

ENERGY PERFORMANCE ASSESSMENT OF EXISTING DWELLINGS & NON-RESIDENTIAL BUILDINGS

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ABSTRACT

The existing buildings stock in European countries accounts for over 40% of final energy consumption in the European Union (EU) member states, of which residential use represents 63% of total energy consumption in the buildings sector. Consequently, an increase of building energy performance can constitute an important instrument in the efforts to alleviate the EU energy import dependency and comply with the Kyoto Protocol to reduce carbon dioxide emissions. This is also in accordance to the European Directive on the energy performance of buildings (EPBD), which is currently under consideration in all EU member states. The Energy Performance Assessment for Existing Dwellings (EPA-ED) and for Non-Residential Buildings (EPA-NR) are two new methodologies supported by software, developed in the framework of two European projects that focus on energy related issues and are suitable for audits, labeling and issuing an Energy Performance Certificate for existing buildings, in accordance to the EPBD. This paper presents an overview of the two EPA methods and software that can be used to perform building energy audits and assess buildings in a uniform way, perform demand and savings calculations, provide owners with specific advice for measures that can improve energy performance, issue an Energy Performance Certificate for existing buildings, and include some representative results from the pilot studies performed in several European countries.

Keywords: Buildings, Energy Performance Assessment, EPA-ED, EPA-NR, EPBD

1. INTRODUCTION

The European Union (EU) Member States are working intensively to improve energy efficiency in all end-use sectors and to increase the exploitation of renewable energy sources (RES) in order to tackle environmental concerns deriving from energy consumption of fossil fuels, and to support self-sufficiency and energy security. Energy efficiency is expected to play a key role in meeting the EU target in accordance to the Kyoto commitments to reduce CO₂ emissions in an economic way.

The existing buildings stock in European countries accounts for over 40% of final energy consumption in the European Union (EU) member states, of which residential use represents 63% of total energy consumption in the buildings sector. Consequently, an increase of building energy performance can constitute an important instrument in the efforts to alleviate the EU energy import dependency (currently at about 48%) and comply with the Kyoto Protocol to reduce carbon dioxide emissions. This is also in accordance to the European Directive (2002/91/EC) on the energy performance of buildings – EPBD [1], which is currently under consideration and will be implemented by January 4, 2006 into national law by the EU member states.

The EU final energy consumption for 2002 in the buildings sector [2] amounted to 435 Mtoe (40.3% of the total EU-25 final energy use), of which 274 Mtoe in dwellings (25.4%). The member states with the highest final energy consumption in the residential and tertiary buildings is Germany, United Kingdom, France and Italy. In terms of the percentage of buildings' final energy consumption to the total energy consumption (% buildings/total) the highest burden occurs in the new EU member states [3], including Latvia (56.9% of the total), Hungary (56.1%), Estonia (53.5%), Poland (53%) and Lithuania (50.7%).

The number of dwellings in EU-25 are about 196 million, with more than 50% of the existing residential buildings built before 1970 and about 1/3 of the dwellings built during the 1970-1990 [4]. The annual rate of construction of new dwellings expressed as a percentage of the size of existing stock ranging from 0.3% in Sweden to 3.5% in Ireland, with an average of 1.1%, while the estimated annual replacement rate (ratio of the annual demolition rate to the size of existing stock) for dwellings in Europe is only 0.07% [5]. However, growth in European construction will begin to slow down, with new housing construction expected to be +0.7% in 2005 compared to +4.4% in 2004 [6]. Furthermore, the emphasis is expected to shift towards renovation and maintenance of the existing housing stock in western Europe, while in the developing markets of eastern Europe is expected to accelerate sharply. About 70% of the residential buildings are over 30 years old and about 35% are more than 50 years old. This is an important observation given that most national building regulations that mandate thermal insulation of building envelopes were introduced after the 1970's following the energy crisis. With regard to the ageing technical installations, it is estimated that about 10 million residential boilers are older than 20 years old, and thus have a significantly lower thermal performance than today's common units.

