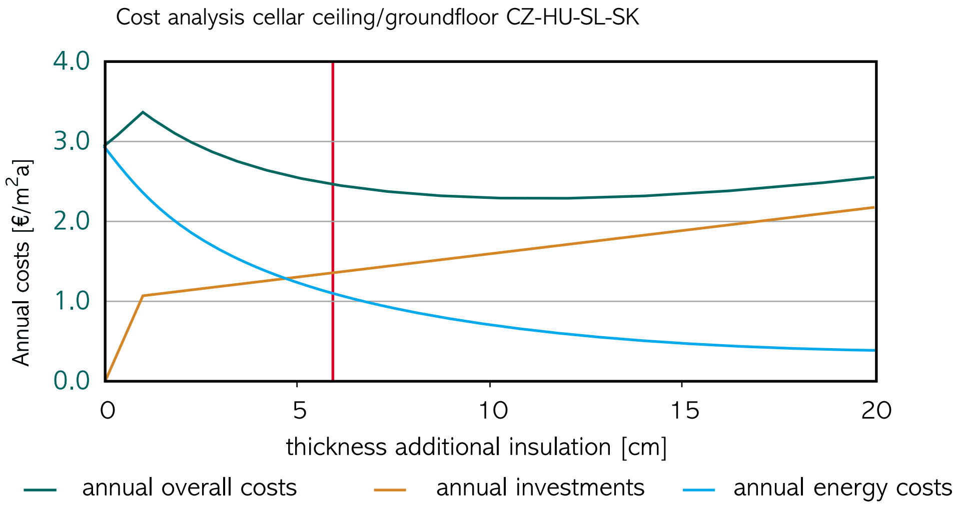
Baltic Republics



Poland



CZ-HU-SL-SK



4.4 WINDOWS

> Description of the measure

The windows of a residential building usually cover 20 to 30 % of the façade. Therefore the thermal resistance of windows is of great importance to the energy performance of a building. The U-values range from approx 4.0 W/m²K in old buildings in the NEW-8 Member States with single panes, to 0.7 W/m2K for the current best available technology in Europe. This suggests the opportunity for major energy-efficiency improvements.

Windows are also characterised by their g-value, describing the fraction of solar energy that passes through the glazing, providing heat gains and reducing energy demand for heating. Normally the g-value decreases with improving (reduced) U-value of the window. However, the decreased U-value usually overcompensates the decline in the g-value leading to an energetic improvement. In warm climates, a lower g-value can be seen as favourable since the risk of overheating of the building is decreased.

The following glazing types can be distinguished (with declining U-value):

- Single glazing (only in old buildings)
- Double glazing
- Double glazing with gas filling (i.e. Argon) or coating
- Triple glazing

Window frames can be characterized by their U-value and the material used (i.e. wood, aluminium or PVC). Depending on the quality of the frame and glazing, a total U-value for a window can be determined.

The thermal performance of the windows can be improved during a retrofit of a building in two ways.

- Exchange of the glazing only.
  This method can only be applied if the window frames are in a good condition and should be accompanied by a renewal of the seals.

- The total exchange of the window allows improvement of the thermal performance of the frame and glazing in one step.

> Investment cost

In this report, it is assumed that the total exchange of the window is usually undertaken. However, the replacement of the window can be carried out as an independent energy-efficient measure or as a coupled measure when the windows/frames are in poor condition and have to be replaced. The replacement costs of the windows to the minimum requirements of the building regulations in the respective country are taken into account as non-energy related costs. Additional costs to meet the expert forecast EPB standard are treated as energy related costs.

The estimated costs and the impact on U-values of the exchange of windows in the 3 zones investigated are shown in Table 15, normalised to a one square meter section of the replaced windows.

Table 15: Characteristics and investment costs of improved windows in three climatic zones

Windows: investment replacement		Baltic Republics	Poland	CZ-HU-SL-SK
U-value before retrofit	[W/m²K]	3.0	3.5	4.0
U-value after retrofit	[W/m²K]	1.66	2.00	1.70
Total investment costs	[€/m²]	184	170	182
Additional investment	[€/m²]	54	60	92

The total investment costs as well as the energy related costs for a replacement of windows are considerably higher than for insulation of the wall, roof or floor. Table 16 shows the economic assessment of the effects of improved windows to meet to the expert forecast EPB standard.

Table 16: Economic assessment of external insulation in three climatic zones

Windows: results replacement		Baltic Republics	Poland	CZ-HU-SL-SK
End-energy savings	[kWh/m²a]	159	156	213
CO_2 emission savings	[kg/m²a]	21	47	48
Mitigation costs (independent)	[€/tCO_2]	308	123	76
Mitigation costs (coupled)	[€/tCO_2]	-134	-46	-62
Cost-saved energy (independent)	[cent/kWh]	4.1	3.7	1.7
Cost-saved energy (coupled)	[cent/kWh]	-1.8	-1.4	-1.4
Amortisation (independent)	[a]	27	26	19
Amortisation (coupled)	[a]	8	9	10

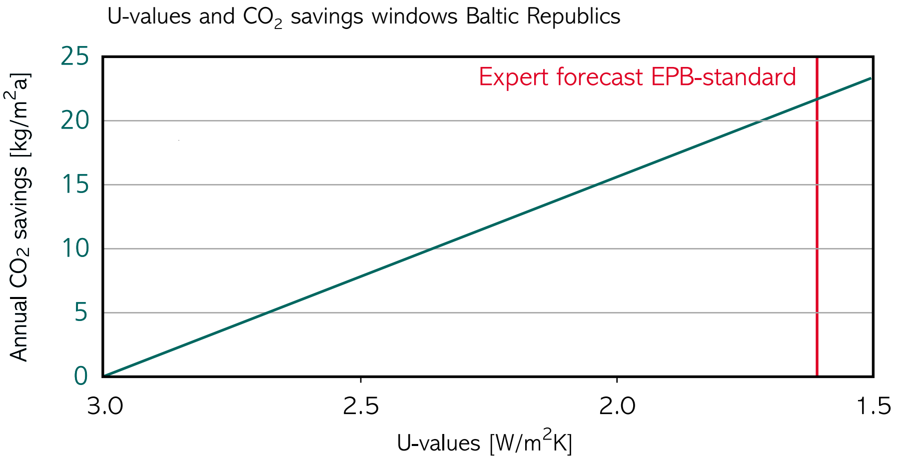
The economic benefit of the replacement of windows depends on whether the measure is carried out as an independent thermal efficiency measure or as a coupled action. An independent measure is usually not cost effective, whereas it is economically viable in all climatic zones to install energy efficient windows where this is part of a necessary replacement within the renovation cycle.

> Economic optimum

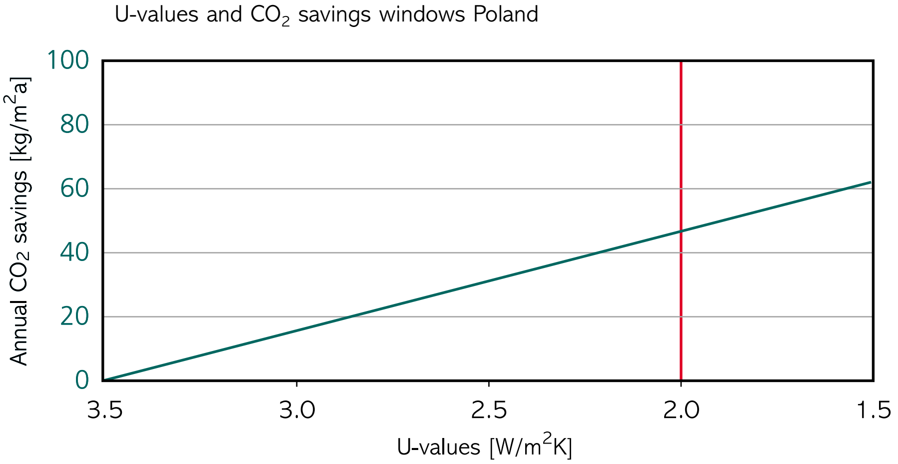
Figure 13 shows the annual costs of a coupled replacement in the three climatic zones referred to one m² of replaced window area. It can be seen that the predicted standards are already good, but could, especially in Poland, be further improved.

Figure 13a: U-values, CO_2 savings and economic optimum for improved windows

Baltic Republics



Poland



CZ-HU-SL-SK

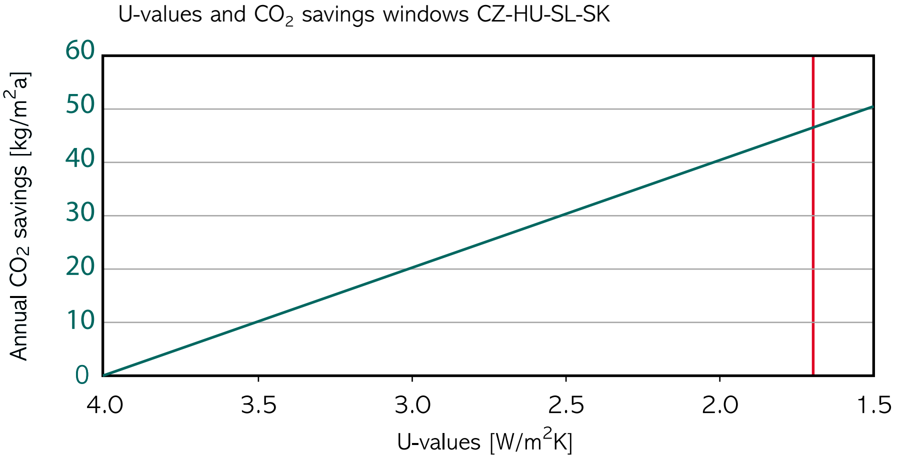
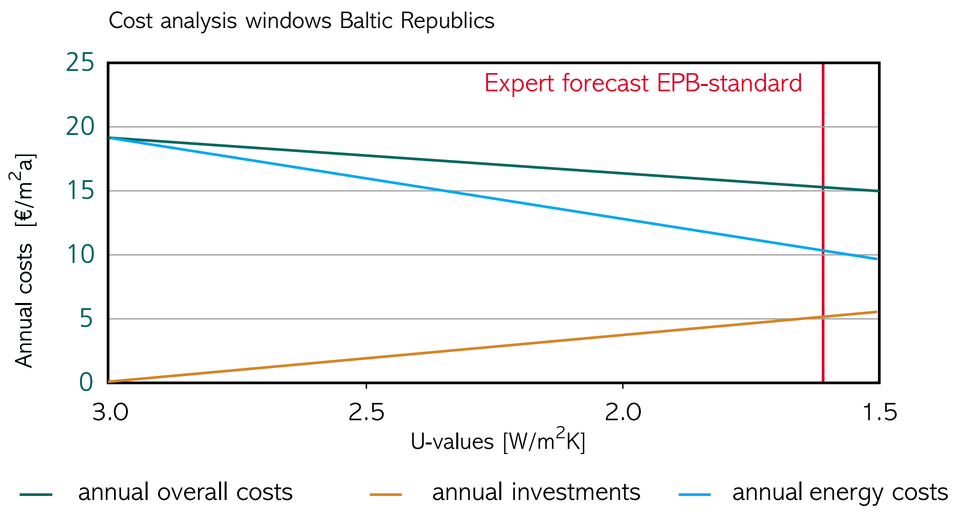
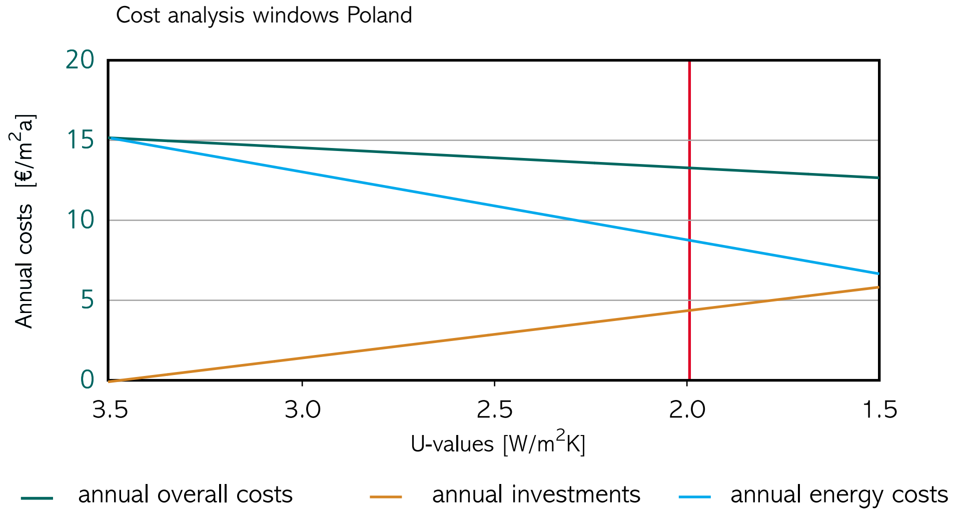


