

# Cost Optimality

Discussing methodology and challenges within the recast Energy Performance of Buildings Directive





## THE BUILDINGS PERFORMANCE INSTITUTE EUROPE - BPIE

The Buildings Performance Institute Europe (BPIE) is dedicated to improving the energy performance of buildings across Europe, and thereby helping to reduce CO<sub>2</sub> emissions from the energy used by buildings.

Its mission is to support the development of ambitious, yet pragmatic building-related policies and programmes at EU and Member State level and to drive their timely and efficient implementation by teaming up with relevant stakeholders from the policy and research community, the building industry and consumer bodies.

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# CONTENT

FOREWORD .....	4
COST-OPTIMAL REQUIREMENTS FOR BUILDINGS .....	6
Political background .....	6
Essentials of the EPBD recast.....	9
The principle of cost-optimal requirements.....	12
Reference buildings in Europe.....	17
Measures to improve the energy performance of buildings.....	19
AN OVERVIEW OF THE COMPLETE PROCESS .....	22
CALCULATION STEPS .....	24
Calculation of delivered energy and primary energy .....	24
Economic assessment.....	25
EXAMPLES OF CALCULATIONS .....	28
Retrofit.....	28
New buildings.....	30
SUMMARY AND OUTLOOK .....	32
ANNEX .....	34
Some definitions.....	34
Sources of further information.....	35
Directive 2010/31/EU .....	36

## FOREWORD

Buildings are the biggest single contributor (about 36%) to European CO<sub>2</sub> emissions that amount to approximately 5 gigatonnes (Gt)<sup>1</sup>. Reaching the declared long-term target of reducing greenhouse gas (GHG) emission levels by 80–95% by 2050 will therefore need a major effort to improve building energy efficiency.

Given that the renovation cycle for buildings is approximately 30 years (probably less for commercial buildings) during which the performance of a building in principle does not change, we must ensure that new buildings and renovation measures on existing buildings optimise the energy saving potential.

- ▶ *Energy performance requirements for existing buildings are a key element of national building sector policies*
- ▶ *The 2002 version of the EPBD did not address the ambition level of the energy performance of buildings. The EPBD recast of 2010 now introduces the principles of cost-optimal energy performance that are decisive to move national requirements to more effective levels*

This is why defining minimum energy performance requirements for new and existing buildings represent a key element in European building codes. The European Commission has introduced requirements to set such standards in all Member States through the 2002 Energy Performance of Buildings Directive (EPBD) but did not at that time give guidance on the desired ambition level.

The recast of the EPBD in 2010 now includes a provision that national energy performance requirements should be set with the view to achieving cost optimum levels by applying a harmonised calculation methodology (Directive 2010/31/EU, Article 5 and Annex III a<sup>2</sup>).

The Commission requests Member States to use and apply this methodology to calculate the required cost-optimal levels for their specific country and compare them with the national requirements they have set in their national building regulations.

<sup>1</sup> For all sectors.

<sup>2</sup> Please see the end of the document.

The methodology will be discussed and refined in the comitology process starting in the second semester 2010.

This document has been created to support this process. It is mainly targeted at policy makers (such as staff of the European Commission, the European Parliament, national ministries), and other market actors (such as NGOs, national or EU industry and professional associations) who will either be directly involved in the internal comitology process or external (political) consultation processes.

We hope you will find valuable background information here to guide your decisions and recommendations. It is important to come to a strong and workable methodology which will steer national - and thereby European - ambition levels in the right direction.



**Dr. Tudor Constantinescu**

Executive Director

Brussels, September 2010

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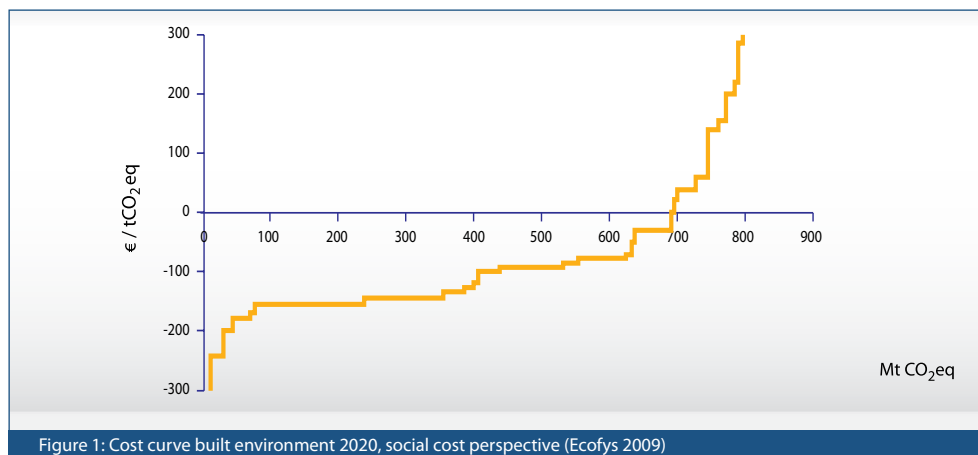
# COST-OPTIMAL REQUIREMENTS FOR BUILDINGS

## Political background

The building sector has been identified by various studies as a sector that offers considerable potential for the cost-effective reduction of greenhouse gas emissions, making it an important field for climate protection action.

Two recent independent EU-wide assessments show the potential for energy savings and GHG emission reductions in the built environment sector. The Fraunhofer Institute and partners (2009)<sup>3</sup> show that, by implementing energy savings measures, fuel-use in the EU built environment can be reduced by 22% (2020) and by 46% (2030) compared to 2005. Ecofys et al. (2009)<sup>4</sup> shows that GHG emissions can even be reduced by 44% (2020) and 60% (2030) compared to 2005, when full energy savings are applied in conjunction with renewable energies.

Both studies indicate that 75%-85% of the technical savings potential for 2020 is comprised of cost-effective options. This means that over the lifetime of clean technologies, energy savings will more than compensate for the investment costs.



Simultaneously, these measures also help to reduce political and financial dependence on fuel imports and buying energy. Significantly, they also have a positive effect in reducing the energy bill, while adding to comfort and quality of life.

3 Fraunhofer-Institute for Systems and Innovation Research (Fraunhofer ISI) and partners (2009). Study on the Energy Savings Potentials in EU Member States, Candidate Countries and EEA Countries. Final Report for the European Commission Directorate-General Energy and Transport.

4 Ecofys (2009). Sectoral Emission Reduction Potentials and Economic Costs for Climate Change (SERPEC-CC) Summary report.

The possible combination of multiple benefits makes the building sector a crucial field for policy makers at EU and national levels. A policy framework is needed which can support the national markets in unlocking these potentials.

The maximum savings potential within the building sector has not yet been fully recognised. Both the quality of measures and the speed of implementation (especially in building renovation) demonstrate the scope for improvement.<sup>5,6</sup> So far, Member States have adopted different approaches and different ambitions in their building regulations, influenced by national political processes, building traditions and individual market conditions.

- ▶ *Research demonstrates that financial and environmental aims are not necessarily a contradiction but can actually support each other*
- ▶ *The principle of cost-optimal energy performance requires a common understanding of all stakeholders*

In order to adapt to the worldwide increase in energy prices and to the EU's 2020 targets for improved energy efficiency,<sup>7</sup> national energy performance requirements will need to be revised over the next few years. The intrinsic relationship between environmental, financial and comfort-related factors suggest that an integrated EU approach should be developed for establishing energy performance requirements for new and existing buildings in Europe.

To proceed towards an integrated and uniform approach that leaves flexibility for the integration of national circumstances, the EU has introduced a framework for a new methodology. The principles established within the recast of the Energy Performance of Buildings Directive (EPBD recast) sketch a methodology for identifying cost-optimal levels of energy performance requirements for buildings. Given these basic principles, further details of the methodology (e.g. energy price forecasts to be used in the calculations) still have to be determined. This will require input from Member States and other stakeholders.

5 Ecofys (2007) "U-values for better energy performance of buildings", report for EURIMA-European Insulation Manufacturers Association.

