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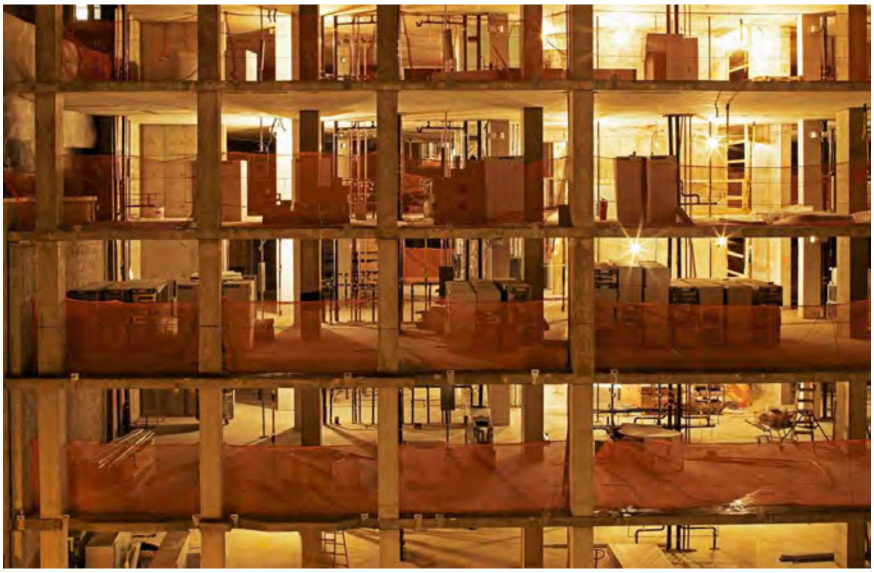
Cost optimal building performance requirements

Calculation methodology for reporting on national energy performance requirements on the basis of cost optimality within the framework of the EPBD



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Thomas Boermans, Kjell Bettgenhäuser, Andreas Hermelink, Sven Schimschar and other Ecofys international staff

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eceee SECRETARIAT
SVEAVÄGEN 98 IV
SE-113 50 STOCKHOLM
SWEDEN

www.eceee.org
eceee@eceee.org

Introductory remarks

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The report was prepared by Thomas Boermans, Kjell Bettgenhäuser, Andreas Hermelink, Sven Schimschar (all of Ecofys) with support from other Ecofys international staff. The research is presented on a best-efforts basis and the views expressed herein are solely those of the authors, who makes no representations or warranties, expressed or implied. The views do not necessarily reflect those of eceee or its members, or those of the report's funders.

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Table of contents

1 Background and objective

On the European level, the principles for the requirements for the energy performance of buildings are set by the Energy Performance of Buildings Directive (EPBD). Dating from December 2002, the EPBD has set a common framework from which the individual Member States in the EU developed or adapted their individual national regulations.
The EPBD in 2008 and 2009 underwent a recast procedure, with final political agreement having been reached in November 2009. The new Directive was then formally adopted on May 19, 2010. Among other clarifications and new provisions, the EPBD recast introduces a benchmarking mechanism for national energy performance requirements for the purpose of determining cost-optimal levels to be used by Member States for comparing and setting these requirements.

The previous EPBD set out a general framework to assess the energy performance of buildings and required Member States to define maximum values for energy delivered to meet the energy demand associated with the standardised use of the building.
However it did not contain requirements or guidance related to the ambition level of such requirements. As a consequence, building regulations in the various Member States have been developed by the use of different approaches (influenced by different building traditions, political processes and individual market conditions) and resulted in different ambition levels where in many cases cost optimality principles could justify higher ambitions[1].
The EPBD recast now requests that Member States shall ensure that minimum energy performance requirements for buildings are set "with a view to achieving cost-optimal levels". The cost optimum level shall be calculated in accordance with a comparative methodology.

The objective of this report is to contribute to the ongoing discussion in Europe around the details of such a methodology by describing possible details on how to calculate cost optimal levels and pointing towards important factors and effects.
The methodology described in this report is consistent with the description of the process as presented in the study "Cost Optimality – Discussing methodology and challenges within the recast Energy Performance of Buildings Directive" published in September 2010 by the Buildings Performance Institute Europe (BPIE).[2] The present document provides additional insights and details.

The following text summarizes the provisions of the EPBD recast text regarding calculating and achieving cost-optimal requirements:

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[1] See e.g. "U-values for better energy performance of buildings", report for EURIMA-European Insulation Manufacturers Association, Ecofys 2007

[2] www.bpie.eu.

Methodology to calculate cost-optimal levels

The Commission shall have established by June 2011 a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements (e.g. the roof of a building). The comparative methodology framework shall require Member States to:

- define reference buildings that are characterized by and representative for their functionality and climate conditions. The reference buildings shall cover residential and non-residential buildings, both new and existing ones;
- define energy efficiency measures that are assessed for the reference buildings. These may be measures for buildings as a whole, for 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. Related calculations should be based on relevant European standards; and
- calculate the costs (i.e. the net present value) of the energy efficiency measures during the expected economic life cycle applied to the reference buildings, taking into account investment costs, maintenance and operating costs, earnings from energy produced and disposal costs.

Assessment and comparison to current standards

With the methodology being supplied by the European Commission, the assessment of input data (e.g. climate conditions, investment costs etc.) and the calculation of the results is done by and on the level of individual Member States. However joint issues like information regarding estimated long-term energy price developments are to be provided by the European Commission. By using this common methodology, the Member States identify cost-optimal levels of minimum energy performance requirements for new and existing buildings and building elements and compare the results of these calculations to the minimum energy performance requirements in force.

Member States are requested to report to the Commission all input data and assumptions used for these calculations and the results of the calculations. Member States need to submit their reports to the Commission at regular intervals of maximum five years, with the first report due by June 2012. If the result of the benchmarking performed shows that the minimum energy performance requirements in force are significantly less energy efficient than cost-optimal levels of minimum energy performance requirements (i.e. exceeding 15%), the Member State needs to explain this difference. In case the gap cannot be justified, a plan needs to be developed by the respective Member State, outlining appropriate steps to significantly reduce the gap by the next review of the energy performance requirements. The Commission will publish a report on the progress of the Member States regarding cost-optimal levels of minimum energy performance requirements.

In the following chapters, the outline of a possible methodology for calculating and comparing the cost of different packages of energy-related measures when applied to new or existing buildings or building elements is described.

2 Deriving minimum performance requirements

The cost efficiency of energy performance requirements can be assessed by calculating the life cycle costs for the building and building elements on the basis of different packages of measures applied to a reference building and setting them in relation to both the energy use and CO_2-emissions.

Regarding costs, a societal viewpoint and a private perspective can be distinguished and may lead to different results. For setting performance requirements, the societal view should be a first guiding principle, ensuring benefits for the society as a whole.
However it is very important to also assess the costs from a private perspective to make sure that societal and private perspective match, and (if this is not the case) take appropriate legal or political and economic measures to reduce and close this gap, e.g. by distributing efforts and benefits in a better way.[3]
Cost calculations for societal or private perspective differ regarding applicable interest rates, in- or exclusion of costs of CO_2 , subsidies, taxes etc. These differences are further explained in chapter 6.

Reference buildings shall be representative for the building's functionality and geometry and need to be defined for new buildings and retrofit situations. The design and/or selection of reference buildings are the responsibility, for the most part, of the national and regional authorities.

An example of the results for different packages applied to a chosen reference building is shown in Figure 1 below. The figure depicts global costs (see explanations in chapter 6.2) of packages related to primary energy use. Corresponding graphs can also be developed related to CO_2-emissions of assessed packages. This is also the case for the following figures 2 and 3.