Refurbishment (i.e. upgrading to better condition) of the existing and ageing building stock offers an opportunity to take cost-effective measures and transform them to resource-efficient and environmentally-sound buildings, with an increased social and financial value. Similar opportunities may exist even during building renovations (i.e. repairs and restorations to good condition). Protecting the architectural heritage is a primary benefit, but it may also be financially attractive. In many cases, building refurbishment costs much less (even for high investment retrofit operations) than demolition and reconstruction (about half to one-third of the cost). In light of sustainability principles and policies it makes more sense than ever to renovate or refurbish old buildings. Some have even suggested that we should stop constructing additional new buildings, limiting ourselves to improve the existing stock, its functional quality and durability [7]. In any event, the immediate goal must be to ensure that at least new buildings are constructed in a sustainable way.

Accordingly, the real challenge for the effective implementation of the EPBD is to properly retrofit existing buildings in a manner that will use the minimum non-renewable energy, produce minimum air pollution as a result of the building operating systems, minimize construction waste, all with acceptable investment and operating costs, while improving the indoor environment for comfort, health and safety. Several efforts have been made from EU members States to develop methodologies and software tools in order to enable architects and engineers during their decision-making process for building refurbishment, to make an accurate first assessment of a building's existing structural condition, energy performance, indoor environmental quality, and some other criteria depending on the use of the building, with a good estimate of the total cost for refurbishment. A number of decision support software have been developed in the framework of European projects over the past few years [8], for the assessment of different scenarios during renovations or refurbishment of buildings like EPIQR [9] and Investimmo for residential buildings, TOBUS for offices [10] and XENIOS for hotels [11]. These methodologies and software can also address the EPBD issues. Results from building energy audits and the assessment of various energy conservation interventions are available for apartment buildings [12-14], for offices [15] and for hotels [11].

Focusing on energy related issues and issuing an Energy Performance Certificate according to the EPBD, a new group of methodologies have emerged. First, a methodology on the Energy Performance Assessment for Existing Dwellings (EPA-ED) was recently completed in the framework of a European project. The EPA-ED software is based on a set of tools that enable the consultants to audit and assess a dwelling or an entire building in a uniform way. The consultant is then supported to provide owners with specific advice for measures that can improve the energy performance of the dwelling or building. The prototype software was used for a number of pilots performed in four European countries. All final deliverables from the EPA-ED project are available from www.epa-ed.org. A similar European project on the Energy Performance Assessment for existing Non-Residential buildings (EPA-NR) is currently underway. Up-to-date information can be found at www.epa-nr.org. The following sections present an overview of the EPBD and the EPA methodologies, software and results from the pilot building audits and applications.

2. OVERVIEW OF EPBD

The European Directive on the energy performance of buildings (EPBD) requires that an energy performance certificate is made available when buildings are constructed, sold or rented out. The certificate has to express the Energy Performance (EP) of the building. The certificate has to be accompanied by recommendations for the cost effective improvement of the energy performance. The calculation of the energy performance should be carried out according to a methodology based on a general framework set out by the EPBD.

2.1 Background of EPBD

As a result of the Kyoto Protocol, the European Union (EU) has agreed to a total reduction of greenhouse gas emissions by 8% below 1990 levels during the first commitment period (2008-2012). Accordingly, the European Commission has launched the European Climate Change Programme (ECCP) in 2000, in order to establish a community strategy for the implementation of the Kyoto protocol.

Within the first ECCP report, cost effective measures for the reduction of green house gas emissions were identified and a list of priority actions on community level was given. Within these actions, improving of the energy performance of buildings took an important part. A new directive on energy performance of buildings was recommended. This directive, referred to as Directive 2002/91/EC on the energy performance of buildings (EPBD), was adopted finally in late 2002 [1].

2.2 Definitions energy performance and certificate

The “energy performance of a building” is defined as the amount of energy actually consumed or estimated to meet the different needs associated with a standardized use of the building. This amount shall be reflected in one or more numeric indicators, which have been calculated, taking into account:

- Insulation,
- technical and installation characteristics,
- design and positioning in relation to climatic aspects, solar exposure and influence of neighbouring structures,
- own-energy generation, and
- other factors, including indoor climate, that influence the energy demand.

The “energy performance certificate” is a document that indicates the energy performance of a building, calculated according to a methodology based on the general framework set out by the EPBD.