6 Impact assessment for the EPBD recast, European Commission 2008.

7 The EU has agreed a set of goals and related instruments for 2020. Most prominent are the 20% or 30% reduction of GHG emissions compared to 1990, the 20% improvement in energy efficiency over a business as usual development and the 20% share of renewable energy use by 2020.

## COST-OPTIMAL ENERGY PERFORMANCE

The new methodology links energy performance requirements to financial targets. This supports the general objective of reducing costs during a building's lifecycle while creating societal/environmental benefits. Rising energy prices offer even more scope for improving current regulations, as the cost savings from reduced use of energy are higher and can justify higher upfront investment.

The methodology will combine uniform calculation rules with specific national data to ensure an individualised and fair treatment of Member States. The financial calculations will also foster open competition; they are neutral regarding technologies and do not imply that certain products have priority over others.

*However the methodology and its implementation do face some challenges:*

- ▶ *examining the costs should not imply that future environmental targets are ignored. These targets need to be taken into consideration in a methodology that matches financial and environmental benefits;*
- ▶ *all further boundary conditions such as technical requirements (e.g. to avoid moisture in a building) and comfort issues also need to be considered;*
- ▶ *several details of the methodology (like the task of making suitable energy price forecasts) are not yet fixed and need proper consideration to ensure the success of the approach;*
- ▶ *a common understanding of all stakeholders is crucial to make sure that calculations and the interpretation of the results are made in a uniform and comparable way. This requires clear guidelines around the process and regular exchange between the Member States.*



## Essentials of the EPBD recast

The EU Directive (2002/91/EC) on the Energy Performance of Buildings (EPBD) sets requirements for the energy performance of buildings at EU level. Since December 2002, the EPBD has put in place a common framework from which individual Member States in the EU have developed or adapted their own national regulations.

The EPBD required the implementation of its provisions into Member States' legislation by January 2006. The EPBD demands improvement in the overall energy efficiency of all new buildings. It also incorporates a requirement for the renovation of large existing buildings (with a floor area of over 1,000 square metres).

*The EPBD covers four elements that have to be integrated into national legislation:*

- ▶ *a methodology for calculating the energy performance of buildings;*
- ▶ *a definition of minimum energy efficiency requirements per Member State;*
- ▶ *energy performance certificates (EPC's)<sup>8</sup> for new and existing buildings;*
- ▶ *regular inspection of heating and air conditioning systems.*

### KEY CHANGES

Recently, the EPBD underwent a recast procedure (2010/31/EU). The key changes, compared to the 2002 version of the EPBD are as follows:

#### - Clarification

A large number of explanations and provisions in the existing EPBD are strengthened and clarified, e.g. the type of information included in energy performance certificates or the inspection of heating and air-conditioning systems.

#### - Extended scope

The 2002 EPBD stated that Member States must ensure that the use of alternative systems, such as renewable energy or combined heat and power, are considered during the planning phase for all new buildings with a floor area above 1,000 m<sup>2</sup>. Existing buildings with a floor area of more than 1,000 m<sup>2</sup> which undergo major renovation need to upgrade their energy performance. The 1,000 m<sup>2</sup> threshold excluded smaller buildings such as single family houses. The 2002 EPBD therefore missed out a substantial part of the European building stock and its energy-saving potential. In the recast, the threshold of 1,000 m<sup>2</sup> has been removed for new and existing buildings.

8 "Energy performance certificate" means a certificate recognised by a Member State or by a legal person designated by it, which indicates the energy performance of a building or building unit.

### - Nearly zero-energy buildings

A new article has been introduced on nearly zero-energy buildings. These are very high energy performance buildings requiring almost zero or a very low amount of energy that will be largely covered by energy from renewable sources.

As of 2019, public authorities occupying a new building are responsible for ensuring that the building is a “nearly zero-energy building” and from 2021, all new buildings must be nearly zero-energy buildings.

Member States also need to develop policies and set concrete targets to increase the number of nearly zero-energy buildings resulting from building refurbishment.

► *The EPBD recast defines ambition levels in two areas:*

*- The methodology for cost-optimal levels for energy performance requirements (for new and existing buildings)*

*- The requirements for nearly zero-energy buildings to be realized as from 2019 (only new public buildings) or 2021 (for all new buildings)*

### - Minimum energy performance requirements

The 2002 EPBD described how the energy performance of buildings should be evaluated. It required Member States to define a maximum energy consumption level based on a standard use of the building, but it did not contain any guidance on desirable levels of energy consumption.

The 2010 EPBD recast now requests that Member States ensure that minimum energy performance requirements for buildings are set “with a view to achieving cost-optimal levels”. The cost-optimal level shall be calculated in accordance with a comparative methodology.

### - The EU basics for calculating cost-optimal levels<sup>9</sup>

By June 2011, the Commission has to establish a comparative methodology for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements (e.g. the roof of a building).

*The methodology requires Member States to:*

- ▶ *define reference buildings that are representative in terms of functionality and climate conditions. The reference buildings need to cover residential and non-residential buildings (e.g. offices), both for new and existing;*
- ▶ *define energy efficiency measures to be assessed for the reference buildings. These can be measures for buildings as a whole, for building elements, or for a combination of building elements;*
- ▶ *assess the final and primary energy<sup>10</sup> need of these reference buildings. The calculations must be done in accordance with relevant European standards;*
- ▶ *calculate the costs of the energy efficiency measures during the expected economic lifecycle of the reference buildings. Investment costs, maintenance and operating costs, earnings from energy produced and disposal costs (if applicable) need to be taken into consideration.*

### ASSESSMENT AT MEMBER STATE LEVEL

The Commission provides the general methodology and will also take care of joint issues, such as information on estimated long-term energy price developments.

Applying this methodology, individual Member States assess the input data (e.g. climate conditions and investment costs) and calculate the results. The methodology and local data will then allow Member States to identify cost-optimal levels of minimum energy performance requirements for new and existing buildings. They should also compare the results of this calculation with the minimum energy performance requirements that are currently in effect.

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<sup>9</sup> The full legal text (Article 5 "Calculation of cost-optimal levels of minimum energy performance requirements" and "Comparative methodology framework to identify cost-optimal levels of energy performance requirements for buildings and building elements") can be found in the Annex of this brochure.

<sup>10</sup> "primary energy" means energy from renewable and non-renewable sources which has not undergone any conversion or transformation process.

## MONITORING AND REPORTING

Member States must report their calculation results to the Commission, accompanied by the input data and assumptions made for these calculations. Member States must submit reports to the Commission at regular intervals of a maximum of five years, with the first report due by June 2012.

If the results at the Member State level demonstrate that the current minimum energy performance requirements are significantly less energy efficient (by more than 15%) than what has been identified as cost-optimal, the Member State needs to provide a justification for this difference. In the event that this difference cannot be justified, the respective Member State will be asked to develop a plan, outlining appropriate steps to reduce this gap by the next review of the energy performance requirements.

The Commission will publish a report on Member States' progress in reaching cost-optimal levels of minimum energy performance requirements.

## The principle of cost-optimal requirements

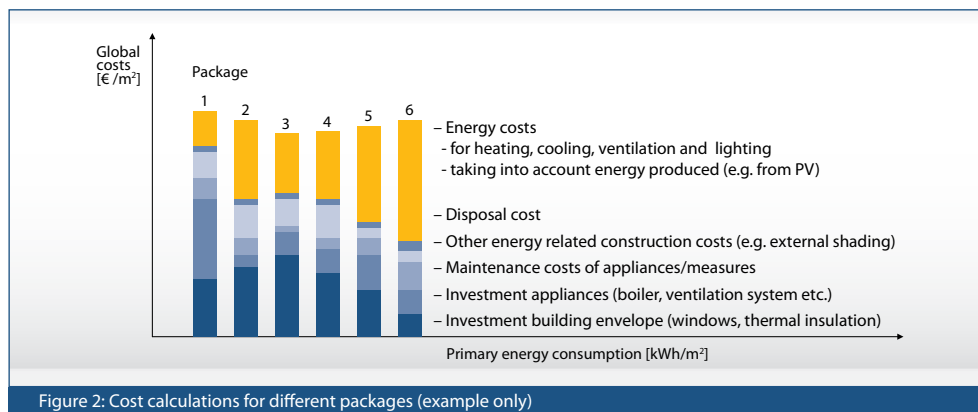
The EPBD recast requires the European Commission to establish the comparative methodology framework by 30 June, 2011. The following sections explain in more detail the principles mentioned in the EPBD Annex III.