[3] e.g., measures to solve the owner/tenant or investor/user conflict in rented buildings or ways to monetize and internalise costs of CO_2 -emissions

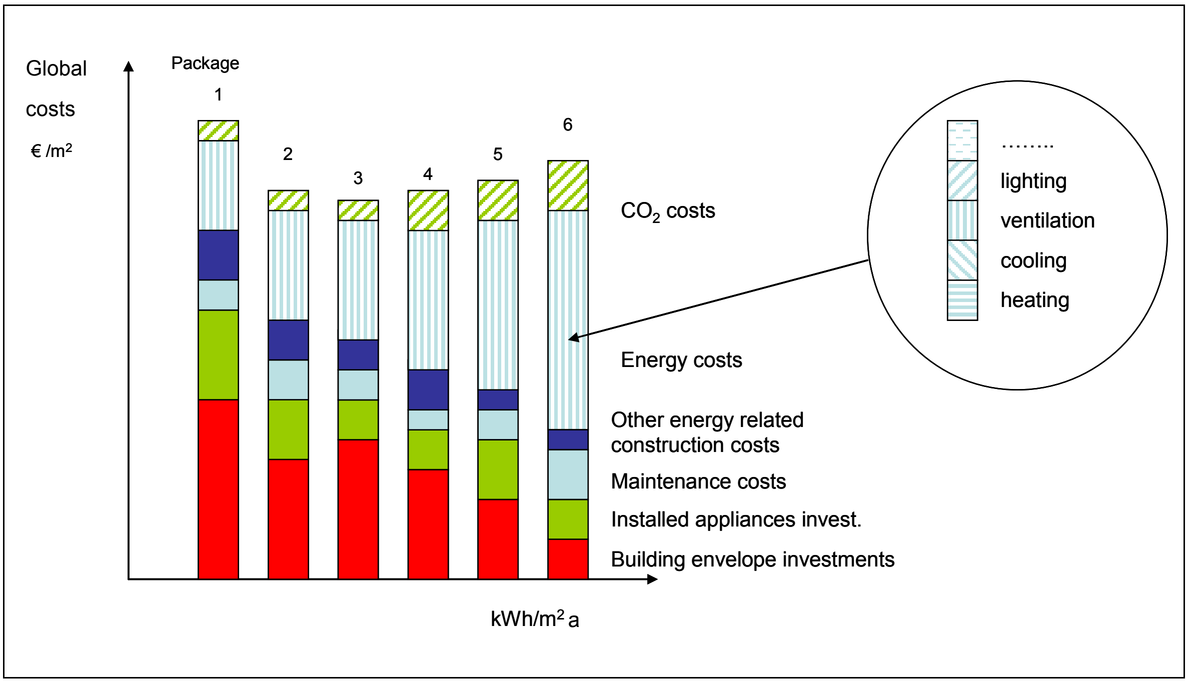

Figure 1: Cost calculations of different packages (example only)

From the variety of specific results for the assessed packages, a specific cost curve can be developed; see Figure 2. The combination of packages with the lowest cost will provide the minimum level of requirement at the optimal cost. If packages should have the same cost, the package with the lower energy use should normally be selected.

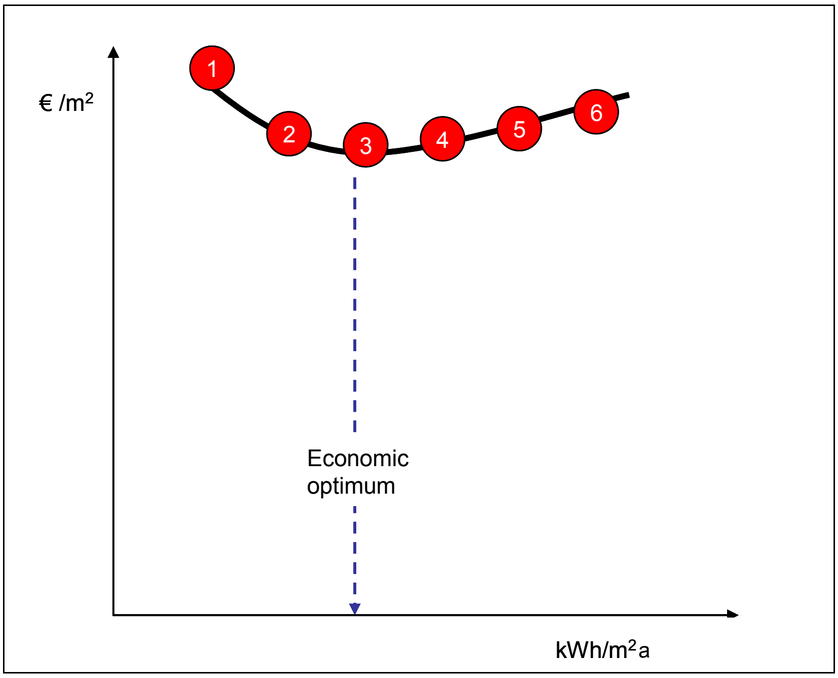

Figure 2: Defining a cost optimum

To get a clear and comprehensive picture of the representative curve, all kinds of commonly used combinations of measures should be taken into account, both short-term and long-term, covering the span from combination of measures to comply with current regulations and best practices, up to combinations to realize very low and nearly zero energy buildings and passive houses, including various options for renewable energy supply.

In reality, the targeted large number of solutions will most probably not form an exact curve. It can be assumed that the data sets will form a “cloud” from which an average curve can be derived.

Relation to "nearly zero energy buildings" (NZEB) target of the EPBD recast

A new article has been introduced in the EPBD recast on nearly zero energy buildings. These are described as buildings that have a very high energy performance with the nearly zero or very low amount of energy required to a very significant extent be covered by energy from renewable sources. As from first of January 2019, public authorities that occupy and own a new building shall ensure that the building is a nearly zero energy building. As from first of January 2021 on, all new buildings have to be nearly zero energy buildings.

In case the economic optimum does not deliver sufficient guidance to reach such NZEB targets by the indicated dates, the methodology should be robust enough to be used as a transparent steering tool to improve framework conditions in order to "push" the economic optimum towards the point that will meet environmental and societal targets. Parameters that could push the optimum towards even more ambitious levels could be e.g. reduced interest rates, direct support, loan guarantees, inclusion of CO_2-price in energy costs, cost reductions (economies of scale), performance and productivity improvements (learning curves). Such approaches could support a smooth transition from private-economic cost optimal requirements (2010 – 2020) to nearly zero energy standard for new buildings after 2020 (for new public buildings already after 2018).

Looking at such a cost curve (see Figure 3), the minimum performance requirements for sustainable buildings should be set within the part of the curve that delivers the best energy and environmental performance at the lowest cost, which could be better than current requirements at less or at the same overall cost. Societal priorities may also lead to setting minimum requirements that are stricter than the private cost-optimal, as for example to the left of the "Best practice" field in Figure 3.

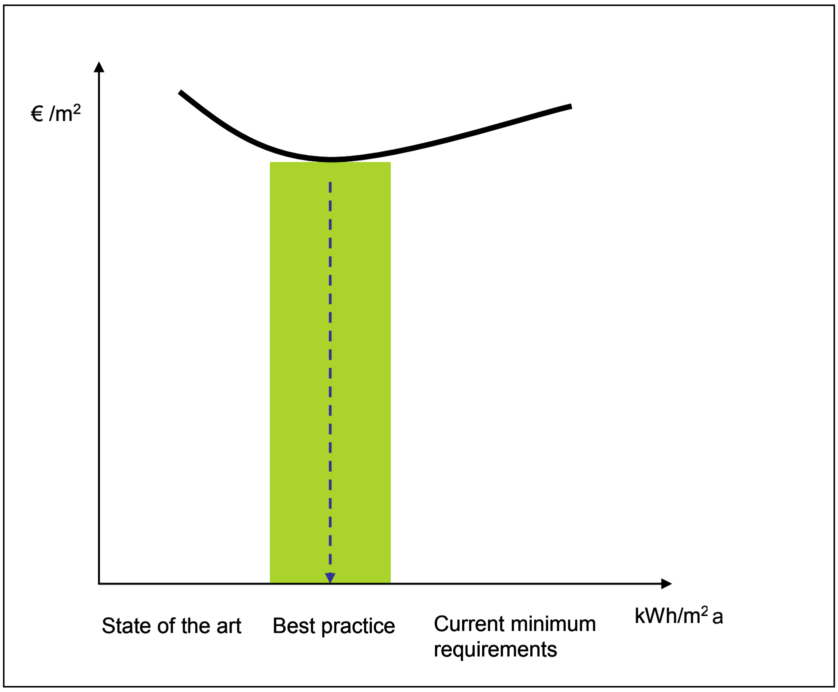

Figure 3: Position of minimum performance requirements (example)

To perform these kinds of calculations, it is necessary to:

- Identify the market segments and the segmentation of the current energy performance requirements (different requirements for different building types) where applicable;
- define and select a sufficient number of reference buildings that are characterised by their functionality, characteristics and regional conditions, including indoor and outdoor climate conditions;
- specify packages of energy saving- energy efficiency- and energy supply measures to be assessed;
- calculate per reference building the energy demand and energy supply for a wide number of packages representing “current practices”, “best practices” and “state of art solutions”;
- calculate on the supply-related primary energy and CO_2-emissions for the combination of packages for the reference building;
- assess the corresponding energy-related investment costs, energy costs and other running costs of relevant packages applied to the selected reference buildings;
- from the cost curve of packages for a reference building identify the best performing package with respect to delivered energy, primary energy and CO_2-emissions; and
- identify the optimum energy performance requirement for a weighted average of all reference types per market segment;
- use, when appropriate, the established reference buildings and relevant packages to identify, using the same methodology, cost-optimal energy performance requirements for building elements and technical building systems.