Figure 13b: U-values, CO_2 savings and economic optimum for improved windows

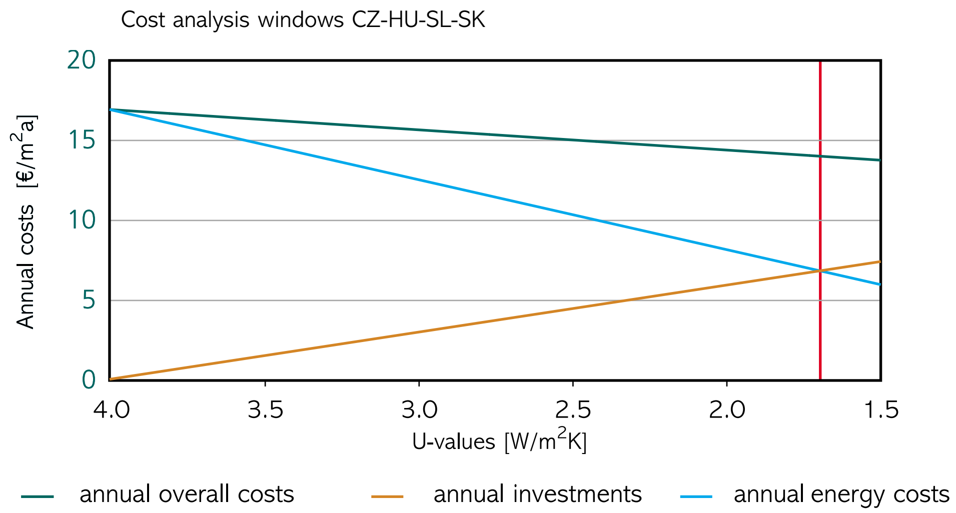
Baltic Republics



Poland



CZ-HU-SL-SK



4.5 HEATING

> Description of the measure

The reduction of CO_2 emissions from a heating system can be achieved either by a fuel switch to an energy carrier with a lower CO_2 emission factor (i.e. fuel switch from coal to gas heating) or by the replacement of an old boiler by a new, more efficient system[6]. The latter will be investigated further assuming that the building envelope was already improved to the levels of the expert forecast EPB standard. This approach reflects the fact that the more favourable approach is the reduction of the energy demand of a building before installing a more efficient heating system. If the order of measures is reversed, the capacity of a new heating system would be oversized after retrofitting the building envelope. As the basis of the following calculations, gas fired systems are used. Economically it is especially important whether work is carried out on a heating system just to make it more energy efficient or whether this takes place as part of a replacement due to age or reliability.

> Replacement of gas boilers as an energy-efficiency measure only

In the first place, the effect of replacement of an existing gas boiler by a standard gas boiler is assessed for an apartment block. In this, the production of domestic hot water is taken into account. An improvement of the heating system also affects the usually combined supply of domestic hot water. Individual heating and district heating were not considered.

Table 17: Characteristics and investment for independent efficiency improvements of heat production in multi-family houses in three climatic zones

Investment heat generation: independ. replacement (standard boiler)		Baltic Republics	Poland	CZ-HU-SL-SK
Efficiency before retrofit (not renovated)[7]	[%]	75	75	75
Efficiency after retrofit (standard boiler)	[%]	85	85	85
Total investment costs (standard boiler)	[€]	7,900	7,900	7,900

Table 18 shows that, in any climatic zone, the replacement of a boiler in an apartment block just for energy efficiency reasons is not cost effective due to the relatively large investment required. Considering the higher investment cost per m^2 of living area for a new heating system in a single-family house, this leads to the conclusion that replacement of the gas boiler is even less cost effective in a single-family house unless required for maintenance purposes.

[6] Taking into account that the efficiency of the district heating is determined by parameters outside of the considerations of this report, improvements in the district heating networks are not taken into account.

[7] all factors are related to the lower heating value (LHV, not including condensation energy)

Table 18: Economic assessment of independent efficiency improvements of heat production in multi-family houses in three climatic zones

Results heat generation: independent replacement (standard boiler)		Baltic Republics	Poland	CZ-HU-SL-SK
End-energy savings	[kWh/m²a]	12	13	11
CO_2 emission savings	[kg/m²a]	2.5	2.6	2.3
Mitigation costs (independent)	[€/tCO_2]	13	4	29
Cost-saved energy (independent)	[cent/kWh]	0.3	0.1	0.6
Amortisation (independent)	[a]	12	12	14

> Coupled replacement of gas boilers in multi-family houses

In a second step, the results of an improvement in the efficiency of the heating system coupled with an otherwise necessary replacement are assessed. Here a standard boiler in the old system is replaced by a condensing boiler. The difference in investment between a standard and a condensing boiler is considered as an energy related cost.

Table 19: Characteristics and investment for coupled efficiency improvements of heat production in multi-family houses in three climatic zones

Investment heat generation: coupled replacement (condensing boiler)		Baltic Republics	Poland	CZ-HU-SL-SK
Efficiency after retrofit (standard)	[%]	85	85	85
Efficiency after retrofit (condensing)	[%]	97	97	97
Energy-related investment costs	[€]	2,050	2,050	2,050

Table 20 shows that, for all zones where replacement of a gas heating system is required due to the age of a system or maintenance problems, the installation of a condensing boiler is cost effective.

Table 20: Economic assessment of coupled efficiency improvements of heat production in multi-family houses in three climatic zones

Results heat generation: coupled replacement (condensing boiler)		Baltic Republics	Poland	CZ-HU-SL-SK
End-energy savings	[kWh/m²a]	1	1	1
CO_2 emission savings	[kg/m²a]	0.2	0.2	0.2
Mitigation costs (coupled)	[€/tCO_2]	-110	-112	-105
Cost-saved energy (coupled)	[cent/kWh]	-2.2	-2.3	-2.1
Amortisation (coupled)	[a]	3	3	4

> Coupled replacement of gas boilers in single-family houses

In order to verify whether this last conclusion is also valid for smaller houses the assessment of similar measures for a terraced house are displayed in Table 21.

Table 21: Economic assessment of coupled efficiency improvements of heat production in single-family houses in three climatic zones

Results heat generation: coupled replacement (condensing boiler)		Baltic Republics	Poland	CZ-HU-SL-SK
Energy-related investment costs	[€]	900	900	900
\`End-energy savings	[kWh/m²a]	1	1	1
CO_2 emission savings	[kg/m²a]	0.2	0.2	0.2
Mitigation costs (coupled)	[€/tCO2]	70	49	81
Cost-saved energy (coupled)	[cent/kWh]	1.4	1.0	1.6
Amortisation (coupled)	[a]	17	15	17

In all countries the coupled replacement of the gas boiler in single-family houses is not cost effective. This is caused by the higher prices in Eastern Europe for the condensing boilers which are not commonly used so far. The cost effectiveness is anticipated to improve with higher market penetration of condensing systems and thus decreasing market prices in the future.

4.6 OVERVIEW OF ENERGY-EFFICIENCY MEASURES

Table 22 - Table 24 summarises the evaluations of measures to reduce the heating energy consumption, which could become standard in the three regions investigated by the time the EPBD is implemented into national legislation. The results show that most of the measures can be carried out cost effectively, especially in Poland and the CEEC4.

Table 22: Overview of individual energy-saving measures in the Baltic Republics

Baltic Republics	Insulation			Replacement	
	Wall external	Pitched roof	Floor	Windows	Boilers[8]
End-energy savings [kWh/m²a]	76	59	24	159	12 / 1
CO_2 emission savings [kg/m²a]	10	8	3	21	2.5 / 0.2
Mitigation costs (Independent) [€/tCO_2]	-3	-74	130	308	13
Mitigation costs (Coupled) [€/tCO_2]	-131	-74	130	-134	-110
Cost-saved energy (Independent) [cent/kWh]	0.0	-1.0	1.8	4.1	0.3
Cost-saved energy (Coupled) [cent/kWh]	-1.8	-1.0	1.8	-1.8	-2.2
Amortisation (Independent) [a]	14	11	19	27	12
Amortisation (Coupled) [a]	8	11	19	8	3

[8] As an independent replacement, the installation of conventional gas boilers in multi-family houses is assessed. The coupled replacements compare the additional costs and energy savings of a condensing boiler to a conventional boiler.

Table 23: Overview of individual energy-saving measures in Poland

Poland	Insulation			Replacement	
	Wall external	Pitched roof	Floor	Windows	Boilers[6]
End-energy savings [kWh/m²a]	100	70	34	156	13 / 1
CO_2 emission savings [kg/m²a]	30	21	10	47	2.6 / 0.2
Mitigation costs (Independent) [€/tCO_2]	-28	-51	-20	123	4
Mitigation costs (Coupled) [€/tCO_2]	-71	-51	-20	-46	-112
Cost-saved energy (Independent) [cent/kWh]	-0.8	-1.5	-0.6	3.7	0.1
Cost-saved energy (Coupled) [cent/kWh]	-2.1	-1.5	-0.6	-1.4	-2.3
Amortisation (Independent) [a]	11	9	12	26	12
Amortisation (Coupled) [a]	7	9	12	9	3

Table 24: Overview of individual energy-saving measures in the CEEC4 CZ-HU-SL-SK

CZ-HU-SL-SK	Insulation			Replacement	
	Wall external	Pitched roof	Floor	Windows	Boilers[6]
End-energy savings [kWh/m²a]	107	109	44	213	11 / 1
CO_2 emission savings [kg/m²a]	24	24	10	48	2.3 / 0.2
Mitigation costs (Independent) [€/tCO_2]	-75	-121	-66	76	29
Mitigation costs (Coupled) [€/tCO_2]	-129	-121	-66	-62	-105
Cost-saved energy (Independent) [cent/kWh]	-1.7	-2.7	-1.5	1.7	0.6
Cost-saved energy (Coupled) [cent/kWh]	-2.9	-2.7	-1.5	-1.4	-2.1
Amortisation (Independent) [a]	9	6	9	19	14
Amortisation (Coupled) [a]	5	6	9	10	4

5] THE ASSESSED RETROFIT PACKAGES

At this point in the report, the influence of applying single measures during the retrofit of buildings has been assessed. However, the combination of these measures into retrofit packages offers the possibility to benefit from synergies and further improve the energetic and economic performance of retrofit measures in the building stock. For example, due to insulation the maximum heat load capacity decreases and a smaller heating system can be installed. To reach an optimal performance, the combination of single measures to suitable packages has to follow the principle of Trias Energetica, which is defined by 3 steps:

1. Firstly, limit demand for energy trough rational use of energy,
2. then use renewable energy to fulfil remaining demand, if possible, and
3. use fossil fuels, if necessary, as efficiently and cleanly as possible

Following this approach, the improvement of the insulation levels can be seen as an important prerequisite for energy efficient buildings. Therefore the investigated retrofit packages according to the expert forecast EPB standard focus on the first principle, implemented by a significant reduction of energy demand for heating by adding insulation to the building envelope and replacing old with low U-value windows.

Step two, the use of renewable energies is not taken into account as a measure in the predicted EPB retrofit packages. Renewable energies are an important part of innovative retrofit projects and gain substantial market shares. However, the aim of the study was to assess the effect of the basic and most widely applied measures in the building stock in Eastern Europe.

Step three is taken by replacing an old existing heating system with a new condensing boiler having a significantly higher efficiency.

In the following section of the report retrofit packages are described which are estimated to meet the expert forecast EPB standard in the three zones investigated. Again the economic performance of the packages is assessed for independent and coupled actions.

5.1 DESCRIPTION OF STANDARD BUILDINGS

The effect of the retrofit packages is analysed for terraced houses and multi-family houses on the basis of the standard building types of the BEAM model (see Chapter 2.1). The main characteristics of the model houses are described in Table 25.