### ANALYSING ECONOMIC AND ENVIRONMENTAL BENEFITS

Regarding the costs of energy performance requirements, the EPBD recast prescribes that the whole lifecycle should be considered and not just, for example, the up-front investment. The cost-efficiency of different packages of measures (combinations of compatible energy efficiency and energy supply measures) can be assessed by calculating and comparing the energy-related lifecycle costs.

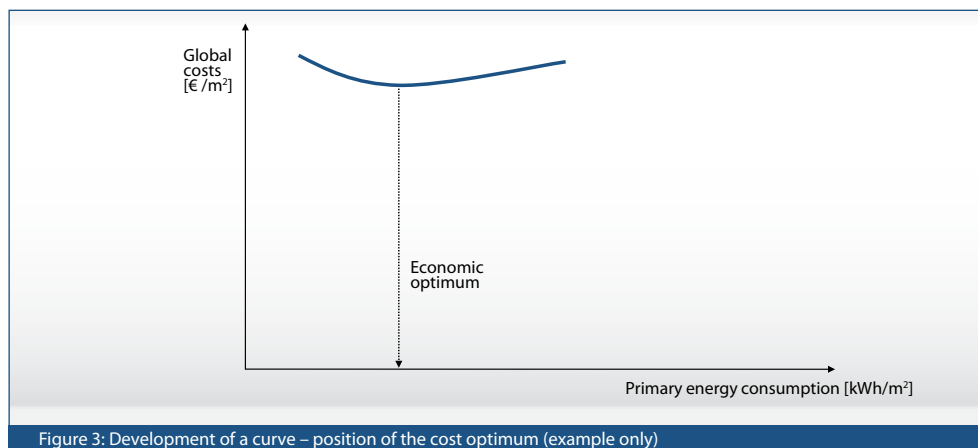


An example of the results for different packages of measures<sup>11</sup> applied to a reference building is shown in Figure 2. The figure depicts the costs of packages as global costs<sup>12</sup> related to the primary energy used.



## DEFINING THE OPTIMUM FROM THE COST CURVE

From the variety of specific results for the assessed packages, a cost curve can be derived (see Figure 3). The lowest part of the curve represents the economic optimum for a combination of packages.



To establish a comprehensive overview, all combinations of commonly used and advanced<sup>13</sup> measures should be assessed in the cost curve. The packages of measures range from compliance with current regulations and best practices to combinations that realise nearly zero-energy buildings. The packages also include various options for local renewable energy generation. The packages need to fit

<sup>11</sup> A package of measures is a combination of compatible energy efficiency and energy supply measures to be applied to a building, e.g. the application of low energy windows, thermal insulation, a condensing boiler and a solar thermal system.

<sup>12</sup> The global cost calculation method is described in EN 15459: (Energy performance of buildings – economic evaluation procedure for energy systems in buildings). This method results in a net present value of all costs during a defined calculation period.

<sup>13</sup> To the extent that market and related market prices already exist.

with national circumstances (e.g. climate), but experiences and solutions from other Member States can clearly help to complete the picture.

The variety of solutions are unlikely to form an exact curve as in the example, but rather a “cloud” of data points from which an average curve can be derived. By varying one parameter (e.g. insulation levels) and keeping others consistent, different components can be optimised.

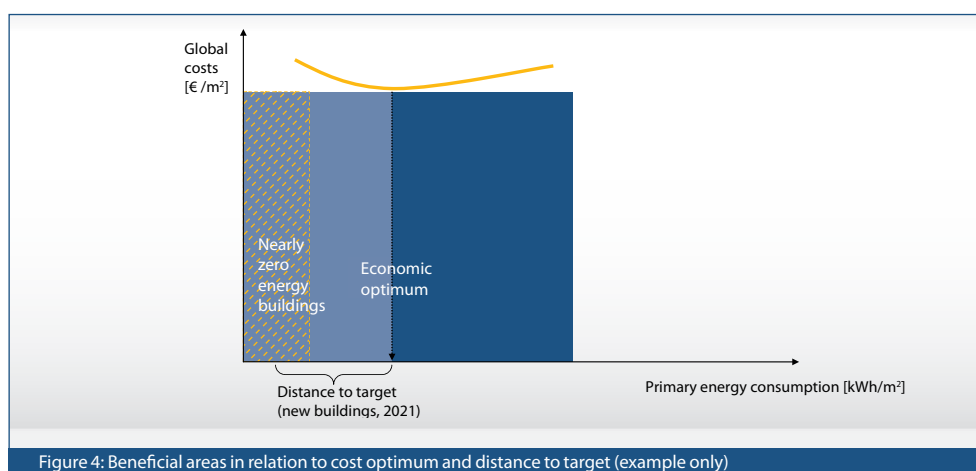


Figure 4: Beneficial areas in relation to cost optimum and distance to target (example only)

## SETTING OF MINIMUM PERFORMANCE REQUIREMENTS

The minimum energy performance requirements are represented by the area of the curve that delivers the lowest cost for the end-user and/or for the company or society. Potentially, these requirements could prove to be more effective and efficient than current national requirements, at less or equal cost.

The area of the curve to the right of the economic optimum represents solutions that underperform in both aspects (environmental and financial). To prepare for higher energy or environmental targets (e.g. related to 2020), certain Member States might choose even stricter requirements than the economic optimum (left area of the curve). In figure 4, the distance to target for new buildings, so they are “nearly zero-energy buildings” as from 2021, is made visible.

If packages create very similar costs, the package with the lower energy use should ordinarily be selected. This package will lead to higher environmental benefits and at the same time reduce fuel dependence. It is likely to be more profitable taking an extra measure now than taking it later, when a more ambitious future performance is desired.

## COST NEUTRALITY AND MARGINAL COST

Cost neutrality can be derived by comparing the global costs of a package of measures in relation to a chosen reference. Regarding cost neutrality, it seems difficult to aim at a concept which, in financial terms, is the equivalent of a situation with no energy saving measures. But it can be reasonable to accept situations that are beyond the optimum of the curve but are equal to current standards.

However, in such a case it would seem more promising to “push” the economic optimum towards that level. This could be achieved, for example, via financial incentives such as soft loans at reduced interest rates.

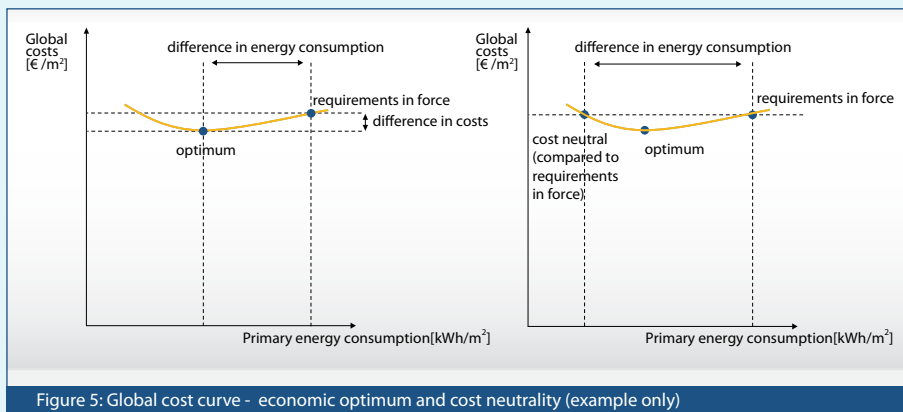


Figure 5: Global cost curve - economic optimum and cost neutrality (example only)

Marginal costs describe the costs and savings of the last measure in a package, which is relevant when developing a package of measures step by step. At the optimum of the cost curve, marginal costs are zero. This means that the marginal costs are equal to the amount of marginal savings. If the global cost curve shows jumps, for instance when shifting to completely new concepts such as the passive house<sup>14</sup>, marginal cost calculations can be misleading. In these cases, only the global package costs give an accurate picture.