Two-step-approach vs. direct move to very low energy buildings

The methodology could also be used to compare a two-step-approach (build a standard new building and renovating it at a later stage to a final target) with a direct move to a more ambitious target.
If, for example, nearly zero energy would be required also for existing buildings at a later stage (e.g. 2030) it could be financially attractive to do this in one step and already now. The following graphs describe the global costs of different options around this issue. For this specific example, a calculation time (see also chapter 6.3) of 60 years has been chosen to be able to assess the effects of such a two-stage approach.

The following figure compares the global costs of a new single-family house to which a standard or an advanced package of energy efficiency measures is applied. In this example, the standard option at a lower ambition level turns out to be financially more attractive.

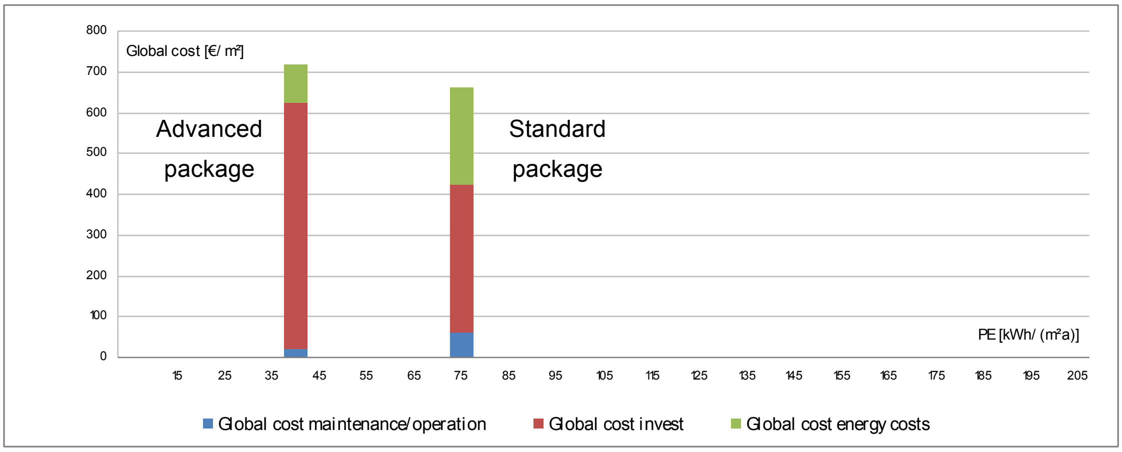

Figure 4: Comparison of two different packages for new single family building (indicative)

In the case when the building is upgraded after 30 years to the advanced standard, extra costs develop from the fact that it is, for example, more difficult to implement a ventilation system with heat recovery or a heat pump system in an existing building at a later stage compared to a situation in a new building with integral planning right from the start.

In the example below, this leads to a situation where the one- and two step approaches show very similar costs, with the one-step approach being more beneficial in environmental terms.

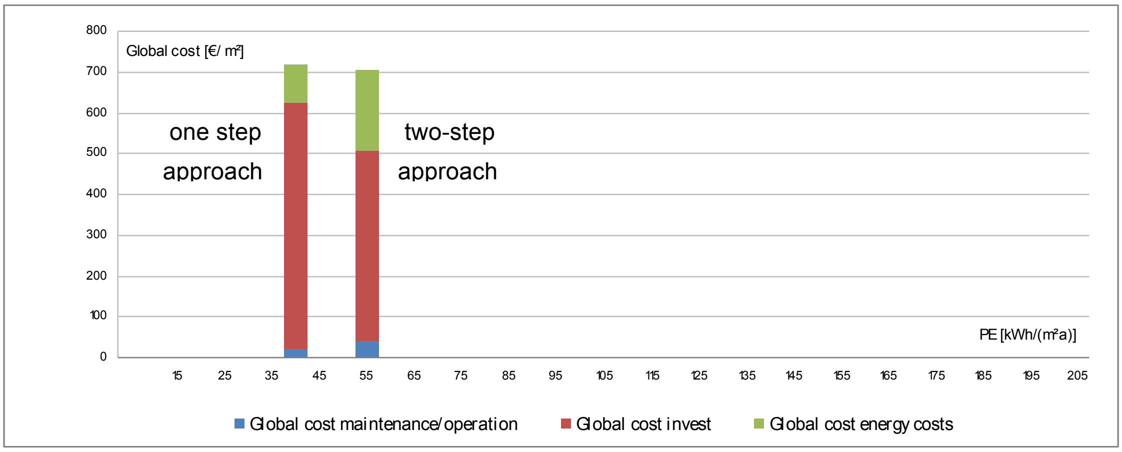

Figure 5: Comparison of one- and two step approach. Renovation executed after 30 years (indicative)

In the case where an improvement is carried out prematurely (e.g. after 20 years, before the end of the first retrofit cycle), the costs of the two-step approach increase, as parts of the measures, e.g. thermal insulation, need to be exchanged before the end of their lifetime and it is not likely that residual values can be realized by selling the used material in the market.
As a consequence, the one-step approach in this example turns out to be more attractive from a financial and environmental point of view.

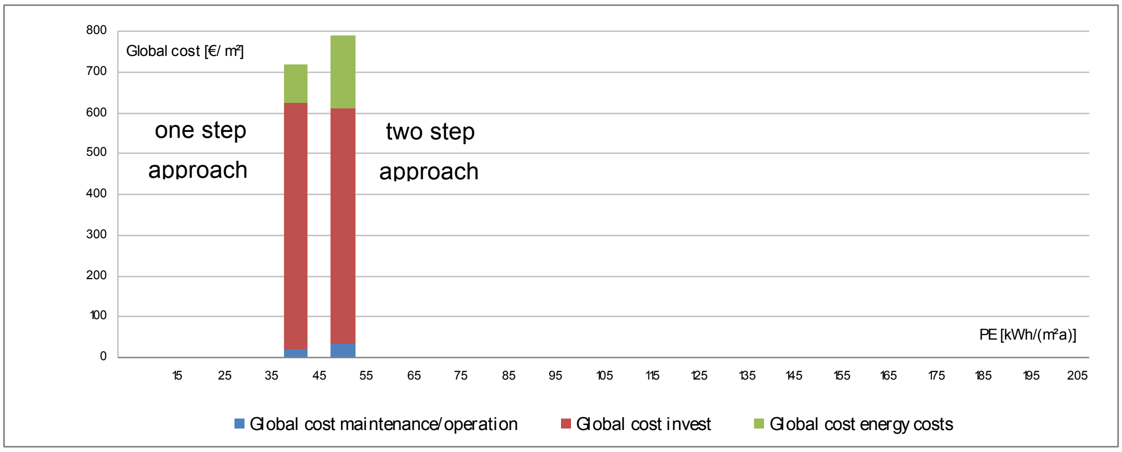

Figure 6: Comparison of one- and two-step approach. Renovation executed after 20 years (indicative)

The shown effect depends on the specific measures in a one- or two-step approach and on the circumstances, like timing of the second step, energy price developments, interest rates etc. However it is clear that a direct move can be more feasible than it looks at first, and that the described methodology to calculate cost-optimal requirements offers the possibility to assess such effects.

Renovation or demolition

The method on cost optimality in relation to existing buildings is meant to define energy performance requirements for buildings during renovation. It is not designed in normal circumstances to be used to make decisions regarding whether to renovate a particular building or to demolish it. Such a decision needs to be carefully taken by the individual owner of a building when facing the choice of either renovating the building according to the building regulations or to demolish it and e.g. build a new one. This is then also influenced by many other parameters like e.g. the area where the building is located, specifics of the rental market, societal issues etc. However parts of the calculation process for the cost optimal methodology can be used to support the decision of renovation vs. demolition and building new.

3 Reference buildings

3.1 Background

The calculations need to be based on well chosen and well defined reference buildings, which represent the average situation for different types of new buildings and retrofits in a market segment at country or regional level. Therefore, national and regional building typologies, as far as available, should be used. Additionally, the following aspects play a role when defining the reference buildings on which the chosen packages of measures are applied.

Structure of performance requirements:
The reference buildings and the structure of current energy performance requirement should correspond, for example:

- if national requirements distinguish between different climate zones and/or regions of a country, the reference building should be representative for the specific climate zone and/or region; or
- if different energy performance requirements are given for different kinds of buildings, including age categories, the reference buildings shall be representative for the specified segment.