Table 25: Characteristics of the standards used in building-types

Standard building types	Terraced House	Multi-family house
Dwelling units	1	16
Living area	120m^2	1,637m^2
Volume	421m^2	5,374m^2
Form factor A/V	0.64	0.38
Standard energy supply	Gas boiler	District heating

5.2 RETROFIT PACKAGES – BALTIC REPUBLICS

The retrofit package for the Baltic Republics concerns improvement of the building envelope. The U-values of walls, roofs, cellar ceilings and windows are reduced by additional insulation and a replacement of windows. The most common energy supply for multi-family houses in the Baltic Republics is district heating. For single-family houses gas heating systems are assessed. The district heating system assumed for multi-family houses is supposed to remain unchanged, the gas heating system in single-family houses is replaced by a new condensing boiler. The packages for the Baltic Republics are summarised in Table 26.

Table 26: Details of retrofit actions (expert forecast EPB-standard, Baltic Republics)

Baltic Republics			Before retrofit	After retrofit
Building envelope	U-value roof	[W/m²K]	0.70	0.20
	U-value façade	[W/m²K]	0.90	0.26
	U-value cellar ceiling	[W/m²K]	0.70	0.29
Windows	U-value	[W/m²K]	3.00	1.66
	g-value	[ ]	0.76	0.60
Energy supply (gas)	Annual efficiency	[%]	75	97

The retrofit packages described in Table 26 lead to the results displayed in Table 27. Please note that the results for individual measures in section 4 (assessment of single measures) were related to the surface area of the constructional element or in the case of the heating system referred to in the assessed house-type. In this section the results for the retrofit packages are normalised to the heated floor area of the house.

Table 27: Economic assessment of retrofit actions (expert forecast EPB-standard, Baltic Republics)

Investment and Results		Terraced house	Multi-family house
Total investment	[€/m²]	126	70
Energy-related investment	[€/m²]	67.5	33
End-energy use after retrofit	[kWh/m²]	83	62
End-energy savings	[kWh/m²a]	184	73
CO_2 emission savings	[kg/m²a]	37	15
Mitigation costs (independent)	[€/t]	98	119
Mitigation costs (coupled)	[€/t]	-22	-65
Cost-saved energy (independent)	[cent/kWh]	2.0	2.4
Cost-saved energy (coupled)	[cent/kWh]	-0.4	-1.3
Amortisation (independent)	[a]	22	21
Amortisation (coupled)	[a]	12	10

The retrofit package described leads to end energy-savings of 69% in terraced houses and 54% in multi-family houses. The higher energy-savings in the case of the single-family houses are caused by on the one hand by the larger outside surface relative to the volume, and on the other hand by the exchange of the heating system. Installing such a retrofit package according to the expert forecast EPB-standard independent from otherwise required maintenance measures is usually not cost effective in the Baltic Republics. The possibility to couple the energy efficient retrofit with maintenance measures is provided when improving for example the facades (external insulation) or windows. Such measures account for the major part of investment costs during a retrofit.
Coupled retrofit packages in the Baltic Republics are therefore usually cost effective in single-family and multi-family houses.

It is important to recognise that it is most important in the economic assessment of retrofit measures to analyse the actual situation before retrofit in detail, since cost effectiveness depends heavily on several factors including: the insulation level before retrofit; the exact investment costs for the retrofit measures (which might differ from the average values in this report due to specifics of the project investigated); the type of energy supply used and its corresponding price as well as the climatic conditions.

> Advanced Standard

The assessment of the individual measures in section 4 concludes that the expert forecast EPB-standard for the insulation levels in the Baltic Republics is approximately in the middle of the span which marks an economic optimum. Still the efficiency of the retrofit can be improved by realising a retrofit which is characterized by the far end of the economic optimum, leading to more energy-savings without a significant rise in costs. A possible "advanced standard" and its consequences are described in Table 28. The insulation levels used have been drawn from the optimisation graphs for individual measures in section 4. Results have been taken from the upper limit for U-values of the area in which the measures are most cost effective.

Table 28: Actions according to an "advanced standard", Baltic Republics

Baltic Republics			Before retrofit	After retrofit
Building envelope	U-value roof	[W/m²K]	0.90	0.18
	U-value façade	[W/m²K]	1.20	0.22
	U-value cellar ceiling	[W/m²K]	1.20	0.28
Windows	U-value	[W/m²K]	3.50	1.30
	g-value	[ ]	0.76	0.60
Energy supply (gas)	Annual efficiency	[%]	75	97

The retrofit packages detailed in Table 28 lead to the results given in Table 29.

Table 29: Economic assessment of retrofit actions according to an "advanced standard", Baltic Republics

Investment and Results		Terraced house	Multi-family house
Total investment	[€/m²]	132	74
Energy-related investment	[€/m²]	76	39
End-energy use after retrofit	[kWh/m²]	72	54
End-energy savings	[kWh/m²a]	195	81
CO_2 emission savings	[kg/m²a]	39	16
Mitigation costs (independent)	[€/t]	95	104
Mitigation costs (coupled)	[€/t]	-13	-52
Cost-saved energy (independent)	[cent/kWh]	1.9	2.1
Cost-saved energy (coupled)	[cent/kWh]	-0.3	-1.0
Amortisation (independent)	[a]	21	20
Amortisation (coupled)	[a]	12	11

The retrofit package described leads to end energy savings of 73% in terraced houses and 60% in multi-family houses.
Comparing the advanced retrofit standard with the expert forecast EPB standard confirms the conclusions of the assessment of the individual measures. The investment costs rise only slightly (terraced houses: 5%, multi-family house 6%) being counterbalanced by additional energy savings of 6% (multi-family house: 11%) leading as a result to more energy savings with about the same payback time.

5.3 RETROFIT PACKAGES – POLAND

The retrofit package for Poland also begins with improvements to the building envelope (see Table 30). The U-values of walls, roofs, cellar ceilings and windows are significantly reduced by additional insulation and the replacement of windows. A more efficient condensing boiler replaces the existing heating system.

Table 30: Details of retrofit actions (expert forecast EPB-standard, Poland)

Poland			Before retrofit	After retrofit
Building envelope	U-value roof	[W/m²K]	0.90	0.23
	U-value façade	[W/m²K]	1.20	0.25
	U-value cellar-ceiling	[W/m²K]	1.20	0.60
Windows	U-value	[W/m²K]	3.50	2.00
	g-value	[ ]	0.76	0.63
Energy supply (gas)	annual efficiency	[%]	75	97

The retrofit packages described in Table 30 lead to the results given in Table 31. As for the assessment of the retrofit package in the Baltic Republics, the results are normalised with the heated floor area of the house investigated.

Table 31: Economic assessment of retrofit actions (expert forecast EPB-standard, Poland)

Investment and results		Terraced house	Multi-family house
Total investment	[€/m²]	120	66
Energy-related investment	[€/m²]	67	33
End-energy use after retrofit	[kWh/m²]	94	66
Energy-savings	[kWh/m²a]	240	97
CO_2 emission-savings	[kg/m²a]	48	44
Mitigation costs (independent)	[€/t]	28	119
Mitigation costs (coupled)	[€/t]	-54	-65
Cost-saved energy (independent)	[cent/kWh]	0.6	0.4
Cost-saved energy (coupled)	[cent/kWh]	-1.1	-2.1
Amortisation (independent)	[a]	16	15
Amortisation (coupled)	[a]	9	7

The retrofit package described leads to end energy-savings of 72% in terraced houses and 60% in multi-family houses.
Installing a retrofit package to the expert forecast EPB-standard independent of otherwise required maintenance measures is usually not cost effective in Poland. However, coupled retrofit packages result in payback times of approx 9 years for single-family and approx 7 years for multi-family (apartments) houses, thus being cost effective.

> Advanced Standard

The assessment of the individual measures in section 4 concludes that the expert forecast EPB standard for the insulation levels in Poland is about in the middle of the optimum span, but could be further improved towards higher U-values to the far end of the optimum span, especially when looking at the insulation of the cellar ceiling. A possible "advanced standard" and its consequences are described in Table 32. The insulation levels used have again been drawn from the optimisation graphs for individual measures in section 4.

Table 32: Details of retrofit actions according to an "advanced standard", Poland

Poland			Before retrofit	After advanced retrofit
Building envelope	U-value roof	[W/m²K]	0.90	0.18
	U-value façade	[W/m²K]	1.20	0.22
	U-value cellar-ceiling	[W/m²K]	1.20	0.28
Windows	U-value	[W/m²K]	3.50	1.30
	g-value	[ ]	0.76	0.60
Energy supply (gas)	annual efficiency	[%]	75	97

The retrofit packages detailed in Table 32 lead to the results given in Table 33.

Table 33: Economic assessment of retrofit actions according to an "advanced standard", Poland

Investment and results		Terraced house	Multi-family house
Total investment	[€/m²]	132	74
Energy-related investment	[€/m²]	76	38
End-energy use after retrofit	[kWh/m²]	67	50
Energy savings	[kWh/m²a]	266	113
CO_2 emission savings	[kg/m²a]	54	52
Mitigation costs (independent)	[€/t]	27	5
Mitigation costs (coupled)	[€/t]	-52	-46
Cost-saved energy (independent)	[cent/kWh]	0.5	0.2
Cost-saved energy (coupled)	[cent/kWh]	-1.1	-2.1
Amortisation (independent)	[a]	16	14
Amortisation (coupled)	[a]	9	7

The advanced retrofit package leads to end energy savings of 80% in terraced houses and 69% in multi-family houses. The difference in the savings of the single family house and the apartment house are again caused by on the one hand the exchange of the heating system as well as the larger outside surface relative to the volume and on the other hand by the exchange of the heating system.
Comparing the advanced retrofit standard with the expert forecast EPB standard confirms the conclusions of the assessment of the individual measures. While the investment costs rise only slightly (terraced houses: 10%, multi-family house 12%), the additional energy savings of 11% (multi-family house: 16%) result in greater energy savings with about the same payback time.

5.4 RETROFIT PACKAGES – CZ, HU, SL, SK

The retrofit package for CEEC4 also consists of an improvement of the thermal resistance of the building envelope and an improvement in the heating system by installing a condensing boiler, as shown in Table 34.

Table 34: Details of retrofit actions (expert forecast EPB-standard, CZ, HU, SL, SK)

CZ, HU, SL, SK			Before retrofit	After optimised retrofit
Building envelope	U-value roof	[W/m²K]	1.40	0.23
	U-value façade	[W/m²K]	1.50	0.35
	U-value cellar ceiling	[W/m²K]	1.40	0.46
Windows	U-value	[W/m²K]	4.00	1.70
	g-value	[ ]	0.76	0.63
Energy supply (gas)	annual efficiency	[%]	75	97

The retrofit packages shown in Table 34 lead to the results displayed in Table 35:

Table 35: Economic assessment of retrofit actions (expert forecast EPB-standard, CZ, HU, SL, SK)

Investment and results		Terraced house	Multi-family house
Total investment	[€/m²]	119	66
Energy-related investment	[€/m²]	67	33
End-energy use after retrofit	[kWh/m²]	79	55
Energy savings	[kWh/m²a]	291	121
CO_2 emission savings	[kg/m²a]	59	26
Mitigation costs (independent)	[€/t]	-5	-25
Mitigation costs (coupled)	[€/t]	-72	-116
Cost-saved energy (independent)	[cent/kWh]	-0.1	-0.6
Cost-saved energy (coupled)	[cent/kWh]	-1.5	-2.6
Amortisation (independent)	[a]	13	12
Amortisation (coupled)	[a]	7	6

The retrofit package described leads to end energy savings of 79% in terraced houses and 69% in multi-family houses.

In the CEEC4 the installation of the retrofit package to achieve the expert forecast EPB standard for the EPBD is cost effective either when coupled with maintenance or carried out as an independent measure. This is the result of usually a poor insulation standard before retrofit in comparison to the Baltic Republics and Poland.
Whether this approach is still cost effective when applied to buildings which already have an improved energy performance is considered in Table 36 and Table 37. These are the details and results of the retrofitting of the standard BEAM house-type (see Chapter 2.1) insulated according to the standards which were common practice between 1975 and 1990.