<sup>14</sup> Building concept according to the Passiv house Institute which can be described by a very low heating requirement (less than 15 kWh/(m<sup>2</sup>a)) where the combined primary energy consumption for heat, hot water and household electricity may not exceed 120 kWh/(m<sup>2</sup>a)

## REQUIREMENTS FOR THE METHODOLOGY

To perform these kinds of calculations, Member States need to:

- ▶ *define and select representative buildings that are characterised by their functionality and regional conditions, including indoor and outdoor climate conditions, geometries etc. These representative buildings are called “reference buildings”;*
- ▶ *define combinations of compatible energy efficiency and energy supply measures to be applied to the reference buildings (“packages of measures”);*
- ▶ *assess the delivered energy<sup>14</sup> and primary energy<sup>15</sup> of the selected building;*
- ▶ *consolidate the corresponding energy-related investment costs, energy costs and other running costs as well as disposal costs (if applicable, for example, costs that might occur during the disposal of hazardous materials) of relevant packages applied to the selected reference buildings;*
- ▶ *develop cost curve(s) and derive an optimum.*

The definition of reference buildings and technology packages is a crucial part of the process. These definitions define the scope of the assessment and therefore we need to ensure that all common, suitable and promising combinations of reference buildings and packages are taken into account.

- ▶ *The cost curve assesses all combinations of common and advanced measures with respect to their economic and environmental impact*
- ▶ *The economic optimum provides the package with the lowest cost*
- ▶ *At the same cost level, the package with the lower energy use should be selected*
- ▶ *The definition of reference buildings and technology packages is a crucial part of the process*

14 Delivered energy: energy supplied to the building (e.g. natural gas from the grid). Energy produced by the building itself and delivered back to the market is subtracted.

15 Primary energy: energy from renewable and non-renewable sources which has not undergone any conversion or transformation process.



## Reference buildings in Europe

The building stock in each Member State is different from the next. Buildings differ in:

- ▶ *age;*
- ▶ *status (before or after retrofit);*
- ▶ *type (single- or multi family house, office building, retail etc.);*
- ▶ *size;*
- ▶ *climate conditions;*
- ▶ *desired indoor climate conditions (see EN15251);*
- ▶ *national/local building styles (geometry, materials etc.);*
- ▶ *location (weather exposure, orientation);*
- ▶ *user behaviour.*

The examples on the following page give an impression of the large range of buildings in the EU.

Nevertheless, buildings can be categorised per country in different groups by common and similar properties, e.g. single family buildings of a certain age group.<sup>16</sup> For these groups, reference buildings can be defined to represent each group. In many cases, national and regional building typologies already exist. These can be used or extended, if necessary.

The definition of representative reference buildings is an important step as it affects the position of the economic optimum per building or market segment. The choice and assessment of different reference buildings will also lead to multiple curves. Depending on the type of reference building chosen in a particular situation, this may result in different requirements.

Joint efforts at the EU level to define a “standard” set of reference buildings to be assessed could be helpful to give basic guidance on choice and compilation of reference buildings to the Member States. The Member States should still be encouraged to adapt and extend the set of reference buildings to suit their specific needs and circumstances.

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<sup>16</sup> Please see also Intelligent Energy Europe project TABULA, a recently published study examining the experiences with energy-related building typologies in European countries. At <http://www.building-typology.eu/> you will find the complete report for download as well as an overview of the most important results.



New single family house



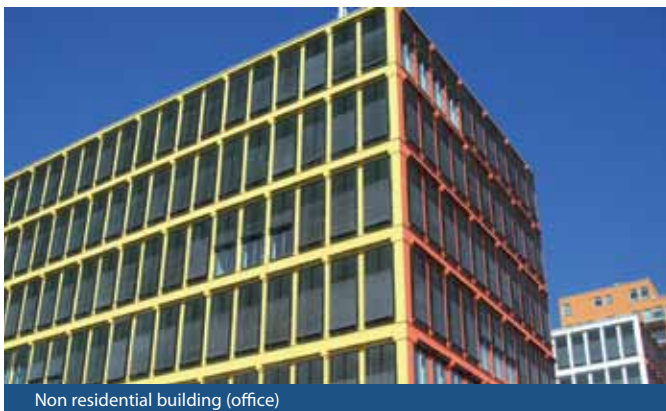
New multi family house



Single family, retrofit situation



Multi family house, retrofit situation



Non residential building (office)



Non residential building (education)

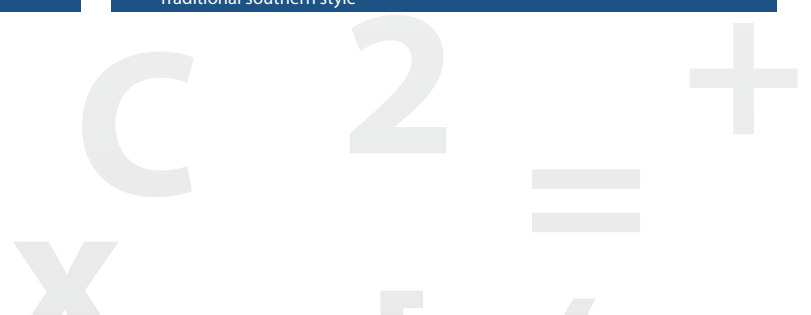


Traditional northern style



Traditional southern style

Figure 6: Examples of buildings in the EU (Sources: fotolia)



## Measures to improve the energy performance of buildings.

When compiling packages of measures, technologies from the following groups should be taken into account.

### - Building envelope

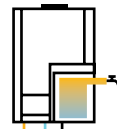
Measures deal primarily with the reduction of heat transmission and improved air tightness of the building envelope with the intention of reducing transmission losses and losses from (too high) air-exchange. This includes:



- ▶ *thermal insulation products (e.g. for insulating walls or roof);*
- ▶ *building materials (e.g. for walls) with low thermal transmission;*
- ▶ *measures to ensure air-tightness (e.g. sealants);*
- ▶ *measures to reduce the effects of thermal bridges (specific construction solutions for connections within façade and roof);*
- ▶ *high efficient glazing (e.g. triple glazing) and low energy window frames and doors (use of insulating materials, specific sealants, etc.).*

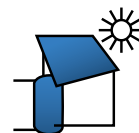
### - Space heating

An active system is usually necessary to meet the demand for heating. This demand can be met by efficient and/or renewable energy systems (e.g. condensing boilers, heat pumps or wood-pellet boilers) in conjunction with suitable storage and distribution systems.



### - Domestic hot water

Domestic hot water is often produced with the same system used for space heating, but it can also be supplied by combined systems (e.g. when integrating solar energy systems) or separate systems. High efficient storage and distribution systems are crucial for reducing heat loss.



### - Ventilation systems

Mechanical ventilation systems help to achieve the necessary air-exchange rates and can also limit losses from air-exchange by heat recovery systems.

#### - **Cooling**

Passive cooling systems such as shading devices can help reduce or avoid cooling loads. Active systems can meet demand for heating. These are mainly electric systems but renewable systems are also available (e.g. solar cooling).

#### - **Lighting**

This includes applications to increase the use of daylight (e.g. tubes or mirrors) and active systems for artificial lighting (e.g. low energy light bulbs).



#### - **Building automation and control**

Other related measures include the implementation of management systems that introduce supervising/steering functions for the building.

#### - **Other building-related measures with impact on thermal performance**

This can include, for example, external shading devices and other active and passive systems not covered by the other groups.

### **COMPILING PACKAGES**

Packages of measures are the basis for creating representative cost curves. These packages need to be calculated both for new buildings and for retrofit activities, for residential and non-residential buildings and will be compared across Member States.

As a first step, packages of measures need to be assessed that comply with the minimum performance requirements in force. On the developed cost curve, these packages will visualise the current ambition level that can be compared to the position of the cost optimum.

The second step focuses on the ambition level beyond current minimum requirements up to and including nearly zero-energy buildings. There is a wide range of innovative solutions. Energy saving measures can be combined with efficient or renewable energy supplies. It is important to highlight the fact that smart combinations of measures can create a strong synergy and lead to results that are more than the sum of individual measures.