2.3 Intention of EPBD

In general the objective of EPBD is to improve the energy performance of buildings over 1000 m² useful floor area. Specifically:

- For new buildings and for major renovation of large existing buildings minimum energy performance requirements should be set. The energy performance is to be upgraded in order to meet minimum requirements in so far as this is technically, functionally and economically feasible;
- In case of large new buildings alternative energy supply systems should be considered. For example, alternative systems to be considered are: decentralised energy supply systems based on renewable energy, CHP, district or block heating or cooling, heat pumps, etc.;
- The inspection of boilers and air-conditioning units on a regular base is compulsory;
- Buildings for public services need to display the energy performance visible to the public.

An Energy Performance certificate should be made available to the owner or by the owner to the prospective buyer or tenant when buildings are constructed, sold or rented out. The certificate has to express the energy performance of the building as a numeric indicator that allows benchmarking. The certificate shall be accompanied by recommendations for the cost-effective improvement of the energy performance. The certificate is valid for the maximum of ten years and should be recognized by the Member State or a legal person designated by it.

Member States need to ensure that the certification of buildings, the drafting of the accompanying recommendations and the inspection of boilers and air-conditioning systems are carried out in an independent manner by qualified and/or accredited experts, whether operating as sole traders or employed by public or private enterprise bodies. They shall also ensure that the technical, environmental and economic feasibility of alternative systems is considered and is taken into account before construction starts.

The Directive has to be implemented by January 4, 2006 into national law by the Member States. Only because of lack of qualified and/or accredited experts, the Directive allows an additional period of three years to be fully applied.

2.4 Methodology for calculation energy performance

The EPBD prescribes that EU Member states shall apply a methodology at national or regional level, for calculation of the energy performance of buildings on the basis of a general framework. This methodology shall include at least the following aspects: (a) thermal characteristics of the building (shell and internal partitions, etc.); these characteristics may also include air-tightness; (b) heating installation and hot water supply, including their insulation characteristics; (c) air-conditioning installation; (d) ventilation; (e) built-in lighting installation (mainly the non-residential sector); (f) position and orientation of buildings, including outdoor climate; (g) passive solar systems and solar protection; (h) natural ventilation; (i) indoor climatic conditions, including the designed indoor climate.

The positive influence of the following aspects shall, where relevant in this calculation, be taken into account: (a) active solar systems and other heating and electricity systems based on renewable energy sources; (b) electricity produced by CHP; (c) district or block heating and cooling systems; (d) natural lighting.

In order to facilitate the EU Member States in setting up a general framework for the calculation the European Committee for Standardisation (CEN) is working on the final elaboration of over 30 new standards to satisfy the requirements of the EPBD. These CEN standards will be the basis for standardisation on national or regional level. An overview of these standards is to be found in the "Umbrella document" (Explanation of the general relationship between various CEN standards and EPBD, CEN/BT WG 173 EPBD N 15 rev) that provides an explanation of the general relationship between various CEN standards and EPBD.

The calculation procedure for assessing the energy performance of buildings is based on the characteristics of the building and its installed equipment. For the purpose of the calculation of the energy performance buildings should be adequately classified into categories such as single-family houses of different types, apartment blocks, offices, education buildings, hospitals, hotels and restaurants, sports facilities, wholesale and retail trade services buildings, other types of energy-consuming buildings.

The calculation procedure is structured in three levels:

- calculation of the building net energy (energy needs for heating and cooling), together with that for ventilation, hot water and lighting;
- calculation of the building delivered energy;
- calculation of the overall energy performance indicators (primary energy, CO₂ emissions, etc.).

Therefore, the calculation sequence is as follows:

1. Calculate the building net energy. This part of the calculation considers only the building properties and not those of the heating/cooling system and results in the net energy use (energy to be given out by heat emitters, or to be extracted from the conditioned space, in order to maintain the specified internal temperature). The existing standard EN ISO 13790 covers the calculation of the heating requirement, and the methodology is being extended in Work Item – WI 14 to include also cooling. To perform this calculation, data for indoor climate requirements, internal gains, building properties and outdoor climatic conditions are also used.
2. Take account of the characteristics of the heating, cooling, domestic hot water and lighting systems, inclusive of controls and building automation, to calculate the delivered energy. Energy used for different purposes and by different fuels is recorded separately. The calculations take account of heat

emission, distribution, storage and generation, and include the auxiliary energy needed for fans, pumps, etc.