Table 36: Characteristics of retrofit actions applied on buildings 1975-1990 (expert forecast EPB-standard, CZ, HU, SL, SK)

CZ, HU, SL, SK			Before retrofit	After optimised retrofit
Building envelope	U-value roof	[W/m²K]	0.90	0.23
	U-value façade	[W/m²K]	1.00	0.35
	U-value cellar-ceiling	[W/m²K]	0.90	0.46
Windows	U-value	[W/m²K]	3.40	1.70
	g-value	[ ]	0.76	0.63
Energy supply (gas)	annual efficiency	[%]	75	97

The retrofit packages described in Table 36 produce the results shown in Table 37:

Table 37: Economic assessment of retrofit actions applied on buildings 1975-1990 (expert forecast EPB-standard, CZ, HU, SL, SK)

Investment and results building 1975-1990		Terraced house	Multi-family house
Total investment	[€/m²]	119	66
Energy-related investment	[€/m²]	64	31
End-energy use after retrofit	[kWh/m²]	79	55
Energy savings	[kWh/m²a]	165	67
CO_2 emission savings	[kg/m²a]	67	15
Mitigation costs (independent)	[€/t]	40	122
Mitigation costs (coupled)	[€/t]	-76	-52
Cost-saved energy (independent)	[cent/kWh]	3.0	2.7
Cost-saved energy (coupled)	[cent/kWh]	-1.7	-1.1
Amortisation (independent)	[a]	22	22
Amortisation (coupled)	[a]	10	10

The retrofit package described leads to end energy savings of 67% in terraced houses and 55% in multi-family houses. For buildings in CEEC4 which already have improved energy efficiency the conclusion is that the measures are still a financial benefit for the investor if coupled to maintenance measures, which are required in any case.

Overall, the evaluation of retrofit packages confirms that in economic terms there is a significant opportunity in coupling energy-efficiency measures with general maintenance and retrofit measures. Due to the comparatively long time span of normal retrofit cycles of about 30-50 years, the opportunities of combining regular retrofits with energy-saving measures should be taken up.

6] TECHNICAL POTENTIAL IN THE NEW-8 BUILDING STOCK

6.1 CO_2 EMISSIONS

To calculate the technical CO_2 savings potential of the EPBD and possible extensions, the theoretical assumption is made that all buildings covered by the Directive or possible extensions are retrofitted now according to the insulation standard entering into force after the implementation of the Directive.

Figure 14 shows that the implementation of the EPBD with the limit for renovation of buildings at 1,000m^2 leads to a technical savings potential of 18 Mt/a.

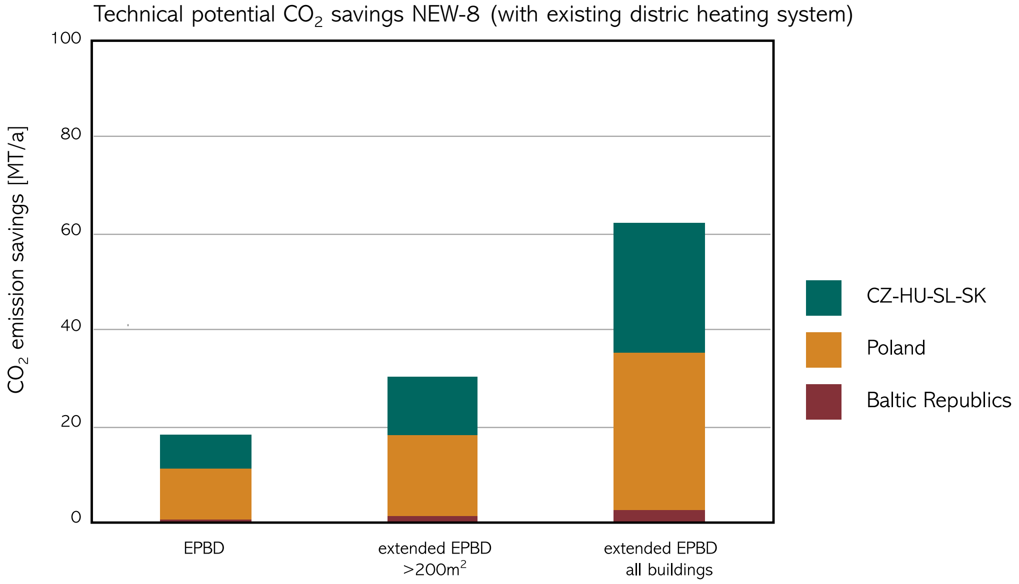
By also extending the Directive to retrofit of all non-residential buildings and apartment houses (Extended EPBD >200m^2) the technical savings potential rises to 31 Mt/a.

If the complete European building stock is included (Extended EPBD all buildings) then the potential rises to 62 Mt/a.

This results in an additional saving potential compared to the Directive of 13 Mt/a for all apartment and non-residential buildings and rises to 44 Mt/a for the complete building stock.

It becomes evident that an extension of the Directive towards renovation of buildings larger than 200m^2 and all non-residential buildings has a small effect compared to the option of also including residential buildings smaller than 200m^2. This can be explained by the large proportion of single-family dwellings in the residential sector.

Figure 14: Technical potential of the EPBD and possible extensions (NEW-8)



	EPBD	Extended EPBD >200m^2	Extended EPBD all buildings
sum	18	31	62
CZ-HU-SL-SK	7	12	27
Poland	10	17	33
Baltic Republics	0.8	1.5	2.8

Table 38: Comparison technical potential EPBD all buildings NEW-8 vs. EU-15

NEW-8 see Table 1	CO_2 Savings [Mt/a]		EU-15	CO_2 Savings [Mt/a]	
	62			398	
	Inhabitants [million]	Buildings [million m^2]		Inhabitants [million]	Buildings [million m^2]
	73,2	2,4		378	18
NEW-8	CO_2 savings [t/cap/a]	CO_2 savings [kg/m^2a]	EU-15	CO_2 savings [t/cap/a]	CO_2 savings [kg/m^2a]
	0.8	26.1		1.1	22.2
Baltic Republics	0.4	9.2	Cold climate	1.0	17.4
Poland	0.9	29.4	Moderate climate	1.3	23.8
CZ-HU-SL-SK	1.0	28.5	Warm climate	0.5	17.4

Comparing the technical CO_2 saving potential of the NEW-8 countries versus the EU-15 (see [Eco**fys** 2004]), the sizes of the examined areas have to be taken into account. Relating the savings potential to the population of the areas to the savings potential in the EU-15 is greater in absolute terms (see Table 38), but taking into account that the living area per inhabitant is about 40% larger in the EU-15, the savings potential per square meter living area in the NEW-8 countries is relatively greater than in the EU-15.

6.1.1 INFLUENCE OF IMPROVED DISTRICT HEATING SYSTEMS

The CO_2 emission saving potential of the EPBD is directly connected to the impact of another European instrument aimed at greenhouse gas emissions reduction. In January 2005 an EU-wide emissions trading system (EU-ETS) started. This system involves CO_2 emissions from installations in energy-intensive industries, including large plants from district heating systems. The first trading phase is from 2005-2007, the second will be in line with the Kyoto commitment period, from 2008-12.
Since district heating was very well developed in the NEW-8 countries during the communist period, large-scale district heating plants (HP) or combined heat and power (CHP) plants centrally supplied most of the high-rise apartment buildings.
Due to the lack of maintenance, high production and distribution losses of district heating systems in the NEW-8 countries a high energy saving potential in district heating networks exists. [CEU 2003] indicates the saving potentials: "The efficiency of heat production of CHP installations in the CEE region as a whole is 70-75% for CHP and 60-80% for HP, which is lower than has been achieved in Western countries (80-90% for CHP and 90% for HP). In general for the countries of the CEE region the overall heat losses are 3-5 times higher, while water losses are 5 to 40 times higher."

It is not in the scope of this study to investigate the impact of the EU-ETS on the CO_2 emissions of district heating networks in the NEW-8 countries, but decreasing emissions from district heating also influences the technical CO_2 saving potential of the EPBD.

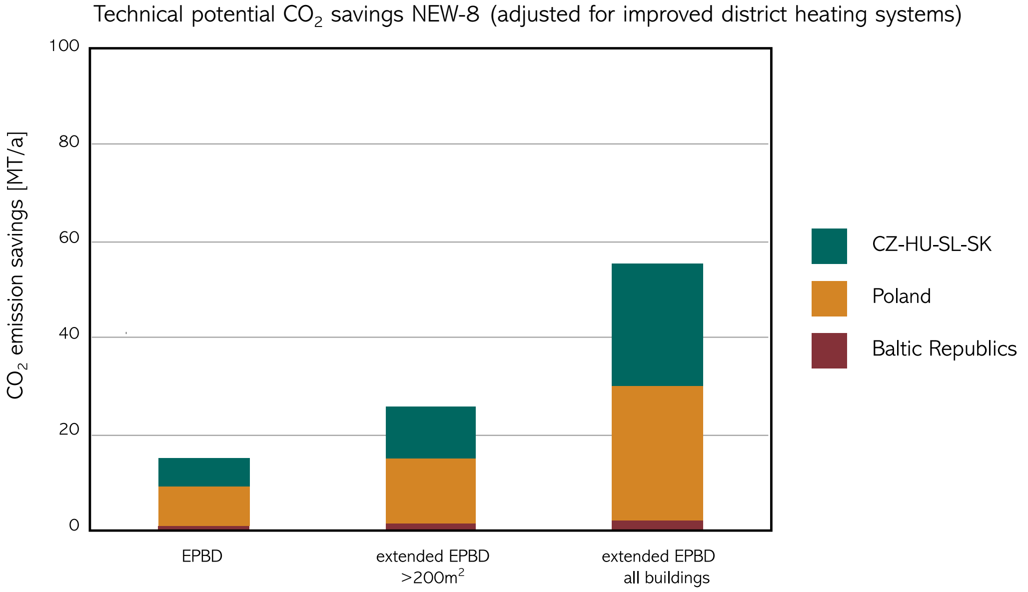
To investigate the range for the technical CO_2 saving potential of the EPBD alternative to Figure 14 it is assumed in the following calculations that the emission factor for district heating in the NEW-8 countries can be improved by 30%. Thereby modification or replacement of existing networks and plants are taken into account, further measures to reduce the CO_2 emissions (e.g. fuel switch from coal to gas or use of biomass) are not considered. Assuming this reduced emission factor for district heating, the CO_2 emissions of the NEW-8 building stock in the year 2002 would be decreased by 15 Mt/a (see Table 39).

Table 39: CO_2 emissions NEW-8 building stock 2002 without and with improved district heating networks

CO_2 emissions	Baltic Republics	Poland	CZ-HU-SL-SK	NEW-8
	[Mt/a]	[Mt/a]	[Mt/a]	[Mt/a]
Building stock NEW-8 2002 current DH	6	70	45	121
Building stock NEW-8 2002 improved DH	5	60	42	106

Figure 15 presents the technical CO_2 saving potential of the EPBD and possible extensions under the theoretical assumption that firstly all district heating systems are modernized. This analysis shows that the minimal overall CO_2 emission savings would add up to 15 Mt/a, if all retrofit measures in the scope of the Directive were realised immediately for the complete residential and non-residential NEW-8 building stock. If the scope of the Directive was extended to all buildings this would lead to a minimum potential for further CO_2 emissions reduction of 40 Mt/a.