Climate conditions:
Climate conditions shall be used in accordance with EN ISO 15927- "Hygrothermal performance of buildings - Calculation and presentation of climatic data" applied as a country average or per climate zone, in case this distinction is being made in the national building regulation. The Heating Degree Days and Cooling Degree Days are defined in the national or regional regulations of standards or can be taken from EUROSTAT data

The minimum respective maximum comfort temperature and the acceptable number of discomfort days also should be taken from the national or regional applicable regulations or standards. Where not available, reference can be made to EN15251 defined parameters of design.

Orientation and shading:
Depending on the geometries of the building and size and distribution of window surface, the orientation of a building as well as shading (from near-by buildings or from trees) can have significant influence on the benefits and loads of passive solar gains and thus on energy demand for heating and/or cooling of a building. The average situation for the reference building(s) shall be reflected in the impacts of orientation, solar gains, shading, demand for artificial lighting, etc.

Construction products in load carrying structures

Construction products in floors, the roof and the building envelope contribute to the thermal performance of the building components and have their impact on the energy demand of a building. A high mass of a building can for example reduce the energy demand for cooling during the summer. Therefore the chosen reference buildings shall reflect the average characteristics for that building type. It is probable that a distinction needs to be made between different kinds of buildings in the definition of reference buildings (e.g. massive buildings and lightweight constructions) if sufficiently large shares occur in a specific country.

3.2 Residential buildings

3.2.1 New

Types that should be distinguished are:

- Different kinds of single family houses (e.g. detached, semi detached, row house) and apartment blocks of different sizes.
- Geometries and other properties should reflect the typical situation in new buildings (e.g. design to facilitate passive solar gains or solar protection etc.)

3.2.2 Retrofit

Types that should be distinguished are:

- Different kinds of single family houses (e.g. detached, semi detached, row house) and apartment blocks of different sizes.
- Geometries and other properties should reflect the typical situation in retrofit situations. Retrofit activities are often applied to buildings from the 70s or earlier, as these buildings are more than 30 years old and in strong need of refurbishment and usually show high energy use.

3.3 Non-residential buildings

3.3.1 New

According to Annex I of the EPBD the following types of buildings can be distinguished:

- Offices
- Educational buildings
- Hospitals
- Hotels and restaurants
- Sports facilities
- Wholesale and retail trade services buildings
- Other types of energy-consuming buildings

The chosen reference buildings should represent average geometries and properties and different size classes should be distinguished.

3.3.2 Retrofit

According to the explanations for the residential buildings, reference buildings need to be defined also for usual retrofit situations in non residential-buildings.

3.4 Building typology

The greater the number of reference buildings that are developed to cover the above mentioned aspects, the more accurate the assessment of cost optimal requirements will be. An example of a building typology (here for residential buildings) is described in Figure 7 below. The example shows what a classification of a building stock can look like. However such classifications need to be adapted when used for the methodology on cost-optimal requirements, e.g. by aggregating age groups.

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Figure 7: Classification scheme of the German Building Typology [IWU 2003]

4 Definition of packages

To get a clear picture of the average cost curve as described above, packages shall be defined and calculated separately for the new building situation and for retrofit activities, each for residential and non-residential buildings (see explanations on reference building in chapter 3).

It is important to note that meaningful combinations of measures can create synergy effects that lead to better results (regarding costs and regarding environmental performance) than single measures. Within a package of measures, efficiency measures with short payback times may allow for other measures that require a higher investment with a longer payback period but which could add substantially to lower primary energy usage and CO_2 emissions associated with the total building concept. The more packages (and variation of the measures included in the assessed package), the more accurate the calculated optimum of the achievable performance will be. In this sense for instance, packages showing the impact on costs and overall energy performance of marginally varying the thermal performance of the building envelope provides a broad spectrum of results.

It is of crucial importance to note that in retrofit activities coupled to normal non-energy maintenance measures, the realized energy savings costs must not be judged against the total costs of all the renovation measures, but need to be projected against, and limited to, the costs of the additional energy-related investments only. These are the total investment costs for energy efficiency measures minus the investment costs for renovation without energy improvements (with pre-existing energy efficiency measures kept in place as part of a baseline). See also Chapter 6.4.1 as well as methodology and explanations in the Ecofys III and IV studies.[4]

To reflect the effect of non-energy related renovation costs, the total costs (investment costs and running costs) of a building undergoing maintenance measures without improvements in energy efficiency (by renewal of façade/cladding, exchange of windows without improvement of U-value, replacement of supply systems without technology shift etc.) shall be assessed as a baseline retrofit option (a package) applied to the respective reference buildings, see Chapter 3.2.2. This would then be the reference or basis for comparison for the retrofit packages that do include energy efficiency measures.

[4] [Ecofys 2005a/b]

Further thoughts on compilation of packages

Packages can be compiled from measures that are related to space heating, domestic hot water, cooling, ventilation and lighting. Concerning type of measures, energy savings measures, efficient supply and renewable energy applications can be distinguished. The packages compiled should cover the range from current regulation up to (nearly) zero energy buildings, both for renovation and for new buildings, as well as for building elements. To provide guidance, packages should be compared that contain a variety of typical solutions that reflect:

- current requirements
- national/regional support schemes
- advanced solutions (passive house / zero energy buildings)

By fixing all parameters and varying only one measure (e.g. thickness of insulation, quality of windows or type of heating system) a large number of variations can be created from the above-described starting points that helps to refine the overall picture.

Single measures that show (also in combination) lower life cycle costs compared to possible alternatives will lead to lower life cycle costs of the total package. This makes clear that if e.g. only 2 measures are chosen, most probably cost (and energy) saving potentials will be missed out. On the other hand, the mere number of measures is not a clear indication of a cost-optimal package either.

The more varieties of measures are compiled and assessed, the clearer the final picture will be. However some boundaries have to be taken into account that refer to technical necessities, like the following list:

- Compiled packages need to comply with technical requirements (prevention of moisture, necessary air exchange etc.) and the demand of users regarding thermal comfort (room temperature, wall temperature etc.), as well as reasonable aesthetics;
- Within a package, the dimensioning of the supply system needs to be based on the energy saving and energy efficiency measures applied and the resulting reduced energy demand of the building in a longer perspective; and
- Lock-in-effects occur, when a measure is difficult to change or improve during or after its lifetime, when it has not been carried out during the normal renovation cycle. For example, air tightness measures are difficult to be improved at a later stage, because the construction will be closed and in many cases does not allow easy access anymore. Therefore such measures should be implemented in the best possible way right at the start.

Beyond the financial assessment and technical boundaries also societal aspects are of importance and should be reflected in the compiled packages, for example:

- The use of renewable energies do not only influence the environmental and financial performance of a building but also decrease the dependency of the building owner and society of fossil fuel (imports); and
- Energy saving measures decrease dependency of the building owner and society on any kind of fuel purchase (renewable or fossil).

5 Delivered energy, primary energy and CO_2-emissions

5.1 European standards for EPBD (CEN)

The original EPBD from 2002 had set out requirements for a calculation methodology (Article 3), minimum energy performance requirements (Article 4), energy performance certificates (article 7) and inspection of boilers and air-conditioning systems (Articles 8 and 9). To facilitate a common approach and comparability, the European Commission gave a mandate to CEN, to develop standards to be applied in the framework of the EPBD.

This resulted in the development of 31 CEN-standards concerning the EPBD. An overview of the developed standards and relations to other European standards are described in CEN/TR 15615:2008 "Explanation of the general relationship between various European standards and the Energy Performance of Buildings Directive (EPBD) - Umbrella Document". The aspects of these standards are drawn together in the following European and ISO Norms and their contents, which relate to the specific needs of the EPBD:

EN ISO 13790: 2008	"Energy performance of buildings - Calculation of energy use for space heating and cooling" Content: Energy for heating and cooling (taking into account losses and gains). It allows different levels of complexity: simplified monthly or seasonal calculation, simplified hourly calculation and detailed calculation.
EN 15603: 2008	Energy performance of buildings - Overall energy use and definition of energy ratings" Content: Energy use for space heating, cooling, ventilation, domestic hot water and lighting, inclusive of system losses and auxiliary energy; and definition for energy ratings.
EN 15217: 2007	"Energy performance of buildings - Methods for expressing energy performance and for energy certification of buildings"
EN 15378: 2007	"Heating systems in buildings - Inspection of boilers and heating systems"
EN 15240: 2007	"Ventilation for buildings - Energy performance of buildings - Guidelines for inspection of air-conditioning systems"

5.2 Calculation steps

The energy demand and delivered energy (energy carriers supplied to the building) and resulting primary energy and CO_2-emissions are calculated in accordance with the CEN standards for the EPBD in three levels:

- Calculation of the building energy demand for heating, cooling and lighting;
- Calculation of the energy delivered to the building for heating and cooling, ventilation, domestic hot water and lighting including auxiliary energy; and
- Calculation of the overall energy use with performance indicators (primary energy, CO_2-emissions)

The calculation sequence is as follows:

- In a first step, the energy demand for heating and cooling are calculated. This part of the calculation considers the building properties and results in the energy to be emitted by supply systems in order to maintain the intended internal temperature. EN ISO 13790 covers heating and cooling. For these calculations, data are taken into account that refer to indoor climate requirements, internal heat gains, building properties and outdoor climatic conditions.
- Taking into account that the methodology should lead to a general assessment of the cost effectiveness of building energy performance requirements, the simplified monthly/seasonal calculation principle may be applied for this methodology. However more complex and detailed calculations methods, also offered by the CEN standards, are possible. Especially the issue of cooling energy demands might make e.g. dynamic simulations necessary.
- In a second step, the characteristics of the space heating, cooling, ventilation, domestic hot water and lighting systems, including controls and building automation are taken into account to calculate the delivered energy. Energy used for different purposes and by different fuels is recorded separately. The calculations take into account heat emission, distribution, storage and generation, including auxiliary energy needed for e.g. fans or pumps. From delivered energy, the corresponding primary energy and CO_2-emissions are calculated.
- System boundaries for these systems must be clearly described and consistently applied. The details are found in the appropriate CEN standards.

Figure 8 describes the overall scheme.

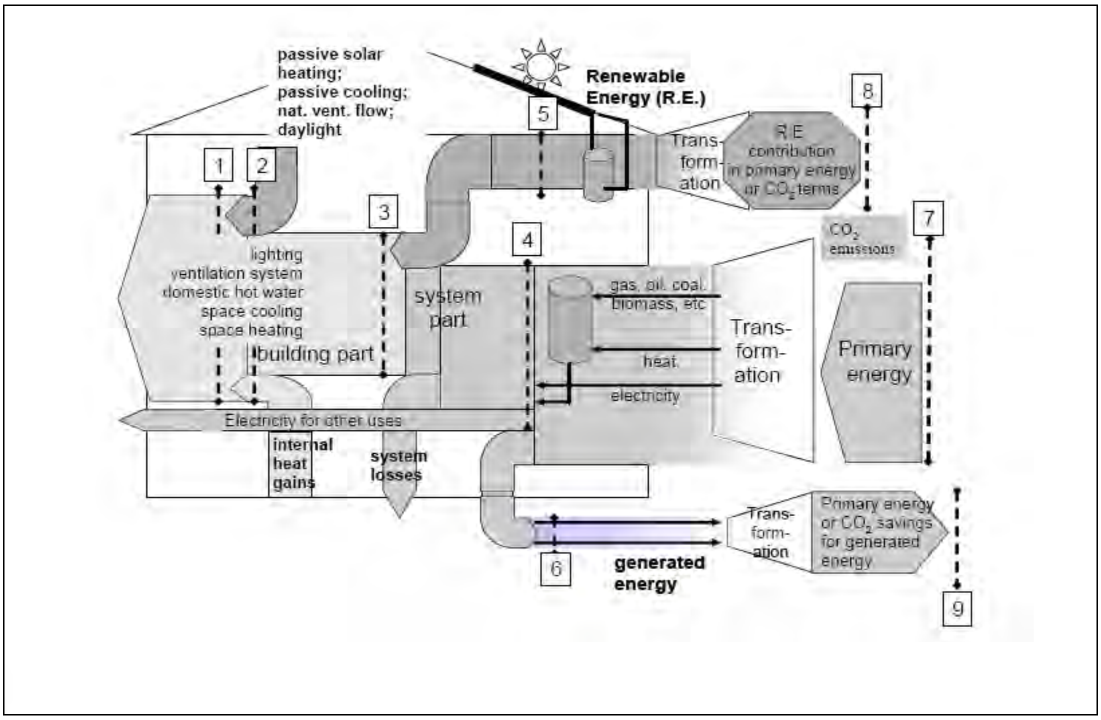

Figure 8: Description of calculation scheme according to CEN/TR 15615 (umbrella document)

The characteristics of the technical building systems are included via the following standards:

Heating systems

EN 15316-1: 2007 “Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 1: General” and EN 15316-4: 2007/2008 “Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies” (6 parts, dealing with boilers, heat pumps, solar thermal systems, cogeneration, district heating and photovoltaic systems) and its normative references.

Domestic hot water

EN 15316-3: 2007 “Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies” (3 parts, dealing with tapping requirements, distribution and generation of domestic hot water) and its normative references.

Ventilation

EN 15241:2007 “Ventilation for buildings - Calculation methods for energy losses due to ventilation and infiltration in commercial buildings” and its normative references.

Cooling

EN 15243: 2007 “Ventilation for buildings - Calculation of room temperatures and of load and energy for buildings with room conditioning systems” and its normative references.

Lighting

EN 15193: 2007 “Energy performance of buildings - Energy requirements for lighting” and its normative references.

Building automation

EN 15232: 2007 “Energy performance of buildings - Impact of Building Automation, Controls and Building Management” and its normative references.

Further information and details are provided in CEN/TR 15615:2008 (umbrella document), which gives an overview of all EPBD-related standards, including common definitions.

Preferably the calculations shall be in full accordance with the EN standards as specified in Chapter 5.1. However, national calculation methods may deviate from this. If the calculations are done in full accordance with the CEN standards, the energy performance of the chosen reference buildings may still be calculated separately according to the (possibly deviating) current national calculation scheme, and can be provided as additional information and for establishing a link to national requirements.

The scope of the calculation of primary energy demand might (at a possible later stage) be enlarged towards a full LCA calculation (cradle to grave) that also includes the energy needed for the production of energy-related products and systems and their disposal. (See also work of CEN/TC 350 - Sustainability of construction works.) Such corresponding calculations could be handled as an add–on to the calculation of primary energy demand, as described above.

Regarding learning curves (better system performance, increased productivity of labour and subsequent cost reductions), the assumption on efficiencies and investment costs of components and systems shall reflect the assumed values for the time period until the next update of the calculations. Developments beyond that point need to be tackled in the next assessment. However, awareness of this dynamic process is an important consideration in setting current and future requirements.

5.3 Results

To be able to use a simple indicator for different building geometries and sizes, the results shall be expressed in kWh and in CO_2, respectively, both per m² conditioned floor area and year.

Parameter	**Method**	**Unit**	**Taken into account for**
Delivered energy	CEN standards for EPBD	[kWh/m²a]	energy costs (or sales)
Primary energy	CEN standards for EPBD	[kWh/m²a]	environmental targets
CO_2 –emissions	CEN standards for EPBD	[kgCO_2/m²a]	environmental targets
Results of national calculation schemes	national schemes	[X]	Comparison

In deriving overall performance indicators, it is also necessary to set minimum performance requirements for components such as roof, wall, and floor insulation, as well for windows. By fixing all parameters and varying the performance of a specific component optimal requirements can also be derived at component or system level. Hereby it is important to note that performance requirements for boilers and other installed appliances and equipment are being set under the framework of the Ecodesign Directive. It will be a task for the coming period to make sure that the results from the cost-optimum methodology and requirements from the Ecodesign directive support each other.

6 Economic models for cost assessments

6.1 Overview of different assessment methods

An economic model to assess the impact of different options for energy efficiency, energy supply and renewable energy on a building over its service life needs to take into account the corresponding investments, replacement needs (resulting from different lifetimes of components), running costs during the use of the building (including energy costs) and disposal (if relevant).

From a variety of different economic calculation methods, the following two options can deliver sufficiently exact results for an assessment of long-term investments as they both take into account discounted cash flows and cover the entire lifetime of the investment:

> *Equivalent annuity method*
>
> The annuity calculation method transforms any costs during a given timeframe to average annualized costs by the use of an annuity factor.
>
> *Net present value*
>
> 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.

6.2 Description of calculation model used

The EN 15459 (Energy performance of buildings – economic evaluation procedure for energy systems in buildings) describes a method for economic calculation of the heating systems, depending on data from other systems that may influence the energy demand, and refers regarding energy delivered to the CEN standards related to the EPBD.

The calculation scheme of EN 15459 can be applied to all kinds of buildings (residential and non-residential, new and retrofit situations) and can take into consideration investments in systems for:

- Space heating
- Domestic hot water
- Ventilation
- Cooling
- Lighting
- Building fabrics and insulation

In the two options, EN 15459 provides both ways of calculation: an annuity method and a present value calculation (described as global costs).