3. Combine the results from 2) for different purposes and from different fuels to obtain the overall energy use and associated performance indicators.

2.5 Towards energy labelling

In order to meet the obligations of the EPBD the EU Member States are working to determine national EP numeric indicators. For example, it can be the total energy use per building floor or energy use corrected for the building type if that is common in a country. Raising a system of energy labels based on this numeric indicators gives a tangible “face” to energy performance. It presents a simple and instant communication and contributes to increasing awareness about the quality of our buildings. Many labelling designs have been already developed for all kinds of purposes. Some of the most successful ones on a European level are energy rating of household electrical appliances and the fuel rating of automobiles. Along these lines, there can be different approaches for labelling of buildings and the kind of information that will be included in the certificate. For example, the German Energy Agency (DENA) prepared a 10 page certificate according to the German Energiepass Certificate - DIN V 18599, which was used during field tests and finally issuing 4000 certificates [16].

Beyond the simple and easy-to-use appearance, labelling can be a powerful and rich tool for governments to achieve environmental performance objectives. In order to arrive at an adequate labelling method as an effective means to achieve the targets formulated in the energy policy it is crucial to: (a) Formulate a clear description of the objectives, the functionality of the labelling scheme and the required overall accuracy of the scheme; (b) Consider the feasibility of these objectives and desired accuracy of the labelling scheme related to the accuracy of the assessment method and the performance of an assessment in practice.

2.6 Cost effectiveness

The cost for building audits, certification, calculations and analysis of results for energy saving recommendations will vary in different countries. However, in most countries the idea is to establish a minimum cost according to a specific floor area for most buildings and then introduce additional charges for larger buildings [17]. The cost should range about 400-600 Euro/building for small size buildings (i.e. up to 1500 m²), while for larger size buildings (i.e. >1500 m²) the additional costs may be proportional to the floor surface (i.e. 400-600 € plus 11 €-cents/m²).

The additional costs for the calculations and analysis of possible energy conservation measures, assessment of different scenarios, and recommendations should depend on the building complexity and the nature of interventions / scenarios. These costs should amount to at least 100 € per measure, and should be higher for more complex measures. In any event, the costs should depend on the duration of the audit and the nationally established rates of engineering fees for other similar building designs and studies. Overall costs for a small size building should range from 1,500 to 10,000 € depending on the building characteristics, i.e. size, year of construction and the proposed energy conservation measures. Costs for audit and assessment of different scenarios that have already been performed for a hospital amount to about 12,000 €.

2.7 Available experience and current status of implementation

Some countries have had considerable experience with building certification. For example, The Netherlands have introduced schemes, which are mandatory for new buildings and voluntary for existing buildings, including dwellings [18]. The UK and Denmark are considered to have been the forerunners in producing single institutionalised certification schemes, however, these schemes need to be reformed to fully comply with all the provisions of the EPBD [19]. In Denmark, a scheme for homes has been operating since 1981. Since 1985, the scheme's used within the existing stock has been enforced through legislation, which requires home sellers to have an energy audit and make the results available to potential buyers. In the UK, energy ratings for new dwellings have been mandatory since 1985. Two primary certification methods have emerged for the domestic sector, SAP (Standard Assessment Procedure), being the government-approved method. However, the direct provision of home energy ratings and

recommendations for private sector homeowners in existing dwellings is currently relatively rare. Developments in this area in the UK are presented in [19].

Figure 1 presents an overview of the current status of EPBD implementation at national level for EU-25, based on a recent survey [20]. National efforts for the implementation of the EPBD vary significantly between the different EU member states. Based on the available information, all member states have initiated their efforts for the national implementation of EPBD. Some have fallen behind and will probably take advantage of the 3year delay period for full implementation of EPBD for existing buildings. More advanced are: Denmark, Germany, Czech Republic, The Netherlands and UK. An overview is summarized in the following paragraphs. Additional information for all EU-25 is available in [20] from www.epa-nr.org.