## INNOVATIVE SOLUTIONS

Innovative solutions and examples from other Member States (such as the passive house concept) can complement the overview of possible combinations. The more packages (and variation of the measures included in the analysed package), the more accurate the calculated economic optimum will be. If possible, the packages should also avoid lock-in-effects,<sup>17</sup> in case more complex requirements are introduced to the building stock at a later stage.

In retrofit activities that are linked to maintenance measures, it is important not to judge the realised energy cost savings against the total costs of all the renovation measures. A decision should be based on the cost of the additional energy-related investments only.

To reflect this effect, the total costs of a building undergoing maintenance measures without improvements in energy efficiency (e.g. replacement of windows without improvement of their energy performance) could be assessed as a package applied to the reference buildings. This would then be the basis for comparison for the retrofit packages.

- ▶ *First, packages that must comply with the current minimum performance requirements are to be assessed*
- ▶ *Then a wide range of solutions corresponding to the ambition level beyond current minimum requirements must be analysed*
- ▶ *Innovative solutions and examples from other Member States complement the overview of possible packages*

<sup>17</sup> Lock-in-effects occur when a measure is difficult to change or improve during or after its lifetime. For example, air tightness measures are difficult to improve at a later stage, because the construction will be closed and in many cases does not allow easy access anymore. This is why such measures should be implemented in the best possible way right from the start.

# AN OVERVIEW OF THE COMPLETE PROCESS

The complete process to assess and report on cost optimal levels for energy performance requirements of buildings is described in the following diagram.

The flow chart begins with the steps that define reference buildings and packages of measures that are applied to these buildings.

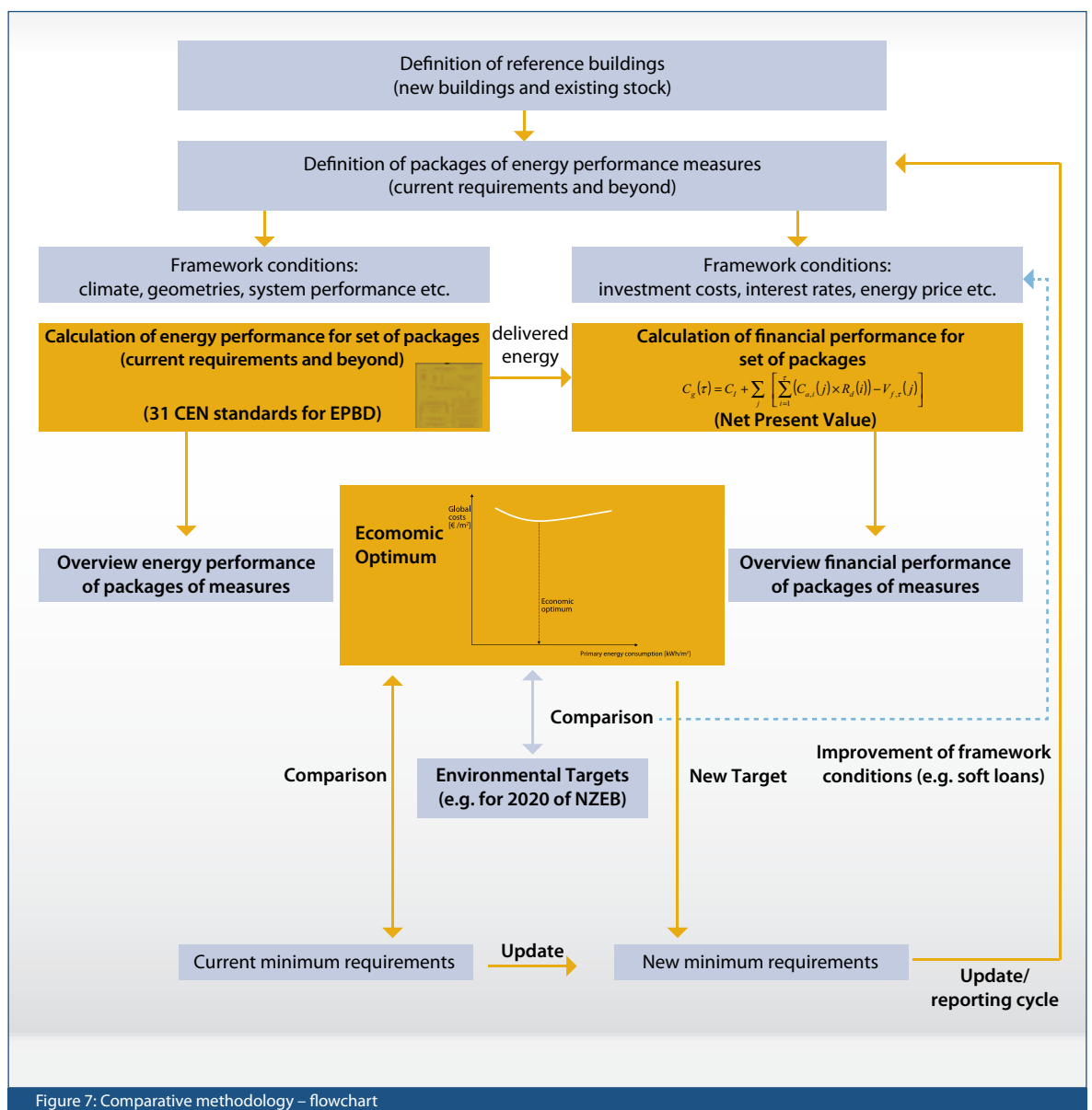


Figure 7: Comparative methodology – flowchart



After combining reference buildings with different packages of measures, the calculation splits into two: the calculation of the energy performance and the calculation of the financial performance of the different combinations of reference buildings and packages.

**- Energy performance:**

The energy performance calculations for the chosen combinations of reference buildings and packages can be performed with the help of the 31 CEN standards<sup>18</sup> that have been developed to support the implementation of the EPBD. Framework conditions for the calculations are climate data, performance of energy systems, etc.

**- Financial performance:**

To assess the financial performance of the chosen combinations, the global cost calculation method from the European Standards EN 15459 (Energy performance of buildings – economic evaluation procedure for energy systems in buildings) can be used. This method results in a discounted value of all costs during a defined calculation. The calculation of energy costs is thereby fed by the results of the energy performance calculations. Input data for the calculations are investment costs, interest rates, fuel prices etc.

A cost curve shows the assessed combinations of energy performance (x-axis) and financial performance (y-axis). It is this way that an economic optimum can be derived.

The relationship between current requirements and the position of the cost optimum is submitted to the Commission in a reporting cycle and can be used to update requirements, if suitable.

The comparison with future environmental targets could feed into a new loop, represented by the dotted line. This loop enables the effect of improved framework conditions (e.g. the introduction of soft loans) to be assessed, shifting the economic optimum towards medium- or long-term targets. Although not part of the EPBD recast, this loop could be used as a national steering tool.

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18 See CEN/TR 15615:2008 "Explanation of the general relationship between various European standards and the Energy Performance of Buildings Directive (EPBD) - Umbrella Document." Reproduced by permission of DIN Deutsches Institut für Normung e.V. The definitive version of the implementation of this standard is the edition bearing the most recent date of issue, obtainable from Beuth Verlag GmbH, 10772 Berlin, Germany.

# CALCULATION STEPS

## Calculation of delivered energy and primary energy

The 31 CEN standards that have been developed for the EPBD<sup>19</sup> provide possible rules for calculating the amount of energy delivered.

The assessment needs to incorporate the following aspects:

- ▶ calculation of the buildings net energy use;
- ▶ calculation of the energy delivered<sup>20</sup> to the building for heating and cooling, ventilation, domestic hot water and lighting including auxiliary energy;
- ▶ energy generated by the building itself (e.g. via photovoltaic systems or combined heat and power);
- ▶ calculation of the overall primary energy use.<sup>21</sup>

This graph describes the overall scheme.