Figure 15: Technical potential of the EPBD and possible extensions (NEW-8)

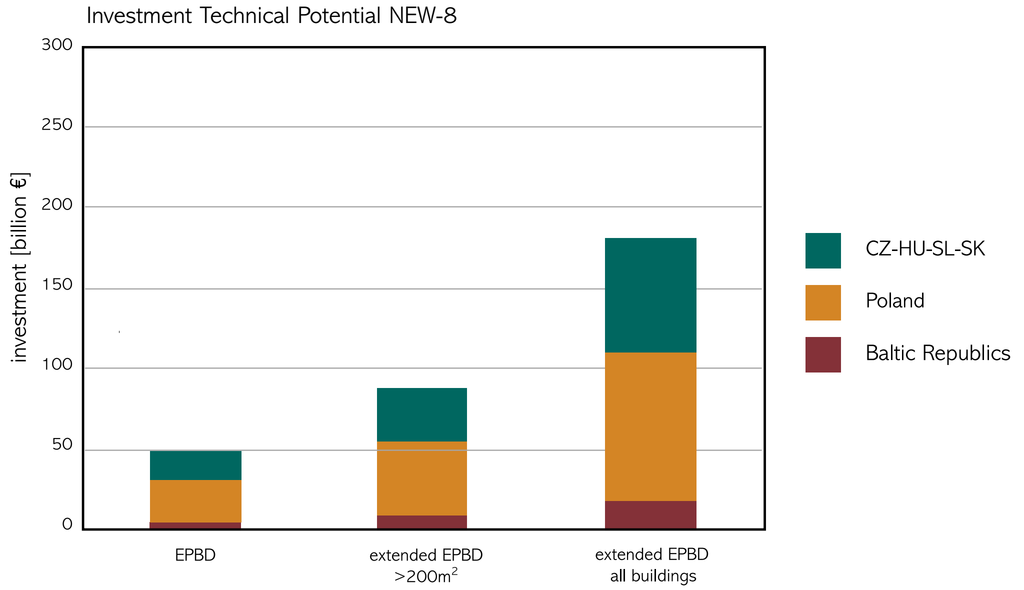


	EPBD	Extended EPBD >200m²	Extended EPBD all buildings
sum	15	25	55
CZ-HU-SL-SK	6	10	25
Poland	8	14	28
Baltic Republics	0.6	1.1	2.3

6.2 COST-ANALYSIS

A total investment of approximately 49 billion EURO would be necessary if all retrofit measures in the scope of the Directive were implemented immediately in the complete residential and non-residential building stock (see Figure 16). An additional investment of 38 billion EURO would be necessary to implement retrofit measures in multi-family apartment dwellings (200-1000m²) and non-residential buildings of less than 1000m² of useful floor space. The inclusion of all house-types would require an additional investment of about 131 billion EURO compared with expenditure to meet the Directive.

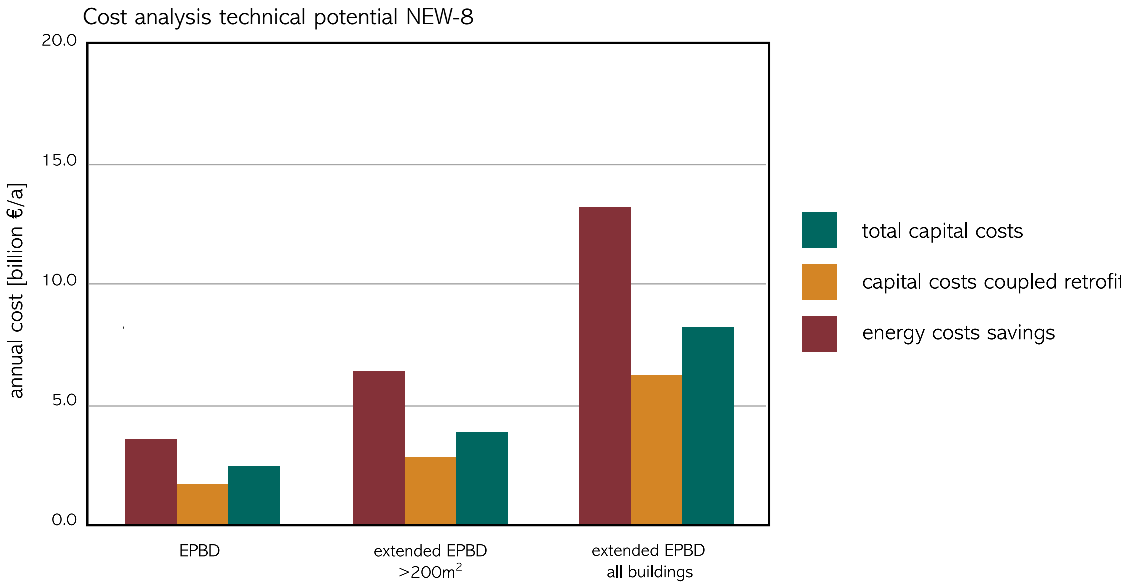
Figure 16: Required investments to mobilise the technical potential (NEW-8)



	EPBD	Extended EPBD >200m²	Extended EPBD all buildings
sum	49	87	180
CZ-HU-SL-SK	19	33	70
Poland	26	46	93
Baltic Republics	4	8	18

In Figure 17 the investment costs are converted into annual capital costs over the lifetime of the energy efficiency measures and compared with the annual energy cost savings. This shows that the technical potential cannot be realized in a cost effective way because the annual capital costs exceed the annual energy cost savings by 57% - 61% depending on the scope of the Directive and its possible extensions.

Figure 17: Annual capital costs vs. energy cost-savings (NEW-8)



	EPBD	Extended EPBD >200m²	Extended EPBD all buildings
total capital costs	3.6	6.4	13.2
capital costs coupled retrofit	1.6	2.8	6.3
energy costs savings	2.3	3.9	8.2

In addition to the total annual capital costs, the energy related annual capital costs are investigated, assuming that the energy-saving measures can be implemented as part of the conventional renovation necessary to avoid deterioration. When taking into account only this energy related share of the total investments it can be seen that the related energy cost savings exceed the annual capital costs of a coupled renovation.

This leads to the conclusion that the large CO_2 saving potential of the building stock can be tapped in a cost effective way if energy-saving measures were combined with the standard renovation cycle.
On the other hand it proves that each renovation without energy-saving measures is a missed chance to reduce the CO_2 emissions of the building stock and does not recur before the next renovation cycle 30-50 years later.

Comparing the cost analysis of the technical potential of the NEW-8 countries with the EU-15 [Eco**fys** 2004] it shows that the energy cost savings in relation to the capital costs in the case of coupled retrofit, are smaller in the NEW-8 countries and thus lead to proportionally less profit. For this there are several reasons:

- First, the annual capital costs per invested capital are higher for the NEW-8 countries due to higher interest rates (see Chapter 0).
- Secondly, energy prices are moderately lower in the new Member States, but also the used energy mix for heating purposes leads to lower average energy costs.
- Thirdly, the ratio between total capital costs and capital costs coupled to retrofit is smaller in the NEW-8 countries. On the one hand additional costs for energy-saving measures compared to costs for renovation without energy improvements are mainly material costs. On the other hand labour costs are generally lower in the NEW-8 countries while material costs are only slightly below EU-15 levels.

When judging the overall profit it should be taken into account that the indexes of the gross domestic product and the price levels in the NEW-8 range between 42 and 78% of the EU-15 values (see Table 1).

7] PHASED DEVELOPMENT IN THE NEW-8 BUILDING STOCK

In addition to the technical potential, scenarios were developed to analyse the effect of a phased application of the EPBD and its possible extensions. These scenarios take into account the fact that the existing building stock will not be retrofitted at once. They also take into account that the building stock is not only affected by retrofitting but also by demolition and by new construction alternatives.
In the following section the scenarios for the implementation of the EPBD (EPBD) and two extensions (extended EPBD>200m², extended EPBD all building-types) are compared to a business-as-usual scenario (BAU) which represents retrofit measures in accordance with common practice.

7.1 INVESTIGATED SCENARIOS

The scenarios were developed to determine the effect of different measures until 2015, including new construction, demolition, retrofit and an improvement of the energy efficiency of district heating systems as factors for the calculations of CO_2 emissions. The following scenarios were analysed:

- Scenario 1 ("frozen technology") represents new construction, demolition and retrofit in accordance with common practice, but no improvement of district heating systems.
- Scenario 2 ("business as usual") is equivalent to the scenario 1 "frozen technology" but includes district heating network improvements.
- Scenario 3 ("EPBD") represents new construction and demolition in accordance with common practice, including district heating network improvements. Equivalent to [Eco**fys** 2002] it is assumed that certificates lead to an increased rate of energy retrofit for all buildings. Furthermore it is assumed that due to the urgent need for refurbishment (see chapter 3.3) retrofit programmes increase the retrofit rate to 3% for those buildings which are subject to the Directive. These buildings are retrofitted according to the standards set by the Directive.
- Scenario 4 ("EPBD > 200m²") has been created on the basis of scenario 3 "EPBD" including extension of the EPBD to all non-residential buildings and all apartment blocks > 200m².
- For Scenario 5 ("EPBD all building-types") single-family houses were also included.

Table 40: Main parameters of investigated scenarios

	Frozen Tech.	BAU	EPBD	EPBD >200m²	EPBD all buildings
New construction rate	1.0%	1.0%	1.0%	1.0%	1.0%
Demolition rate	0.5%	0.5%	0.5%	0.5%	0.5%
Retrofit rate buildings not covered by the Directive	0.2%	0.2%	0.4%	0.4%	-
Retrofit rate buildings covered by Directive	-	-	3.0%	3.0%	3.0%
Improvement District heating until 2015	0%	20%	20%	20%	20%

7.2 CO_2 EMISSIONS

Figure 18 represents the heating-related CO_2 emissions from the different scenarios of the NEW-8 building stock: The scenario "frozen technology" shows that independent developments would result in small CO_2 emissions reduction due to the demolition and replacement with new buildings with better energy performance despite continuous growth of the total building stock. The BAU scenario reflects additionally the improvement of the efficiency of district heating systems. The effects of the EPBD and possible extensions are represented in the remaining three columns.

Figure 19 displays the CO_2 emission savings of the EPBD and possible extensions compared to the BAU scenario. The calculations demonstrate that regulations introduced according to the EPBD in combination with retrofit programs result in a decrease in CO_2 emissions of 5 Mt/a by the year 2010. Extending the scope of the EPBD to all residential buildings (including single- and multi-family apartment dwellings) the CO_2 emission-saving potential compared to the 'business-as-usual' scenario could be raised to 14 Mt/a in the year 2010. This creates an additional saving potential compared to the Directive of 9 Mt/a.

Figure 18: Temporal evolution of CO_2 emissions of the NEW-8 building stock

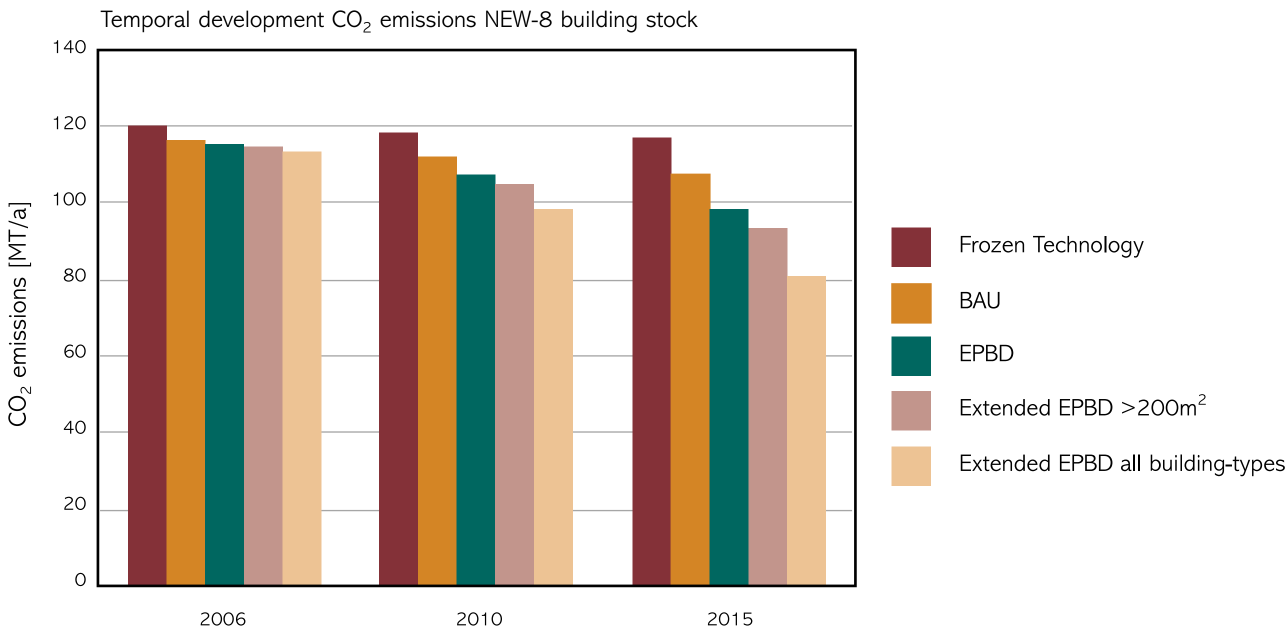
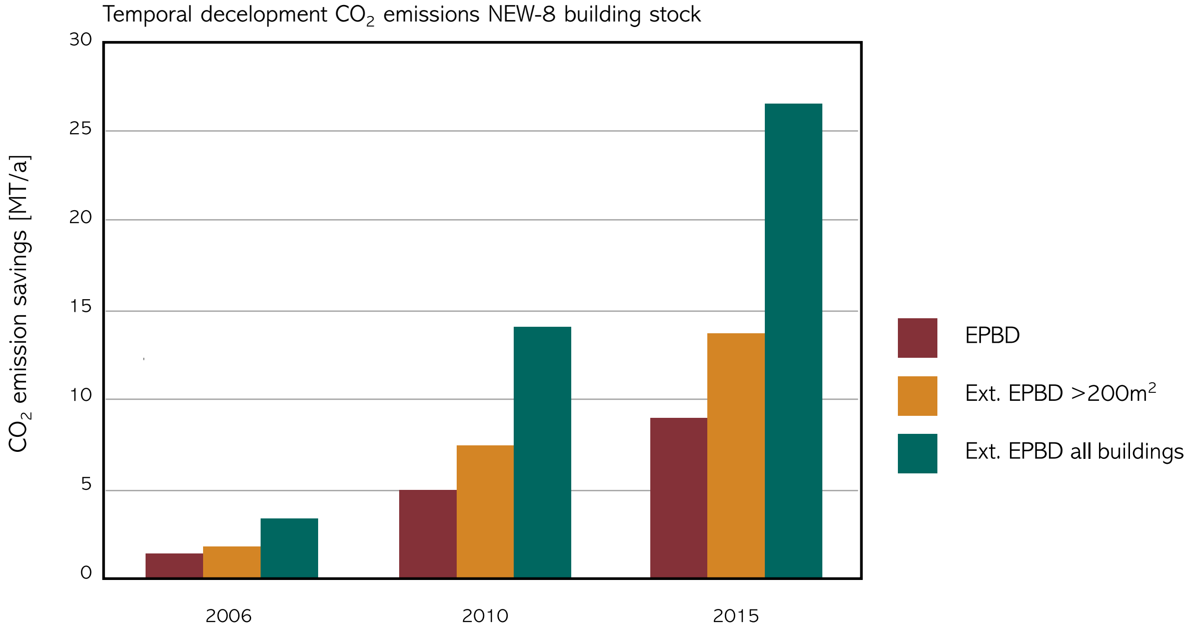