> The **annuity calculation method** transforms any costs to average annualized costs and results in a figure for annual costs. However, to avoid distortions between systems with different life times, it is necessary to define a “design payback period”, which covers also the lifetime of long-lasting equipment within an assessed package (e.g. 50 years). Consequently it is necessary to make projections for energy costs and interest rates for this time span.
>
> The **global cost calculation method** results in a present value of all costs during a defined calculation period (e.g. 30 years), taking into account the residual values of equipment with longer lifetimes. Projections for energy costs and interest rates can then be limited to the calculation period.

Below, the global cost calculation method is illustrated. It allows the choice of a uniform calculation period (with long-lasting equipment taken into account via its residual value) and can be linked to activities on life cycle costing (LCC), which also make use of net present value calculations.

6.3 Global cost calculation

The general calculation approach of the EN15459 regarding the global cost method is described below.

The calculation of global cost considers the initial investment, the annual costs for every year and the final value, all referring to the starting year. Global cost is directly linked to the duration of the calculation period.

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

C_g (τ)	global cost (referring to the starting year τ_0)
C_I	initial investment costs
$C_{a,i}$ (j)	cost during year i for energy-related component j (energy costs, operational costs, periodic or replacement costs, maintenance costs and added costs)
R_d (i)	discount rate for year i
$V_{f,\tau}$ (j)	final (=residual) value of component j at the end of the calculation period (referring to the starting year τ_0)

The discount rate R_d depends on the real interest rate R_R (market interest rate adjusted for inflation) and on the timing of the costs (number of years after the starting year).
The final or residual value $V_{f,\tau}$ (j) of a component is determined by straight-line depreciation of the initial investment until the end of the calculation period and refers to the beginning of the calculation period. Costs or benefits from disposal, if applicable, can be subtracted or added to the final value.

The EN 15459 does not fix a specific calculation period for the global cost calculation method. The calculation period should normally be set at 30 years, as this timeframe covers the lifetime of most of the measures assessed, is a time span for which fixed interest rates are offered (e.g. by banks), and beyond which reasonable forecasts for energy prices are quite difficult.

A detailed description of terms, definitions, symbols and units is given in EN15459:2007.

6.4 Input parameters

For a complete financial assessment, the following financial information for different packages applied to the above-mentioned reference buildings shall be collected:

- energy related investments (insulation, windows, ventilation, installed lighting, energy supply systems and controls, etc.);
- periodic costs for replacement;
- corresponding costs for maintenance, operation and added costs; and
- energy costs for energy carriers (= price of energy as paid by the customer. This includes all costs and profit margin of the supplier)

Differences become apparent, when considering the calculations for establishing the costs for individuals (private costs) or for society. This touches issues such as interest rates, subsidies, VAT and environmental costs. Explanations for these parameters are integrated in the following chapters, where relevant. The following table gives an overview of elements which can characterize a private and a societal perspective:

	Private perspective	**Societal perspective**
Interest rate	market interest rate (adjusted for inflation)	Societal interest rate
Subsidies and incentives (see also box below)	included	excluded
Taxes (VAT and other taxes)	included	excluded
Costs of Emissions	excluded	included

There are also further elements that could be taken into account for a private perspective (e.g. higher value of energy efficient buildings when being sold) or societal perspective (e.g. relief of social system through job creation linked to labour intensive energy performance measures). However these are in many cases difficult to assess and might rather be seen as additional aspects than being included in the cost calculations.

As the individual and the societal view are important for building regulations and policy making, both cases need to be calculated separately for the assessed reference buildings.

Subsidies and incentives

In general, subsidies and incentives are issues that are linked to the private perspective of building owners and investors. The following rules can apply regarding different kinds of incentives when taking these into account from a private perspective:

- direct subsidies: subtract from investment costs
- differentiated taxes: take into account for investments
- Soft loans: calculate with a different (lower) interest rate
- Tax rebates: subtract from annual costs Ca,i (j)

6.4.1 Investments

General

The methodology takes into account investment costs that are directly related to demand-side energy saving and energy efficiency measures or to the energy supply of a building. This includes investments in insulation, windows, energy supply systems, ventilation with heat recovery etc. This means that carpets, interior doors, roof-tiles etc. in general construction products, load-bearing structures and components that do not have a substantial impact on the energy performance, are not included in the cost calculation. Components that have a double function (e.g. exterior wall material that contributes significantly to the thermal resistance of the wall compared to the reference building situation) should be taken into account with the additional energy-related costs in comparison to the standard material of the reference building. The effect of price reductions in the future due to economies of scale, product innovation, etc. do not have to be projected but need to be taken into account in subsequent updates of the calculations for the comparative methodology. (See heading "Reporting and monitoring" in Chapter 1).

It is of crucial importance to note that in retrofit activities coupled to normal non-energy maintenance measures, the realized energy savings costs must not be judged against the total costs of all the renovation measures, but need to be projected against and limited to the costs of the additional energy-related investments only. This is taken into account within this methodology by comparing the total costs (investment costs and running costs) of chosen retrofit packages to a baseline option that only includes maintenance measures without improvements in energy efficiency, such as renewal of façade/cladding, exchange of windows without improvement of U-value, replacement of supply systems without technology shift, etc.). For further explanations, see Chapter 4.

Design, dimensioning, layout, etc. of the measures and systems should be done in accordance with the relevant European standards.

Costs have to be assessed:

- on country level, but can also be assessed on regional level or for different climate zones within a country, if relevant;
- as average price for end consumers (= owners/investors);
- including (private perspective) or excluding (societal perspective) all applicable taxes;
- including subsidies (private cost calculation) or excluding subsidies (societal cost calculation);
- including installation costs;
- including cost for the end of life stage (deconstruction, transport, recycling, disposal) as far as relevant. See also information in Annex A of EN15459:2007 on disposal cost; and
- when appropriate, the actual share of single projects or large developments (regarding economy of scales).

Lifetime of measures:
The lifetime of measures should be set according to the information set out in annex A1 of EN15459.

Interest rates:
Real interest rates (market interest rate corrected for the inflation rate) according to the national average for loans (distinguishing if necessary between new buildings and retrofits, residential and non-residential) need to be applied for the private cost calculation. For societal cost calculation, default societal interest rates shall be used. The duration of loan needs to be adjusted to the chosen calculation period (see Chapter 6.3).

Building envelope
Investment costs should include:

- insulation product;
- additional products for application of the insulation to the building envelope (mechanical fixings, adhesive etc.);
- installation costs of insulation (including water vapour barriers, weather membranes, measures to ensure air-tightness and measures to reduce the effects of thermal bridges); and
- energy-related costs of other building materials, if applicable.

The technical products and systems are described for example in various standards under CEN/TC 88 - Thermal insulating materials and products and CEN/TC 89 – Thermal performance of buildings and building components.

Windows and doors
Investment costs should include:

- glazing
- frame
- gaskets and sealants
- installation costs

The technical systems, products and components are described for example in various standards under CEN/TC 33 - Doors, windows, shutters, building hardware and curtain walling and CEN/TC 89 (see above).

Other building-related measures with impact on thermal performance

This can include e.g. external shading devices, solar control systems, and passive systems not covered elsewhere.

Space heating

Costs should include:

- generation and storage
- distribution and radiators
- control devices
- installation costs

The technical systems are described for example in various standards under CEN/TC 228 - Heating systems in buildings and CEN/TC 57 - Central heating boilers

For reference comfort conditions, EN15251 "Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics" should be taken into account.

Domestic hot water:

Costs should include:

- generation and storage (including solar thermal systems)
- distribution and radiators
- control devices
- installation (including insulation)

The technical systems are described for example in various standards under CEN/TC 228 - Heating systems in buildings, CEN/TC 57 - Central heating boilers and CEN/TC 48 - Domestic gas-fired water heaters.

Ventilation systems

Concerning investments, the costs of mechanical ventilation systems are to be assessed.
Possibilities for natural ventilation are covered in so far as possible with the definition of reference buildings
Investment costs should include:

- ventilation ducts, fans, incl. insulation
  heat recovery unit (if applicable)
- Valves, filters
- control devices
- installation costs

The technical systems are described for example in various standards under CEN/TC 156 - Ventilation for buildings.

EN15251 should be taken into account for reference comfort conditions, indoor climate and requirement for ventilation (with special considerations for commercial buildings.)

Cooling
As a comfortable indoor temperature needs to be ensured, passive or active cooling measures or a combination of both (supplying remaining cooling demand) need to be taken into account, depending on the specific climate conditions. In this category, the costs of active cooling systems are referred to. Passive cooling measures are either covered with the choice of reference buildings (e.g. building mass) covered in category “thermal insulation” (e.g. insulation of roofs to reduce cooling demands) or the category “Other building- related measures with impact on thermal performance” (e.g. external shading). Investment costs of active cooling systems include:
- generation
- distribution
- control devices
- installation

The technical systems are described for example in various standards under CEN/TC 113 - Heat pumps and air conditioning units. EN15251 should be taken into account for reference comfort conditions.