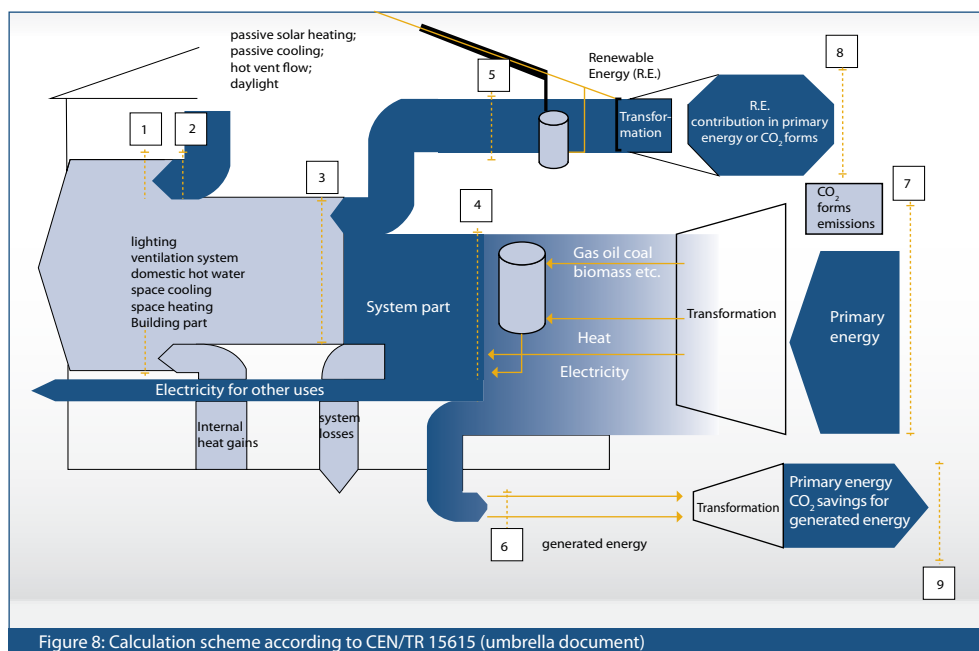


Figure 8: Calculation scheme according to CEN/TR 15615 (umbrella document)

<sup>19</sup> See CEN/TR 15615: 2008 "Explanation of the general relationship between various European standards and the Energy Performance of Buildings Directive (EPBD) - Umbrella document. Reproduced by permission of DIN Deutsches Institut für Normierung e.V. The definitive version of the implementation of this standard is the edition bearing the most recent data of issue, obtainable from Beuth Verlag GmbH, 10772 Berlin, Germany.

<sup>20</sup> Delivered energy: energy supplied to the building (e.g. natural gas from the grid). Energy produced by the building itself and delivered back to the market is subtracted.

<sup>21</sup> Primary energy: energy from renewable and non-renewable sources which has not undergone any conversion or transformation process.



Thereby the numbers 1 to 9 represent the following energy flows:

1. gross energy needs according to user's requirements for heating, cooling and lighting;
2. "natural" energy gains, e.g. passive solar gains or ventilation cooling;
3. building's net energy use;
4. delivered energy, including auxiliary energy, taking into account renewable energy sources [5] and co-generation<sup>22</sup>;
6. generated energy – produced on the premises and exported to the market; this can include part of [5];
7. primary energy usage associated with the building;
8. primary energy associated with on-site generation that is used on-site;
9. primary energy associated with generated energy (delivered back to the market).

## Economic assessment

As a method for an economic assessment, the EPBD recast suggests the net present value (NPV). The net present value is a standard method for the financial assessment of long-term projects. It measures the excess or shortfall of cash flows, calculated at their value at the start of the project.

Such a net present value calculation can be performed by using the global cost calculation method described in EN 15459: (*Energy performance of buildings – economic evaluation procedure for energy systems in buildings*). An appropriate calculation can be described by the following formula<sup>23</sup>:

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<sup>22</sup> Production of electricity and useful thermal energy simultaneously from a common fuel source.

<sup>23</sup> Source: EN 15459: 2007. Energy performance of buildings – economic evaluation procedure for energy systems in buildings. Reproduced by permission of DIN Deutsches Institut für Normung e.V. The definitive version of the implementation of this standard is the edition bearing the most recent date of issue, obtainable from Beuth Verlag GmbH, 10772 Berlin, Germany.

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

$C_g(\tau)$	Global costs referring to starting year $\tau_0$
$C_I$	Initial investment costs
$C_{a,i}(j)$	Annual costs year $i$ for energy-related component $j$ (energy costs, operational costs, periodic or replacement costs, maintenance costs)
$R_d(i)$	Discount rate for year $i$ (depending on interest rate)
$V_{f,\tau}(j)$	Final value of component $j$ at the end of the calculation period (referred to the starting year $\tau_0$ ). Here also disposal cost (if applicable) can be taken into account.

The global costs are defined by:

- ▶ the initial investment costs at the start of the measure;
- ▶ plus the present value of the sum of the running costs (e.g. fuel costs) during the calculation period;
- ▶ minus the net present value of the final value of components at the end of the calculation period.

The EN 15459 does not prescribe the use of a specific calculation period. The calculation period might be set at 30 years, as this timeframe covers the lifetime of most of the measures assessed. Longer calculation periods are not recommended, as beyond a 30-year timeframe, assumptions on interest rates and forecasts for energy prices (these have to be defined for the calculation period) become difficult.

Due to the fact that only one calculation period can be defined for assessing the total building, the chosen calculation time might be shorter or longer than the lifetime of individual components or systems.

To ensure a lifecycle perspective, residual values are taken into consideration for components with lifetimes that are longer than the chosen calculation period. For components that have a shorter lifetime than the chosen calculation period, the replacement of the component needs to be taken into account.

This lifecycle approach is important as it does not limit the assessment to partial or short-term optimisations.

## INVESTMENT COSTS

The methodology takes into account the investment costs of measures that are related to the energy performance of a building.

*These include:*

- ▶ *investments related to the efficiency of the building envelope: measures to reduce the thermal transmittance of building elements, low-energy windows and doors, measures related to air tightness;*
- ▶ *investment in energy supply systems for space heating and domestic hot water: fossil or renewable supply systems, including storage and distribution;*
- ▶ *ventilation/air conditioning: ventilation systems with or without heat recovery, active cooling systems;*
- ▶ *investments in lighting systems;*
- ▶ *other energy-related investments such as external shading devices, building automation/smart buildings;*
- ▶ *installation costs of systems and components.*

## ANNUAL COSTS

Annual costs include costs for energy carriers that cover the demand for space heating and cooling, ventilation, domestic hot water and lighting, including auxiliary energy. They also include operational costs, maintenance costs and costs for periodic replacement. Income from produced energy (e.g. via photovoltaic systems or combined heat and power) can be subtracted from the costs for energy carriers. The lifetime (service lifetime) of measures should be set according to the information set out in European standards (e.g. EN15459).

Energy prices have an influence on the final results of the methodology. The EPBD recast specifies that the Commission must provide information and guidance with respect to long-term energy price developments. Possible sources of information might be price scenarios developed by the International Energy Agency (IEA).

## INTEREST RATES

The choice of real interest rates (interest rate adjusted to inflation rate) is an important input for this calculation. The assumed rates will differ depending on the perspective (private or societal). The final methodology should therefore include guidance on applicable interest rates.

## EXAMPLES OF CALCULATIONS

Here we present some examples of calculations of the economic and environmental effect of packages of measures in reference buildings. These examples are indicative. They do not represent the matrix of reference buildings and packages of measures to be covered in a full assessment at country level.

These examples assume an average value of 3,000 Kelvin days per year for the moderate European climate zone and use the following data for energy prices:

**Table 1: Assumed energy prices<sup>24</sup> during calculation period of 30 years (incl. taxes)**

	Average 2010 – 2039 (excluding inflation)
Natural gas	12 euro cent/kWh
Electricity	21 euro cent/kWh

The lifecycle period for the global costs calculation was set at 30 years. Residual values have been considered for components with a longer lifetime or remaining lifetimes after replacement via straight-line depreciation. An interest rate of 4% (excluding inflation) is assumed.

### Retrofit

In the following example of a retrofit situation, two different packages of measures are applied to a reference multi-family building (707 m<sup>2</sup> of living area).