Figure 19: CO_2 emission-saving potential of EPBD and possible extension in the NEW-8 building stock



	2006	2010	2015
EPBD	1	5	9
Ext. EPBD >200m²	2	8	14
Ext. EPBD all buildings	3	14	26

7.3 COST-ANALYSIS

As described in Chapter 3.3 there is an urgent need of refurbishment in the new Member States. Hence the retrofit rates have to be increased substantially to bring the building stock up to standard which leads to enormous investments. Taking into account the conclusions of Chapter 6, it is imperative to couple these refurbishments to energy-saving measures since each renovation without energy-saving measures is a missed chance to reduce the CO_2 emissions cost effectively. The total investments which are necessary for the refurbishment consist of:

- the energy related investments;
- the costs for maintenance of the building envelope and heating systems, which can be combined with energy-efficiency measures;
- cost for further refurbishment, modernisation or alteration without influence on the energy consumption (e.g. change in floor layout, improvement of residential environment, renovation of stairwell etc.).

This section concentrates on the energy related investments, conversion into annual capital costs and relation of these to the energy-saving costs. The costs for maintenance of the building envelope and heating systems are also identified, cost for further refurbishment are not within the scope of the report.

Figure 20 displays the additional (energy related) investments required to implement the different scenarios compared to the BAU scenario.
In order to reach the targets of the EPBD scenario an annual investment of about 1.1 billion EURO additional to the BAU scenario is needed beginning in the year 2006. Extension of the scope of the EPBD to all buildings requires an additional annual investment amounting to about 3.5 billion EURO.

Table 41 presents the total investments which are necessary for the refurbishment composed of maintenance and the energy related investments. The share of the energy related costs varies between 40-43% depending on the scenario. As described in section 3.3 there is an urgent need for refurbishment, which should be initiated by retrofit programmes. To assess whether it is cost effective to couple these retrofits with energy saving measures, the cost effectiveness of energy related investments is investigated further in the following.

Table 41: Total cost for refurbishment incl. maintenance and energy-related cost

Total investment [billion €] (compared to BAU)	2006	2010	2015
EPBD	2.7	2.7	2.7
Ext. EPBD >200m²	4.2	4.3	4.3
Ext. EPBD all buildings	8.0	8.1	8.2

Relating the investments to the general annual turnover of the construction industry in the NEW-8 countries of 43.7 billion EURO [Eurostat 05], the annual turnover is increased by the EPBD by 6.2%. Extending the EPBD to buildings greater than 200m², the turnover increases by 9.6%; an extension to all buildings would result in an increase of 18.3%. This does not account for investments in modernisation or alteration and demonstrates that the great potential in the building stock can be realized, but that it will be a tremendous task for the new Member States to mobilise the urgently needed refurbishments.

Figure 21 illustrates the conversion of the energy related investments required to meet the EPBD to annual capital costs over the lifetime of the energy efficiency measures. It becomes obvious that the annual capital costs for the EPBD scenario increase from 0.12 billion EURO in the year 2006 to 0.84 billion EURO in the year 2015 and for the extended Directive to renovation of all building-types from 0.29 to 2.60 billion EURO for the same years. This increase is caused by the fact that the investments of one year result in annual costs over the next 30 years and cumulate with every year in which investments are made.

In the same way as annual capital costs increase the energy costs decrease in the same years (see Figure 22). In the EPBD scenario the energy cost-savings rise from 0.16 billion EURO in the year 2006 to 1.2 billion EURO. Extending the scope of the Directive to all buildings the energy cost savings amount to 0.36 billion EURO and 3.53 billion EURO in 2006 and 2015 respectively. The primary reason for the savings is the rising number of well-insulated houses. Of minor influence are energy prices which are assumed to rise at 1.5% per year.

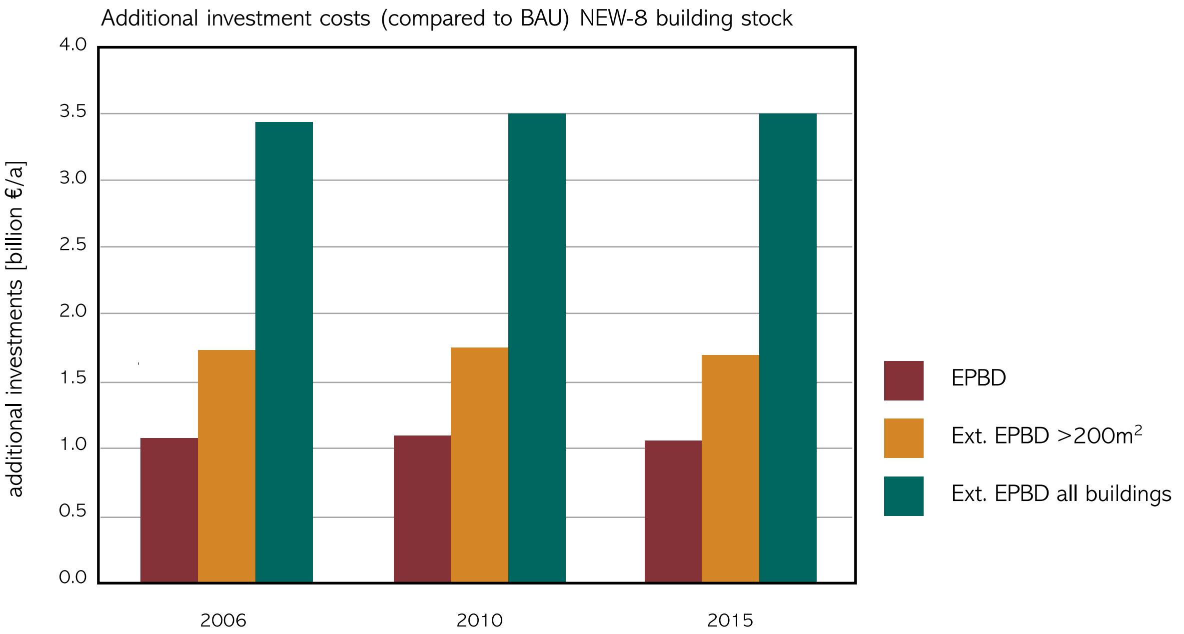
The comparison of Figure 22 and Figure 20 shows that the energy cost savings exceed the new investment costs under all scenarios. This indicates that all the scenarios can be implemented in a cost effective way because the annual benefits rise above annual expenses before the end of the life of the first implemented measure.

The profitability of the scenarios is illustrated in Figure 23 which shows the difference between the annual capital costs and annual energy cost savings. Depending on the scenario, the annual profit rises from 35 million EURO in 2006 to 365 million EURO (EPBD) or 65 million EURO in 2006 to 927 million EURO (extended EPBD to all buildings).

Comparing the cost analysis of the phased implementation in the NEW-8 countries with the EU-15 [Eco**fys** 2004] it shows proportionally less profit. The reasons are analogue to the cost analysis of the technical potential (see 6.2). When judging the overall profit again both the size of the NEW-8 has to be taken into account as well as the gross domestic product and the price levels.

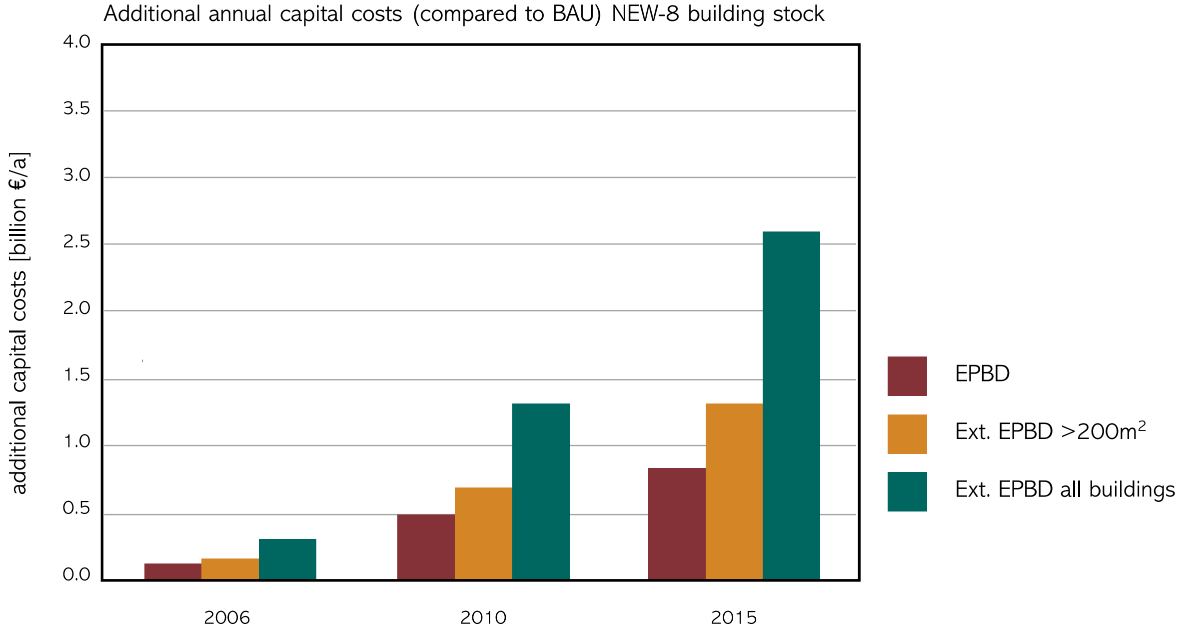
Due to the cost effectiveness of the measures all scenarios lead to negative CO_2 mitigation costs. Comparing this result with the described threshold for acceptable mitigation costs of 20€$_{2000}$/tCO_2e (see Chapter 2.3.3) we conclude that extending the EPBD to renovation of all building-types would result in lower overall CO_2 mitigation costs and thus represents a more attractive option from the economic perspective than more cost intensive mitigation options. The large CO_2 saving potential of the building stock can be tapped in a cost effective way.