Lighting
Concerning investments, active systems for artificial lighting or applications to increase use of daylight are to be assessed. Measures that refer to the design and geometry of the building envelope (size and position of windows) are being covered with the choice of the reference buildings. Investment costs should include:
- type of lighting source and luminaire
- associated control system
- applications to increase use of daylight
- installation

The technical systems are described for example in various standards under CEN/TC 169 - Light and lighting. EN15251 should be taken into account for reference comfort conditions and requirement levels.

Building automation and control
Investment costs should include:
- Building management systems which introduce supervising functions (separate system controls are accounted for within the specific system)
- Installation

The technical systems are described for example in various standards under CEN/TC 247 - Building Automation, Controls and Building Management

Connection to energy supplies (grid or storage)
Investment costs should include:

- costs for first connection to the energy network (e.g. district heat, PV-system)
- storage tanks for combustion fuels
- required related installations

6.4.2 Periodic costs for replacement

Periodic costs for replacement occur according to the lifetime of measures included. Foreseen increase or decrease in costs levels beyond inflation effects (e.g. as a consequence of large scale market introduction) can be taken into account in the average replacement costs of systems. Background assumptions need to be described.

6.4.3 Maintenance, operation and added costs and incomes

This includes maintenance and repair costs (see information in annex A1 of EN15459). Possible added costs include costs of insurance or energy produced that is sold, e.g. to the grid.
Feed –in tariffs usually have a period of fixed price per kWh produced (e.g. for 20 years). After this timeframe the produced energy is assumed to replace energy supply (and corresponding costs) from the grid.

6.4.4 Energy costs and their development

Energy use
Basis for the calculation of energy costs are the calculations of energy delivered per energy carrier (natural gas, electricity etc.) for space heating, domestic hot water, cooling, ventilation and lighting according to the 31 CEN standards around the EPBD. (See CEN/TR15615:2008 - Umbrella Document).
Energy production (e.g. solar thermal systems) reduces the amount of delivered energy needed Energy produced and sold to the grid (e.g. electricity from PV or CHP sold to the grid via a feed-in tariff) is seen as additional income, see explanation in Chapter 6.4.3).

Energy price
The assumed energy price (per kWh and cost for capacity (per kW)) for the design payback period (annuity method) or calculation period (global cost method) can be developed from current costs levels, as for example provided by EUROSTAT, The information from EUROSTAT differentiates prices for domestic and industrial use, depending on delivered volume. Accordingly, different price levels need to be taken into account for the reference buildings as described in Chapter 3.

For the private perspective, all kind of taxes need to be included (VAT etc.). For the societal perspective, those taxes need to be excluded.

The price development in the future (real development, excluding inflation) should to a certain extent be set jointly for the EU, to reflect the global oil market and the internal European energy market. The EC might trigger the development of such a reference, e.g. for oil prices, in cooperation with, for example the IEA.).
Other energy carriers can be coupled to these assumed developments (e.g. natural gas being linked to the oil price) or can be derived from other national or international forecasts. As many energy prices have a strong national, regional or even local influence, such as biomass, district heating and geothermal, these forecasts should take into account expected longer-term political as well as economic developments. Concerning district heat, possible effects from necessary changes in the infrastructure (size of district heating systems, energy delivered per meter of grid etc.) should be taken into account.

Thoughts on the development of energy price scenarios

General approach
As a general approach, a well accepted forecast on energy prices need to be chosen. Possible sources are the World Energy Outlook form IEA or scenarios from, for example, PRIMES.

ENERGY CARRIER	UNIT	SCENARIO	2000	2008	2015	2020	2025	2030
IEA crude oil imports	barrel	Reference	34,3	97,2	86,7	100,0	107,5	115,0
		Low	34,3	97,2	67,6	72,0	76,0	80,0
		High	34,3	97,2	110,6	130,0	140,0	150,0

Table 1: Oil price scenario [2009 $] from WEO 2009 (Source: IEA)

In a second step, a link can be established to consumer prices in the EU Member states as supplied by EUROSTAT to ensure that the chosen scenarios are transferred to the real market situation in the different EU countries. In principle 2 options can be distinguished.

Option 1:
- Calculate change in % related to current value for forecast period
- Apply % change from scenarios to current level of consumer prices per country as supplied from EUROSTAT.

This represents a simple and straightforward approach; however the situation in the base year has a high influence on the assumed price development in the future.

Option 2:
- Assess the average historic ratio between indicator and statistical data from EUROSTAT per country (e.g. relation between price in dollar per barrel of oil and price for end user in the EU-Member States in EURO/kWh residual fuel oil)
- Transfer projection of indicators to forecast of consumer price development by the use of assessed relation to statistical data from EUROSTAT.

Option 2 allows developing the forecast on a broader basis (ratio between indicator and statistical data over e.g. the last 10 years). Uncertainties can arise from trends regarding the ratio, which might make a projection necessary for the ratio instead of being able to use an average.

Energy carriers with a lack of statistical data

Special attention needs to be paid to energy carriers that show a lack of available forecasts and are not included in consumer price data from EUROSTAT. These are e.g. district heating, woodchips and other biomass (strong local differences, lack of forecasts, etc.). A possible solution is to have assessments of current prices by national market reviews and to link the assumed price development to other energy carriers for which forecasts exist. Therefore energy carriers should be chosen that have a direct link during energy production (e.g. district heating and the price of coal) or encounter direct competition in the end-user market.

Sensitivity analysis

It is recommended to use different price scenarios (e.g. high, medium, low) to assess the sensitivity of results. The following graphs show examples of the global costs and primary energy use of two different packages of measures, taking into account different energy prices.

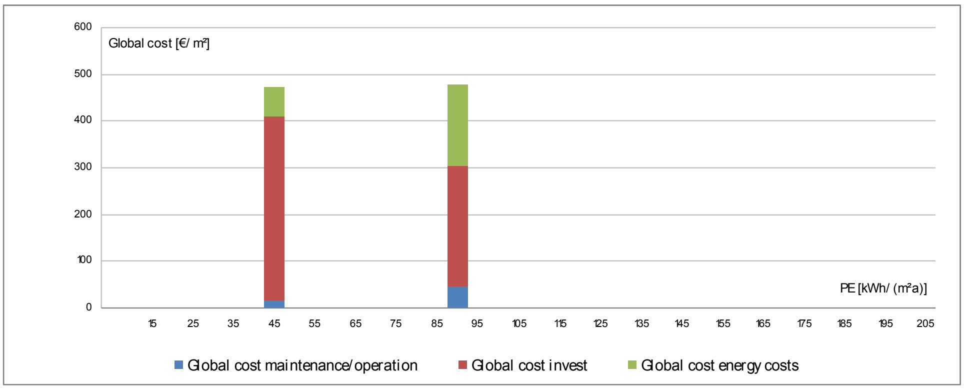

Figure 9: Comparison of two different packages for new single family building (indicative) – average energy price assumption of 12 cent/kWh gas

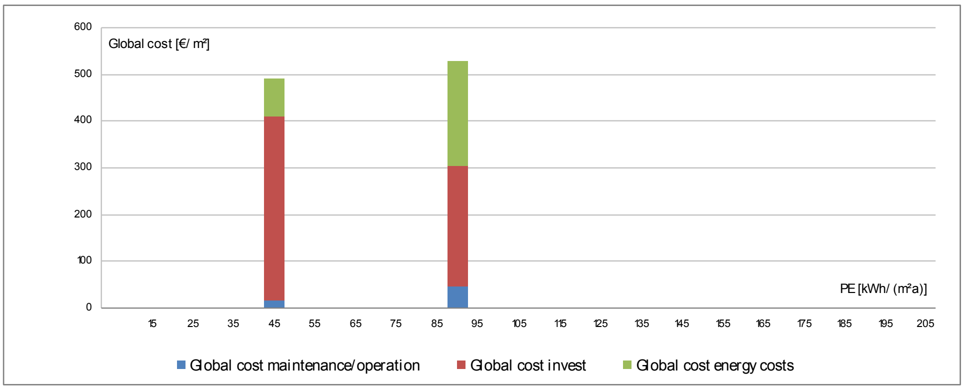

Figure 10: Comparison of two different packages for new single family building (indicative) – sensitivity analysis high price (+30%)