**Table 2: Retrofit package 1**

Insulation	Insulation of floor, façade and roof (5 cm/8 cm/12 cm)
Windows	U-value of windows of 1.6 W/m <sup>2</sup> K
Energy supply	Gas boiler
Calculated energy demand	66 kWh/m <sup>2</sup> a (space heating) 12.5 kWh/m <sup>2</sup> a (domestic hot water)

<sup>24</sup> Price development taken from accompanying document to the proposal for a recast of the energy performance of buildings directive (2002/91/EC) – Impact assessment, European Commission 2008

**Table 3: Retrofit package 2**

Insulation	Insulation of floor, façade and roof (15 cm/20 cm/25 cm)
Windows	U-value of windows of 0,8 W/m <sup>2</sup> K
Energy supply	Ground water heat pump (electric)
Energy demand	30 kWh/m <sup>2</sup> a (space heating) 12.5 kWh/m <sup>2</sup> a (domestic hot water)

For comparison, a situation with only maintenance measures is included (replacement of heating system without technology shift, renewal of façade without insulation measures, replacement of windows at lowest available standard).

**Table 4: Only maintenance measures**

Insulation	No additional insulation, but renewal of façade (plaster)
Windows	U-value of windows of 1.8 W/m <sup>2</sup> K
Energy supply	Gas boiler
Energy demand	209 kWh/m <sup>2</sup> a (space heating) 12.5 kWh/m <sup>2</sup> a (domestic hot water)

The results regarding primary energy consumption and the global sum of energy-related costs over a 30-year period are described in the following graph. For a better comparison between different building types, the results are related to the amount of m<sup>2</sup> of conditioned floor area.

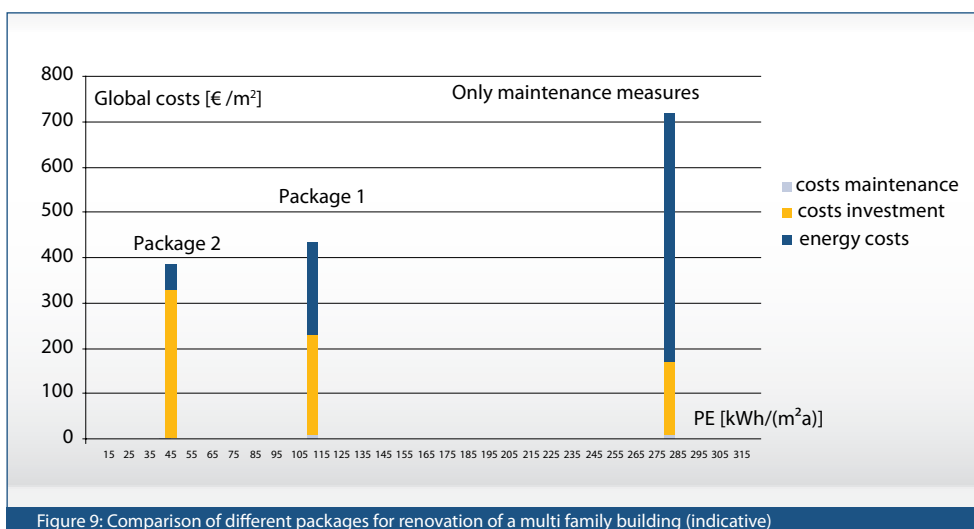


Figure 9: Comparison of different packages for renovation of a multi family building (indicative)

With global costs of 440 EUR/m<sup>2</sup>, package 1 has higher lifecycle costs than package 2 (385 EUR/m<sup>2</sup>). However, the primary energy consumption drops from 108 (package 1) to 41 kWh/m<sup>2</sup>a (package 2). The “only maintenance package” gives, in this comparison, the worst performance in economic and environmental terms with a primary energy consumption of 280 kWh/m<sup>2</sup>a and lifecycle costs of 720 EUR/m<sup>2</sup>.

## New building

In this situation a new building is reviewed. Two different packages of measures are applied to a reference semi-detached single-family house (116 m<sup>2</sup> of living area).

**Table 5: New building package 1**

Insulation	Insulation of floor, façade and roof (10 cm/10 cm/15 cm)
Windows	U-value of windows of 1.4 W/m <sup>2</sup> K
Energy supply	Gas boiler
Energy demand	50 kWh/m <sup>2</sup> a (space heating) 12.5 kWh/m <sup>2</sup> a (domestic hot water)

**Table 6: New building package 2**

Insulation	Insulation of floor, façade and roof (15 cm/20 cm/25 cm)
Windows	U-value of windows of 0.8 W/m <sup>2</sup> K
Energy supply	Ground water heat pump (electric)
Calculated energy demand	27 kWh/m <sup>2</sup> a (space heating) 12.5 kWh/m <sup>2</sup> a (domestic hot water)

The following graph shows the results regarding primary energy consumption and the global sum of energy-related costs over a 30-year period.

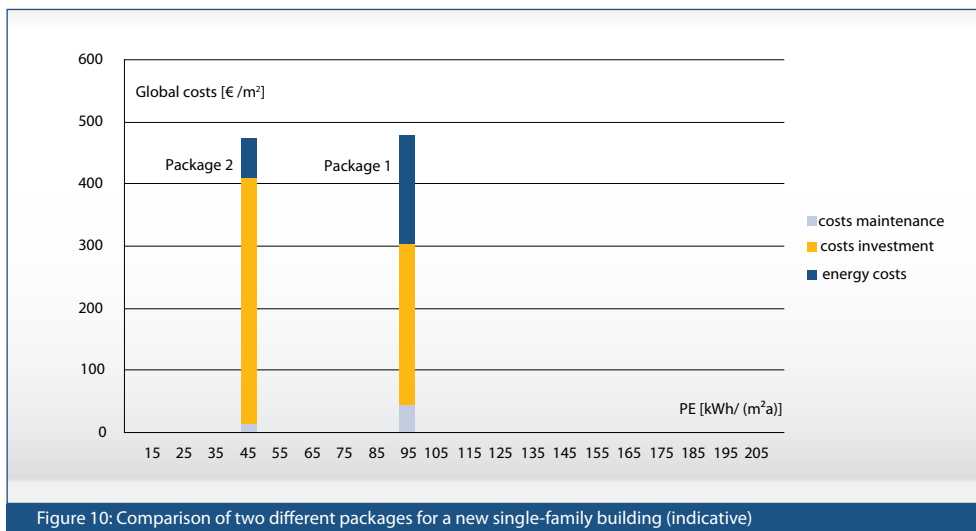


Figure 10: Comparison of two different packages for a new single-family building (indicative)

With global costs of 480 EUR/m<sup>2</sup> (package 1) and 475 EUR/m<sup>2</sup> (package 2), the two solutions demonstrate a similar cost level, although the primary energy use does drop from 92 kWh/m<sup>2</sup>a (package 1) to 45 kWh/m<sup>2</sup>a (package 2).

# SUMMARY AND OUTLOOK

## BENEFITS OF THE METHODOLOGY

The provisions of the EPBD recast on cost-optimal levels for minimum energy performance requirements incorporate a holistic lifecycle approach for buildings which is not limited to partial or short-term optimisations. The methodological approach is unbiased towards different technologies and delivers transparent results. National circumstances can be taken into account to ensure individualised and fair treatment of Member States and their specificities. The process can be performed at low administrative cost at the Member State level.

## EXCHANGE OF EXPERIENCES

The comparison of assessments at Member State level will provide a clear picture of the current situation and theoretical potential if cost-optimal levels are applied across Europe. In addition, the exchange of national information will create a common understanding of opportunities, challenges and even limitations regarding minimum energy performance requirements at European level. The exchange of experiences between Member States in using the methodology should be an integral part of the process. Conferences and other platforms for dialogue will support this exchange. The knowledge gained can provide clear guidance and drive the update of existing national building regulations.

## EXTENDED USE OF THE METHODOLOGY

Besides delivering information to update current requirements, the methodology is suitable for comparing results with advanced environmental targets. If the definition of the economic optimum does not sufficiently stimulate the achievement of such targets, the methodology could also serve as a guiding tool to help improve framework conditions. For instance, soft loans could shift the economic optimum towards environmental and societal targets. This would facilitate a smooth transition in the regulations towards nearly zero-energy buildings for new buildings after 2020. Used in such a way, the methodology principles, although focused on financial performance, are well suited to staying on track with future environmental targets.