Figure 20: Investments (NEW-8)



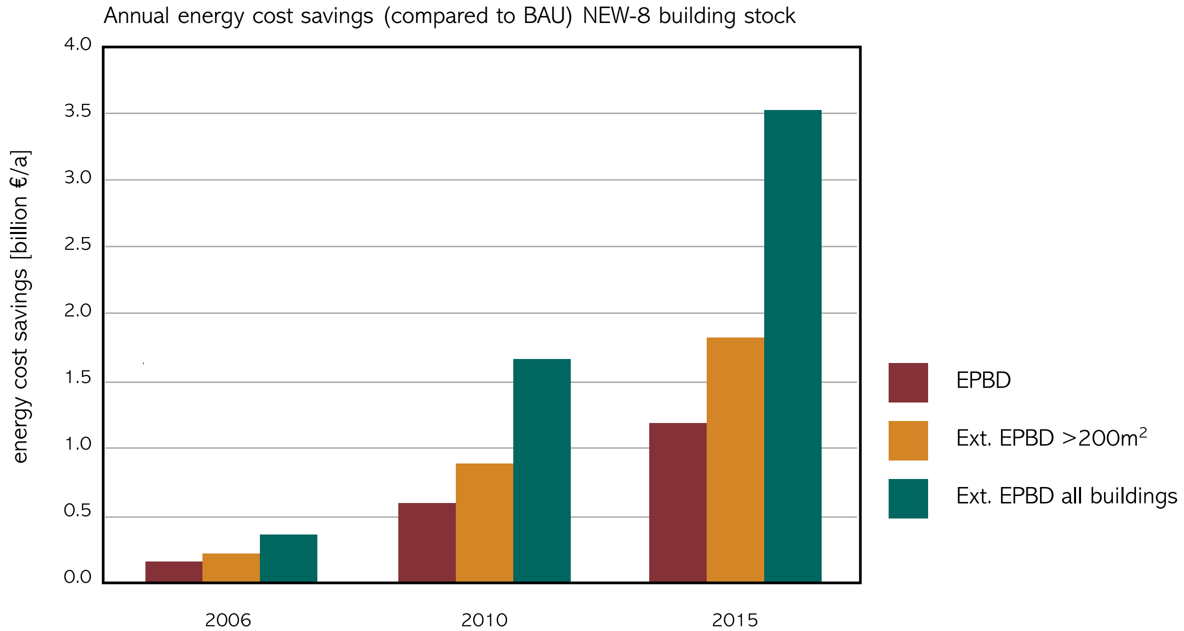
	2006	2010	2015
EPBD	1.1	1.1	1.1
Ext. EPBD >200m²	1.7	1.8	1.7
Ext. EPBD all buildings	3.4	3.5	3.5

Figure 21: Annual capital costs (NEW-8)



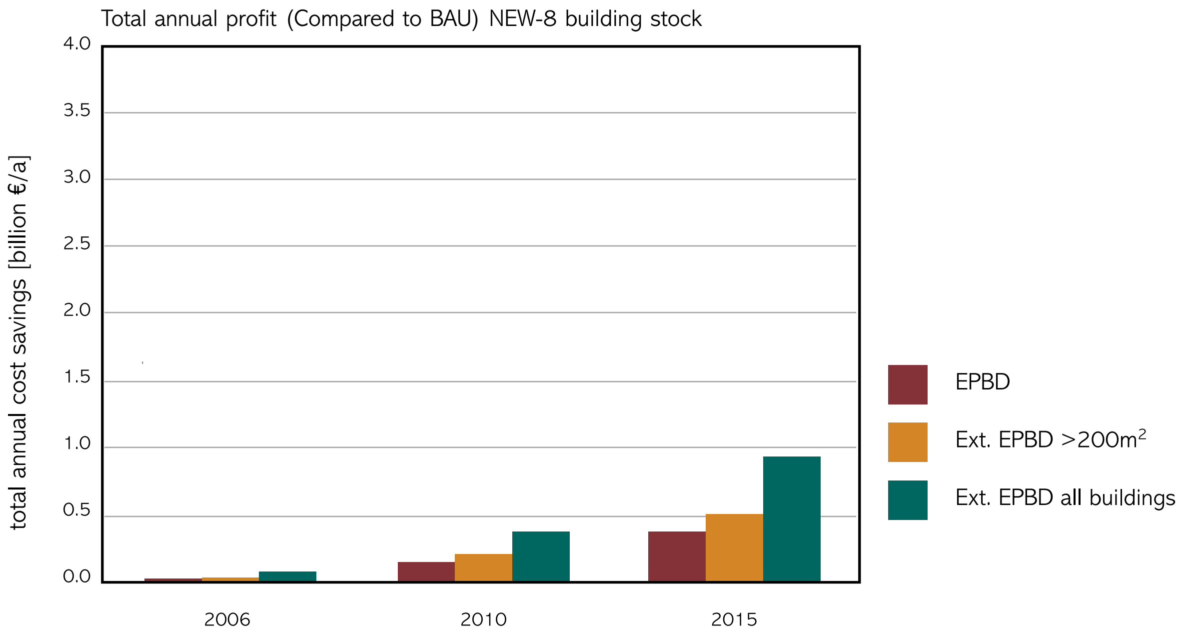
	2006	2010	2015
EPBD	0.12	0.44	0.84
Ext. EPBD >200m²	0.17	0.68	1.33
Ext. EPBD all buildings	0.29	1.31	2.60

Figure 22: Energy cost savings (NEW-8)



	2006	2010	2015
EPBD	0.16	0.59	1.20
Ext. EPBD >200m²	0.21	0.89	1.84
Ext. EPBD all buildings	0.36	1.68	3.53

Figure 23: Total cost savings (NEW-8)



	2006	2010	2015
EPBD	0.16	0.15	0.36
Ext. EPBD >200m²	0.04	0.21	0.51
Ext. EPBD all buildings	0.07	0.37	0.93

7.4 ADDITIONAL BENEFITS

Apart from the CO_2 saving potential and the mitigation costs, other effects have to be considered in the discussion of the economic impacts of implementing greenhouse gas reduction measures. Increased refurbishment activities will have a positive influence on job markets in the new Member States. Furthermore, external costs due to damage expected as a consequence of further warming of the earth's atmosphere will be reduced. Other ancillary benefits of climate policies must also be considered i.e. improved urban air quality.

7.4.1 ENERGY EFFICIENCY & JOB CREATION

As shown in Section 7.3, it will be a tremendous task for the new Member States to realise the urgent need for refurbishment, which will be combined with an increase in turnover of the construction industry of 6-18%, depending on the scenario. The increase of the renovation rate and the implementation of the EPBD is expected to have several effects on employment. The effects on job markets will depend upon complex macroeconomic feedback mechanisms, as is the case with any other policy implementation. Generally the employment effects from additional investments have to be compared to a situation involving an alternative usage of the capital involved i.e. for consumption in consumer goods, additional savings or payment of corporate dividends. The characterisation of these indirect effects involves a large number of uncertainties which can lead to vastly different conclusions.

These include effects on the volume of construction work, effects on the volume of jobs to design and manufacture heating and ventilation installations, effects on the volume of jobs for the maintenance of

technical equipment such as boilers and air conditioning, and effects on jobs due to the implementation and operation of centralised billing systems.
To date only a limited number of studies has addressed the implication of CO_2 emission mitigation measures on job creation, as described in [Eco**fys** 2005].
As a first estimate of direct employment effects, the additional investments can be compared with the turnover and employment of the construction industry, where 1.5 million [Eurostat 04] operatives generate a total turnover of 45 billion EURO/a [Eurostat 05]. This corresponds to a turnover of 35,000 EURO/a per employee. The enhancement of renovation activities without energy-efficiency measures will lead to annual investments of 1.6 billion EURO when concentrating on the large apartment blocks and 4.7 billion EURO[9] if all houses are included, corresponding to 45,000 new jobs or 135,000 new jobs respectively. When combining the refurbishment with energy-efficiency measures there will be an additional positive effect on the job market. This is assuming that the share of material costs for additional energy-efficiency measures in the scenarios discussed above is a factor of 2 – 5 higher than conventional construction activities. Thus, an additional 70,000 - 175,000 EURO/a invested into energy-efficiency packages would generate one new position. The most ambitious packages with additional investments of 3.5 billion EURO annually in energy-efficiency measures would therefore correspond to roughly 20,000 - 50,000 additional new jobs in the construction and installation industries. This does not take into account the influence on other industries (e.g. the energy or manufacturing industry) and is obviously a very rough estimate of direct effects, but certainly warrants further analysis. Nevertheless, if the urgent need for refurbishment will be mobilised and combined with energy-efficiency measures it can be concluded that positive employment effects in the range of 50,000 to 185,000 jobs across the new Member States would result from the implementation of the packages discussed above.

7.4.2 AVOIDED DAMAGE COSTS

Great uncertainties remain in estimating the external damage costs of the greenhouse gas effect. These include uncertainties in understanding the climate mechanisms in the earth's atmosphere as well as uncertainties in evaluating the socio-economic changes resulting from climate change. Physical impacts of climate change have been estimated, including: the rise in sea levels, extreme weather events, human health effects, agriculture, water resources and ecosystems including potential migration processes. A sharp distinction between assessing the damages and allocating clear damage costs is often not possible since the impacts are interlinked with each other.
Table 42 below provides an indicative overview of marginal external damage costs as result of CO_2 emissions. The magnitude of results spans from 0.1 to 16.4 EURO/tCO_2 and is based on calculations run with the model FUND 2.0 with a time horizon until 2100.

Table 42: Summary of recommended marginal external damage costs calculated for ExternE[a] (World Averages) [Friedrich 2001]

Avoided damage costs	Minimum	Low[b]	Central estimate	High[b]	Maximum
($€_{2000}/tCO_2$)	0.1	1.4	2.4	4.1	16

[a] emissions in the period 2000-2009. Costs are discounted to year 2000
[b] lower and higher value correspond to the 67% confidence interval

[9] Investments for renovation activities without energy-efficiency measures are calculated as the difference between the total cost for refurbishment including maintenance and energy related costs (8.2 billion EURO; see Table 41) and the additional energy related costs (3.5 billion EURO) and amounts (4.7 billion EURO; see Figure 20).

Leading experts on valuing damage costs e.g. Tol, Downing and Frankenhauser conclude [Tol 2000]: "...the marginal costs of carbon dioxide emissions are uncertain and sensitive to assumptions that partially reflect ethical and methodological positions, but are unlikely to exceed 50$ per tonne of carbon." 50$/t C would correspond to 13.6$/t$CO_2$.

8] CONCLUSIONS AND POLICY RECOMMENDATIONS

URGENT NEED FOR REFURBISHMENT

For decades, especially during the communist period, maintenance and refurbishment on the building stock was neglected due to lack of resources. Consequently, this building stock is in urgent need of retrofits and upgrades to current state of the art. This fact is widely recognized among the political decision-makers and the importance of this subject is underlined by the attention of the 16th European Housing Ministers Meeting held in Prague, where especially the need for actions in high-rise apartment blocks was acknowledged.

COMBINATION WITH ENERGY EFFICIENCY MEASURES

The ministers agreed that emphasis should be given on integrated strategies involving housing management, maintenance employment, energy-saving measures, urban development and social policy approaches. Especially the energy related aspects are confirmed in this study. It was found that measures are especially cost efficient if coupled to refurbishment, especially in view of the fact that such opportunities may only occur after a period of 30 to 50 years in the renovation cycle.
For large apartment buildings, coupling of measures is contained in the current EPBD and leads to significant CO_2 emissions reduction.

EXTENDING THE EPBD

The investigated cost effective retrofit packages confirm the validity of the principles of Trias Energetica, which postulate that energy-saving measures should be implemented to reduce demand before the remaining energy demand is generated, preferably by renewable technologies, or with energy efficient technologies based on conventional fuels. These principles could be included in the implementation of the EPBD in national legislation by requirements on overall energy performance and also by the institution of minimum insulation levels.
It was observed that the insulation thickness that can be expected as the result of the implementation of the EPBD in the new Member States is close to the economic optimum. However, increased levels of insulation would lead to further savings without significant negative financial impact.
Since energy conservation measures make economic sense in all buildings types and not only in buildings greater 1000m^2, it would be sensible to extend the EPBD and create a contribution towards closing the gap in the EU CO_2 emission target.

MOBILISATION OF THE URGENT NEED FOR REFURBISHMENT

Besides other obstacles, the main impediment for realisation is the lack of capital for the vast investments needed. Policy measures such as governmental support programmes are therefore inevitable to release investments in refurbishment and thus speed up the realisation of energy and CO_2 emission savings.
To ensure that energy-efficiency measures are combined with refurbishment, the following options could be considered for further discussion at policy level.