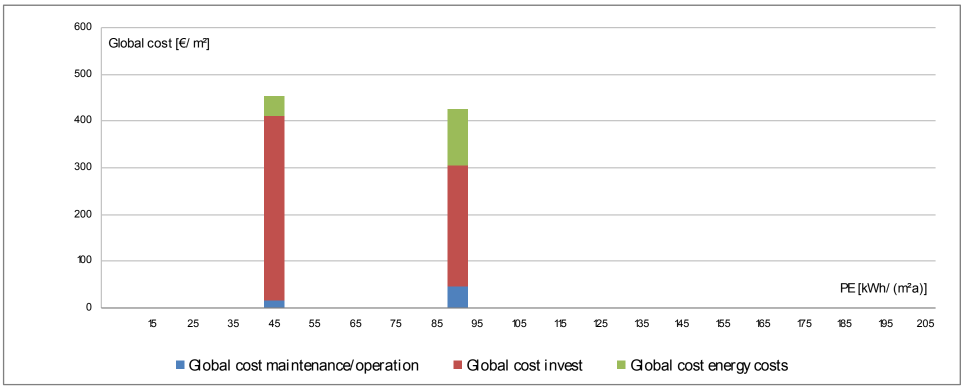

Figure 11: Comparison of two different packages for new single family building (indicative) – sensitivity analysis low price (-30%)

As can be seen from the illustrations in the 3 graphs, the energy price can have a substantial influence on the relative costs of a package and therefore on the optimum of a curve.

Interest rates

According to EN 15459, the interest rate is derived from market interest rates adjusted for inflation (interest rates offered minus inflation rate). Interest rates are subject to changing market conditions (see Figure 12), but also differ with respect to whether viewed from a private or societal perspective.

Figure 12: Development of interest rates for financing (building sector, 10 years fixed interest rate, source: interhyp)

The following figures illustrate the impact of different interest rates on the relative costs of packages of measures. They describe the difference in results when applying lower (2%) or higher (6%) interest rates, compared to a base case of a 4% interest rate.

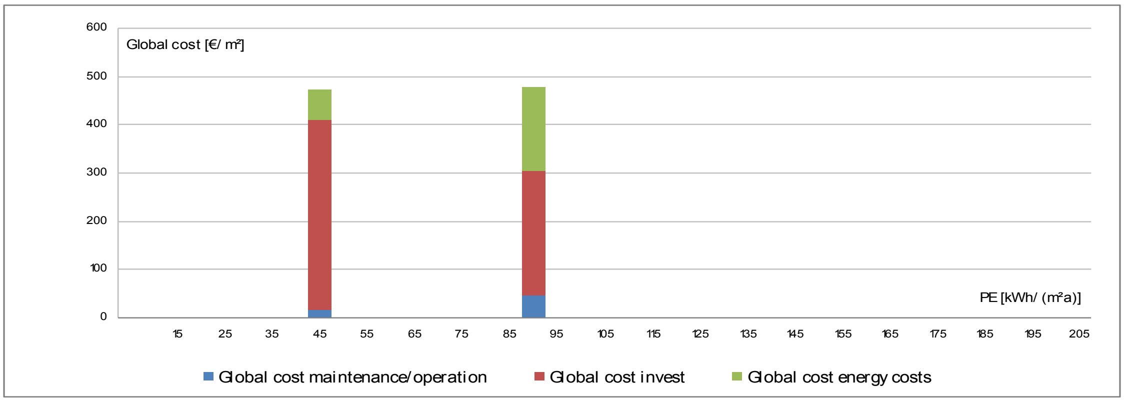

Figure 13: Comparison of two different packages for new single family building (indicative) – average energy price assumption of 12 cent/kWh gas, interest rate of 4%

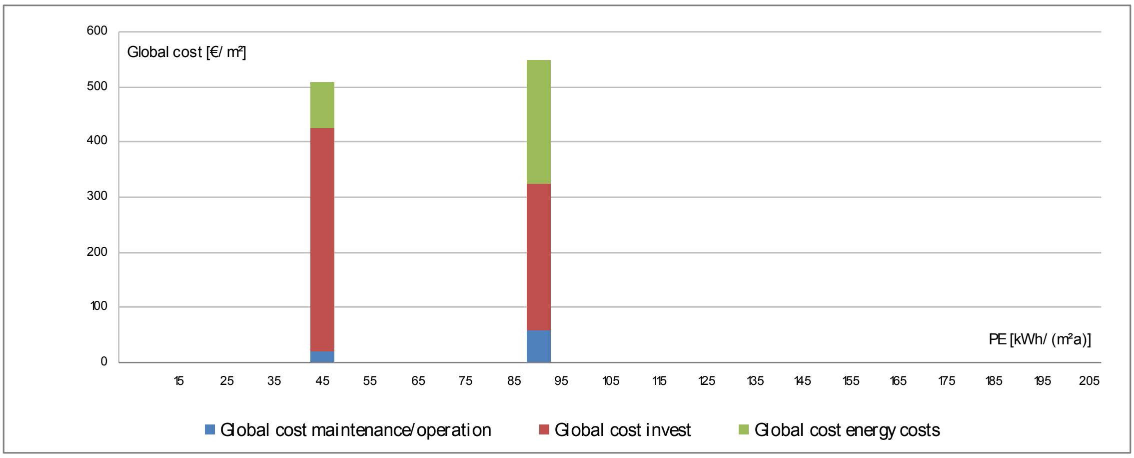

Figure 14: Comparison of two different packages for new single family building (indicative) – average energy price assumption of 12 cent/kWh gas, interest rate of 2%

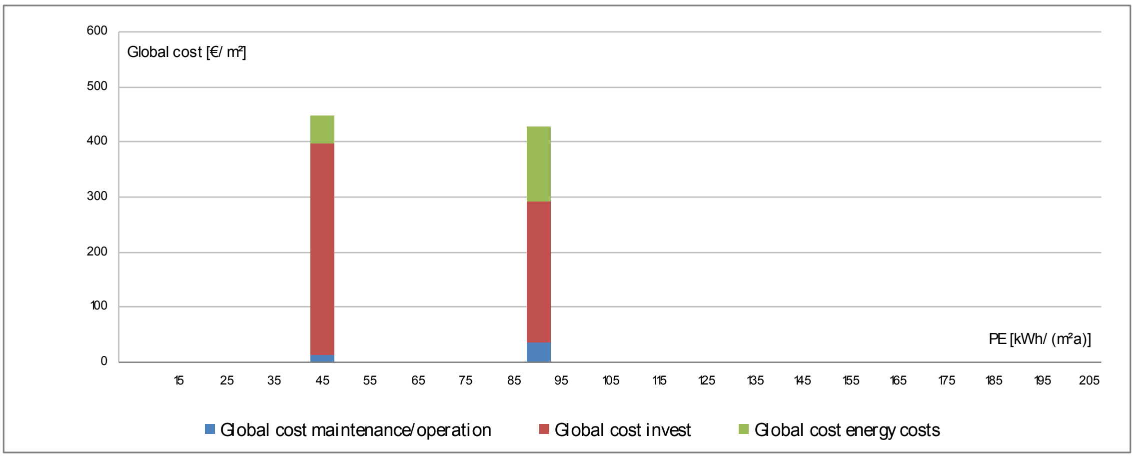

Figure 15: Comparison of two different packages for new single family building (indicative) – average energy price assumption of 12 cent/kWh gas, interest rate of 6%

It is clear from the diagrams that lower interest rates favour investments in energy saving or energy efficiency measures, whereas higher interest rates hamper such activities. Note that as an effect of the financial calculation principle the amount of global costs is higher when lower interest rates are applied. This comes from the effect that future costs (mainly energy costs) are discounted with a lower rate, leading to a higher present value of the global costs at year zero. Nevertheless the comparison between the two assessed cases clearly shows that in the low interest rate case, the investments in energy saving/energy efficiency measures lead to a direct financial benefit compared to the option which leaves a higher energy consumption.

Environmental costs

For the societal cost calculation, the cost for the energy related CO_2-emissions can be included in the cost calculations by multiplying the calculated annual CO_2-emissions (see Chapter 5) with the price, for example, for EU Emission Allowances.

The assumed price for EU Emission Allowances for the calculation period can be developed from current costs levels, as for example provided at the Energy Exchange EEX. The price development in the future (real development, excluding inflation) might be set by the EC.

6.5 Results

As a result of the global cost method, total costs during the calculation period are displayed in EURO that include investment and replacement costs as well as running costs.

To be able to compare different building geometries and sizes, it is proposed to express the results in EURO per m² of conditioned floor area. The conditioned floor area needs to be determined by use of European standards to ensure transparency and to increase comparability.

7 References

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