## FURTHER DEVELOPMENT AND CHALLENGES

Alongside the basic framework of the methodology described in the EPBD recast, further details are to be developed, for example:

- ▶ *energy price forecasts and their updates need to be supplied by the Commission;*
- ▶ *the distinction between private and societal perspectives needs further elaboration;*
- ▶ *in addition, CO<sub>2</sub> emissions could be a useful additional indicator for comparison with GHG reduction targets.*

In this process of defining and agreeing on all the details of the methodology, it is very important that Member States and all other stakeholders (industry, project developers, homeowner associations, NGOs, scientific organisations, etc.) are actively involved. This ensures that the various perspectives are taken into account to make the methodology on cost-optimal requirements a powerful tool for promoting smart and efficient buildings in Europe.

# ANNEX

## Some definitions

<b>Cost-optimal level</b>	Cost-optimal level means the energy performance level which leads to the lowest cost during the estimated economic lifecycle.
<b>Delivered energy</b>	Energy supplied to the building (e.g. natural gas from the grid). Energy produced by the building itself and delivered back to the market is subtracted.
<b>Energy performance certificate</b>	Energy performance certificate means a certificate recognised by a Member State or by a legal person designated by it, which indicates the energy performance of a building or building unit.
<b>Energy performance of a building</b>	Energy performance of a building means the calculated or measured amount of energy needed to meet the energy demand associated with a typical use of the building, which includes <i>inter alia</i> energy used for heating, cooling, ventilation, hot water and lighting.
<b>Global costs</b>	The global cost calculation method is described in EN 15459: <i>Energy performance of buildings – economic evaluation procedure for energy systems in buildings</i> . Global costs are defined as the net present value (NPV) of all costs during a defined calculation period.
<b>Nearly zero-energy buildings (NZEB)</b>	“Nearly zero-energy building” means a building that has very high energy performance, as determined in accordance with Annex I of the EPBD recast. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby.
<b>Net energy use</b>	Net energy use is the energy to be supplied by the energy systems to provide the required services (like maintaining a desired indoor temperature).
<b>Net present value</b>	The net present value (NPV) is a standard method for the financial assessment of long-term projects. It measures the excess or shortfall of cash flows, calculated at their present value at the start of the project.

<b>Package of measures</b>	Combination of compatible energy efficiency and energy supply measures to be applied to a building.
<b>Passive House</b>	Building concept according to the Passiv house Institute which can be described by a very low heating requirement (less than 15 kWh/(m <sup>2</sup> a)) where the combined primary energy consumption for heat, hot water and household electricity may not exceed 120 kWh/(m <sup>2</sup> a).
<b>Primary energy</b>	Energy from renewable and non-renewable sources which has not undergone any conversion or transformation process.
<b>Reference buildings</b>	Representative buildings that are characterised by their functionality and regional conditions, including indoor and outdoor climate conditions, geometries etc.

## SOURCES OF FURTHER INFORMATION

- ▶ *Ecofys (2010). Calculation Methodology for reporting on national energy performance requirements on the basis of cost efficiency within the framework of the EPBD, report for ECEEE.*
- ▶ *Ecofys (2007) U-values for better energy performance of buildings (Ecofys VII), Report for EURIMA*
- ▶ *Ecofys (2005a) Cost-effective Climate Protection in the EU Building Stock. Report for EURIMA*
- ▶ *Ecofys (2005 b) Cost-effective Climate Protection in the Building Stock of the NEW EU Member States. Report for EURIMA*
- ▶ *Website of the European Council for an Energy Efficient Economy with information on the EPBD and its recast ([www.eceee.org](http://www.eceee.org)).*
- ▶ *BUILD UP, the European web portal for energy efficiency in buildings (<http://www.buildup.eu>)*
- ▶ *EU Commission website: Energy policy for a competitive Europe (<http://ec.europa.eu/energy>).*
- ▶ *EU Commission website, specific page for buildings: ([http://ec.europa.eu/energy/efficiency/buildings/buildings\\_en.htm](http://ec.europa.eu/energy/efficiency/buildings/buildings_en.htm))*
- ▶ *Website of European Committee for Standardization (CEN), [www.cen.eu](http://www.cen.eu)*
- ▶ *Intelligent Energy Europe project TABULA. <http://www.building-typology.eu/>*

## Directive 2010/31/EU on the energy performance of buildings (recast)

This Directive was officially adopted by the European Parliament and the Council of the European Union on May 19, 2010 (Article 5 and Annex III)

### ARTICLE 5: CALCULATION OF COST-OPTIMAL LEVELS OF MINIMUM ENERGY PERFORMANCE REQUIREMENTS

1. The Commission shall establish by means of delegated acts in accordance with Articles 23, 24 and 25 by 30 June 2011 a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements.

The comparative methodology framework shall be established in accordance with Annex III and shall differentiate between new and existing buildings and between different categories of buildings.

2. Member States shall calculate cost-optimal levels of minimum energy performance requirements using the comparative methodology framework established in accordance with paragraph 1 and relevant parameters, such as climatic conditions and the practical accessibility of energy infrastructure, and compare the results of this calculation with the minimum energy performance requirements in force.

Member States shall report to the Commission all input data and assumptions used for those calculations and the results of those calculations. The report may be included in the Energy Efficiency Action Plans referred to in Article 14(2) of Directive 2006/32/EC. Member States shall submit those reports to the Commission at regular intervals, which shall not be longer than five years. The first report shall be submitted by 30 June 2012.

3. If the result of the comparison performed in accordance with paragraph 2 shows that the minimum energy performance requirements in force are significantly less energy efficient than cost-optimal levels of minimum energy performance requirements, the Member State concerned shall justify this difference in writing to the Commission in the report referred to in paragraph 2, accompanied, to the extent that the gap cannot be justified, by a plan outlining appropriate steps to significantly reduce the gap by the next review of the energy performance requirements as referred to in Article 4(1).
4. The Commission shall publish a report on the progress of the Member States in reaching cost-optimal levels of minimum energy performance requirements.

### **ANNEXE III: COMPARATIVE METHODOLOGY FRAMEWORK TO IDENTIFY COST-OPTIMAL LEVELS OF ENERGY PERFORMANCE REQUIREMENTS FOR BUILDINGS AND BUILDING ELEMENTS**

The comparative methodology framework shall enable Member States to determine the energy performance of buildings and building elements and the economic aspects of measures relating to the energy performance, and to link them with a view to identifying the cost-optimal level.

The comparative methodology framework shall be accompanied by guidelines outlining how to apply this framework in the calculation of cost-optimal performance levels.

The comparative methodology framework shall allow for taking into account use patterns, outdoor climate conditions, investment costs, building category, maintenance and operating costs (including energy costs and savings), earnings from energy produced, where applicable, and disposal costs, where applicable. It should be based on relevant European standards relating to this Directive.

*The Commission shall also provide:*

- ▶ *guidelines to accompany the comparative methodology framework; these guidelines will serve to enable the Member States to undertake the steps listed below,*

- ▶ *information on estimated long-term energy price developments.*

*For the application of the comparative methodology framework by Member States, general conditions, expressed by parameters, shall be laid down at Member State level.*

*The comparative methodology framework shall require Member States to:*

- ▶ *define reference buildings that are characterised by and representative of their functionality and geographic location, including indoor and outdoor climate conditions. The reference buildings shall cover residential and non-residential buildings, both new and existing ones,*
- ▶ *define energy efficiency measures to be assessed for the reference buildings. These may be measures for individual buildings as a whole, for individual building elements, or for a combination of building elements,*
- ▶ *assess the final and primary energy need of the reference buildings and the reference buildings with the defined energy efficiency measures applied,*
- ▶ *calculate the costs (i.e. the net present value) of the energy efficiency measures (as referred to in the second indent) during the expected economic lifecycle applied to the reference buildings (as referred to in the first indent) by applying the comparative methodology framework principles.*

By calculating the costs of the energy efficiency measures during the expected economic lifecycle, the cost-effectiveness of different levels of minimum energy performance requirements is assessed by the Member States. This will allow the determination of cost-optimal levels of energy performance requirements.





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