- Providing incentives through reduced interest rates on loans: The targeted refurbishment programmes should be coupled with minimum requirements on energy performance. Further improvements in energy efficiency could be activated by reduced interest rates on loans. These policies have to be consistent in order to achieve a good result, which means that the earmarked subsidy amount and the demand for i.e. improved insulation technologies must match. However, tying up these types of subsidies with loan arrangements runs the risk that subsidies are hard to acquire if the customers want to install technology on by themselves. There should be a clear indication which measures are subsidized; though receipt of subsidies should not be dependent upon the equipment supplier an investor purchases technology from. A problem area with such schemes is that subsidies provided for mature and thus commercially available technologies may result in prices increasing and degrade the quality of services.

- Establishing revolving funds for refurbishment projects at regional level: Revolving funds can be developed and administered by public institutions as a financing mechanism to support the investment in energy-efficiency measures in the building sector. A reserve of money could be made accessible to registered organizations or individuals. Over a given period of time the debtor is expected to repay the original sum, which will replenish the fund and allow others to benefit from loans. The financial savings achieved by energy-efficiency projects, which can easily be determined, are funnelled back into the capital fund thus creating an ongoing revolving capital fund. Each year these savings are reinvested into the fund until the capital investment is paid off.

- Lowering the Value Added Tax: As another option, the Value Added Tax (VAT) could be lowered in EU Member States for any product type that contributes to decreasing energy consumption in buildings. Typically, this would apply for insulation material, improved windows or state-of-the-art heating technology to be implemented during refurbishment measures. Lowering VAT would accelerate and support sales mechanisms of these products and could lead to stimulating the construction supply markets in general.

- The right legal framework for retrofitting: Additional financial incentives might be given to investors in energy-saving measures for the existing building stock. In some EU countries investors are allowed to increase rental fees after a refurbishment measure to a maximum of two times the saved energy costs provided the measures improved the energy efficiency of a building. With or without involvement of the EU, a similar legal framework could be expanded to cover other EU Member States.

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ANNEX I] DESCRIPTION OF BEAM (BUILT ENVIRONMENT ANALYSIS MODEL)

For the research project "The contribution of Mineral Wool and other Thermal Insulation Materials to Energy-saving and Climate Protection in Europe" [ECO**FYS** 2002], ECO**FYS** has developed the (Built Environment Analysis Model) BEAM displaying the actual conditions and future developments in the European building stock to analyze potential energysavings through thermal insulation. Statements concerning energy savings through thermal insulation are based on a calculation model structuring the building stock in a simplified manner. This has to be taken into account when evaluating the accuracy of the results. However, the results provide safe indicators of the probable size of energy-saving potentials. To calculate the heating-related CO_2 emissions of the NEW-8 building stock, BEAM was extended to the EU-25. The main elements of BEAM are:

STANDARD HOUSE-TYPES

For the modelling of the European building stock 5 standard houses were taken into account:

- Model house 1: Two-storey terrace-end-house (120m^2);
- Model house 2: small apartment house (less than 1000m^2);
- Model house 3: large apartment house (larger than 1000m^2);
- Small office building (less than 1000m^2);
- Large office building (larger than 1000m^2).

CLIMATE CONDITIONS

Three groups with different climate conditions have been distinguished:

- The Baltic republics will be reported as one group.
- Poland as the largest country will be investigated separately.
- The Central-Eastern European countries Czech Republic, Hungary, Slovakia and Slovenia are summarized as one group (CEEC-4).

Table 43: Inventory of the climate conditions: heating degree days

Country	Heating degree days [Kd/a]
Baltic Republics	4,000
Poland	3,850
CEEC-4	3,400

BUILDING AGE GROUPS

The building stock has been subdivided into three building age groups, which differ substantially due to the respective valid national or regional regulations and the insulation standard connected to them:

- Buildings erected before 1975 (subdivided into buildings already energetically redeveloped and buildings in their initial condition);
- Buildings erected between 1975 and 1990;
- Buildings erected after 1990.

CHARACTERISATION OF THE BUILDING STOCK

Baltic Republics

Table 44: Characterisation of the Baltic building stock

	Building age	Total	Single-family house	Apartment house <1000m²	Apartment house >1000m²	Small non-residential buildings <1000m²	Non-residential buildings >1000m²
	Year	[million m²]	[million m²]	[million m²]	[million m²]	[million m²]	[million m²]
Baltic Republics	< 1975	201.6	85.1	37.0	31.4	17.6	30.5
	1975-1990	87.7	36.0	16.6	13.7	7.8	13.6
	1990-2001	15.1	6.5	2.7	2.3	1.3	2.2
	Total	**304.4**	**127.6**	**56.3**	**47.5**	**26.7**	**46.3**
Estonia	< 1975	40.0	17.8	7.7	6.1	3.1	5.3
	1975-1990	23.3	10.4	4.5	3.5	1.8	3.1
	1990-2001	2.9	1.3	0.6	0.4	0.2	0.4
	Total	**66.2**	**29.5**	**12.8**	**10.0**	**5.1**	**8.8**
Latvia	< 1975	53.7	14.7	12.4	9.1	6.0	11.5
	1975-1990	26.8	7.3	6.2	4.5	3.0	5.8
	1990-2001	3.3	0.9	0.8	0.6	0.4	0.7
	Total	**83.9**	**23.0**	**19.4**	**14.2**	**9.3**	**18.0**
Lithuania	< 1975	108.0	52.6	16.9	16.3	8.5	13.6
	1975-1990	37.6	18.3	5.9	5.7	3.0	4.7
	1990-2001	8.8	4.3	1.4	1.3	0.7	1.1
	Total	**154.4**	**75.2**	**24.2**	**23.3**	**12.2**	**19.5**

Table 45: End-energy Baltic Republics

End-energy use	Residential sector	Commercial sector	Res. + com. sectors
	MWh	MWh	MWh
Baltic countries	33,051,942	8,840,900	41,892,842
Estonia	7,789,210	1,997,233	9,786,443
Latvia	13,300,841	3,533,567	16,834,407
Lithuania	11,961,891	3,310,100	15,271,991

Table 46: Energy supply Baltic Republics

Energy supply (end-energy)	Gas	Oil	Coal	Electricity	Wood	District heating
Single-family houses	11.0%	7.4%	3.1%	0.9%	61.7%	15.9%
Apartment houses	2.3%	1.5%	0.9%	0.4%	17.8%	77.1%
Emission factor [kg/MWh]	202	266	338	610	20	237

Table 47: U-values Baltic Republics

U-values [W/m²K]	Built before 1975 not retrofit.	Built before 1975 already retrofit.	Built from 1975 until 1990	Built from 1991 until 2002	New building 2003-2006	Retrofit 2003-2006	New building after 2006	Retrofit after 2006
Windows	3.00	2.60	2.60	2.10	1.90	1.90	1.66	1.66
Façade	0.90	0.78	0.78	0.33	0.27	0.30	0.23	0.26
Floor	0.70	0.64	0.64	0.34	0.26	0.58	0.25	0.29
Roof	0.70	0.62	0.62	0.28	0.19	0.24	0.17	0.20

Poland

Table 48: Characterisation of the Polish building stock

Building age	Total	Single-family house	Apartment house <1000m²	Apartment house >1000m²	Small non-residential buildings <1000m²	Non-residential buildings >1000m²
Year	[million m²]	[million m²]	[million m²]	[million m²]	[million m²]	[million m²]
< 1975	642.8	236.5	93.1	149.6	77.8	85.8
1975-1990	327.6	120.5	47.4	76.2	39.7	43.7
1990-2001	154.0	56.7	22.3	35.8	18.6	20.6
Total	1124.3	413.7	162.8	261.7	136.2	150.1

Table 49: End-energy Poland

End energy use	Residential sector	Commercial sector	Res. + com. sectors
	MWh	MWh	MWh
Poland	168,963,601	37,926,483	206,890,084

Table 50: Energy supply Poland

Energy supply (end-energy)	Gas	Oil	Coal	Electricity	Wood	District heating
Single-family houses	23.4%	7.5%	34.6%	0.5%	18.2%	15.8%
Apartment houses	14.2%	4.6%	21.1%	0.3%	11.1%	48.7%
Emission-factor [kg/MWh]	202	266	338	610	20	539

Table 51: U-values Poland

U-values [W/m²K]	Built before 1975 not retrofit.	Built before 1975 already retrofit.	Built from 1975 until 1990	Built from 1991 until 2002	New building 2003-2006	Retrofit 2003-2006	New building after 2006	Retrofit after 2006
Windows	3.50	2.60	2.60	2.40	2.30	2.30	2.00	2.00
Façade	1.20	0.50	0.75	0.55	0.45	0.25	0.30	0.25
Floor	1.20	1.00	0.70	0.70	0.70	0.70	0.60	0.60
Roof	0.90	0.45	0.45	0.30	0.30	0.30	0.23	0.23

Czech Republic, Hungary, Slovenia, Slovakia

Table 52: Characterisation of the building stock in Czech Republic, Hungary, Slovenia, Slovakia

	Building age	Total	Single-family house	Apartment house <1000m²	Apartment house >1000m²	Small non-residential buildings <1000m²	Non-residential buildings >1000m²
	Year	[million m²]	[million m²]	[million m²]	[million m²]	[million m²]	[million m²]
Total	< 1975	620.4	297.9	51.3	96.6	77.8	96.8
	1975-1990	273.6	131.7	21.8	43.3	33.5	43.2
	1990-2001	53.5	26.1	4.0	8.4	6.5	8.4
	Total	**947.5**	**455.8**	**77.1**	**148.4**	**117.8**	**148.4**
Czech Republic	< 1970	261.5	115.6	28.1	41.9	35.6	40.3
	1970-1990	89.8	39.7	9.7	14.4	12.2	13.8
	1990-2001	11.4	5.0	1.2	1.8	1.6	1.8
	Total	**362.7**	**160.3**	**39.0**	**58.1**	**49.3**	**55.9**
Slovakia	< 1970	104.5	45.4	8.0	21.5	10.0	19.6
	1970-1990	64.2	27.9	4.9	13.2	6.1	12.0
	1990-2001	12.6	5.5	1.0	2.6	1.2	2.4
	Total	**181.3**	**78.9**	**13.9**	**37.2**	**17.3**	**34.0**
Hungary	< 1970	214.9	120.2	11.3	25.2	27.4	30.8
	1970-1990	99.4	55.6	5.2	11.7	12.7	14.2
	1990-2001	23.0	12.8	1.2	2.7	2.9	3.3
	Total	**337.3**	**188.6**	**17.7**	**39.5**	**43.0**	**48.3**
Slovenia	< 1970	39.5	16.7	3.9	8.0	4.8	6.1
	1970-1990	20.2	8.5	2.0	4.1	2.5	3.1
	1990-2001	6.6	2.8	0.6	1.3	0.8	1.0
	Total	**66.3**	**28.0**	**6.5**	**13.5**	**8.1**	**10.2**

Table 53: End-energy in Czech Republic, Hungary, Slovenia, Slovakia

End energy use	Residential sector	Commercial sector	Res. + com. sectors
	MWh	MWh	MWh
Total	134,166,558	59,463,083	193,629,642
Czech Republic	52,131,421	22,584,100	74,715,521
Slovakia	26737437,5	11557416,7	38294854,2
Hungary	45,408,776	21,306,150	66,714,926
Slovenia	9,888,924	4,015,417	13,904,340

Table 54: Energy supply in Czech Republic, Hungary, Slovenia, Slovakia

Energy supply (end-energy)	Gas	Oil	Coal	Electricity	Wood	District heating
Single-Family Houses	70%	6%	10%	3%	5%	6%
Apartment Houses	27%	3%	4%	1%	3%	62%
Emission-factor [kg/MWh]	202	266	338	610	20	258

Table 55: U-values in Czech Republic, Hungary, Slovenia, Slovakia

U-values [W/m²K]	Built before 1975 not Retrofit.	Built before 1975 already Retrofit.	Built from 1975 until 1990	Built from 1991 until 2002	New building 2003-2006	Retrofit 2003-2006	New building after 2006	Retrofit after 2006
Windows	4.00	3.40	3.40	2.90	2.10	1.80	1.65	1.70
Façade	1.50	1.00	1.00	0.55	0.38	0.40	0.34	0.35
Floor	1.40	0.90	0.90	0.68	0.48	0.48	0.44	0.46
Roof	1.40	0.70	0.70	0.38	0.28	0.29	0.23	0.23

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