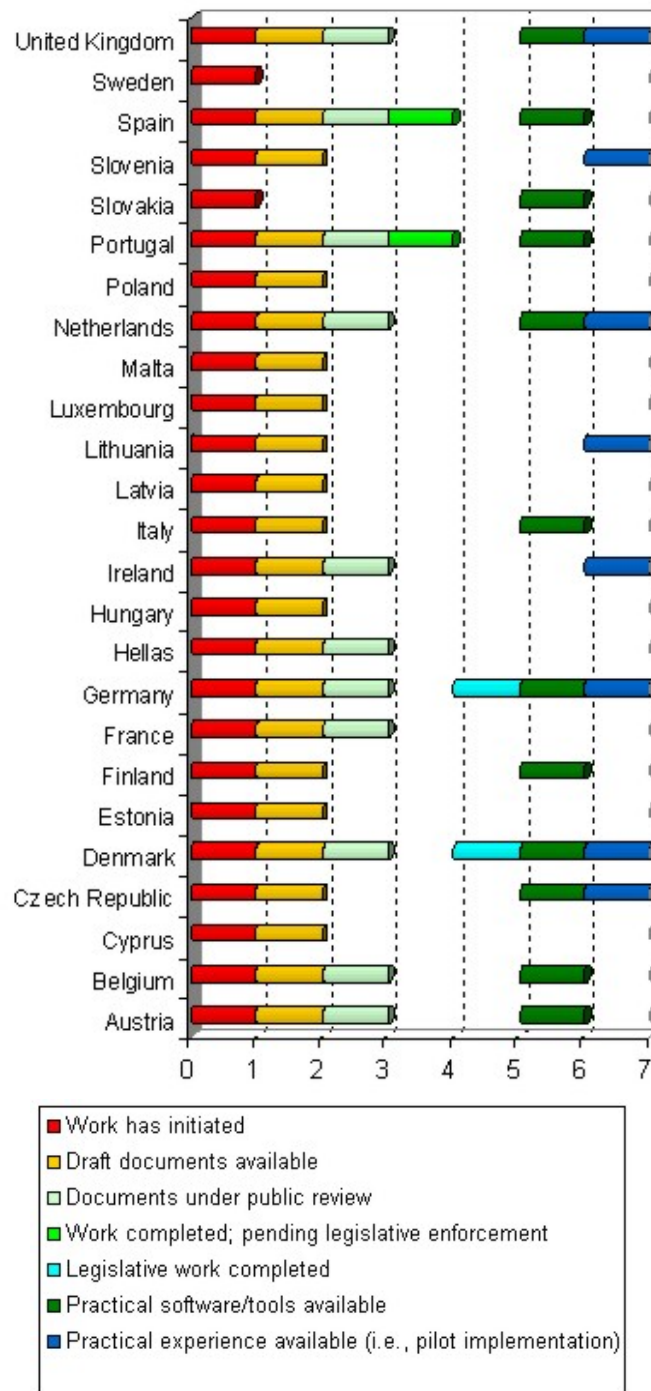


Figure 1. Overview of the current status of EPBD implementation at national level for EU-25 [20].

3. THE EPA METHODS

The two new Energy Performance Assessment (EPA) methods cover existing dwellings (EPA-ED) and non-residential (EPA-NR) buildings. Both methods are based on a systematic approach and suitable tools including a software tool to calculate the energy performance assessment of a building. However, there is no standardized process since this depends on the specific operating conditions and the building end-use, among other factors. Nevertheless, some stages are common in the majority of the assessment processes, although each stage has specific characteristics (Figure 2). They all start with an intake/inspection phase, including an interview with the client, in order to discuss and define strategies and conditions to be taken into account during the assessment, and an inspection (audit) of the building and its installations to collect the input data necessary to perform the energy analysis and establish the energy performance of the present situation and a new situation based on cost-effective energy saving measures. The methods produce an Energy Performance Certificate for buildings with the possibility for additional advice, in accordance with the EPBD requirements. The two major target groups are practitioners and policy makers, who are addressed with a tailored set of tools.

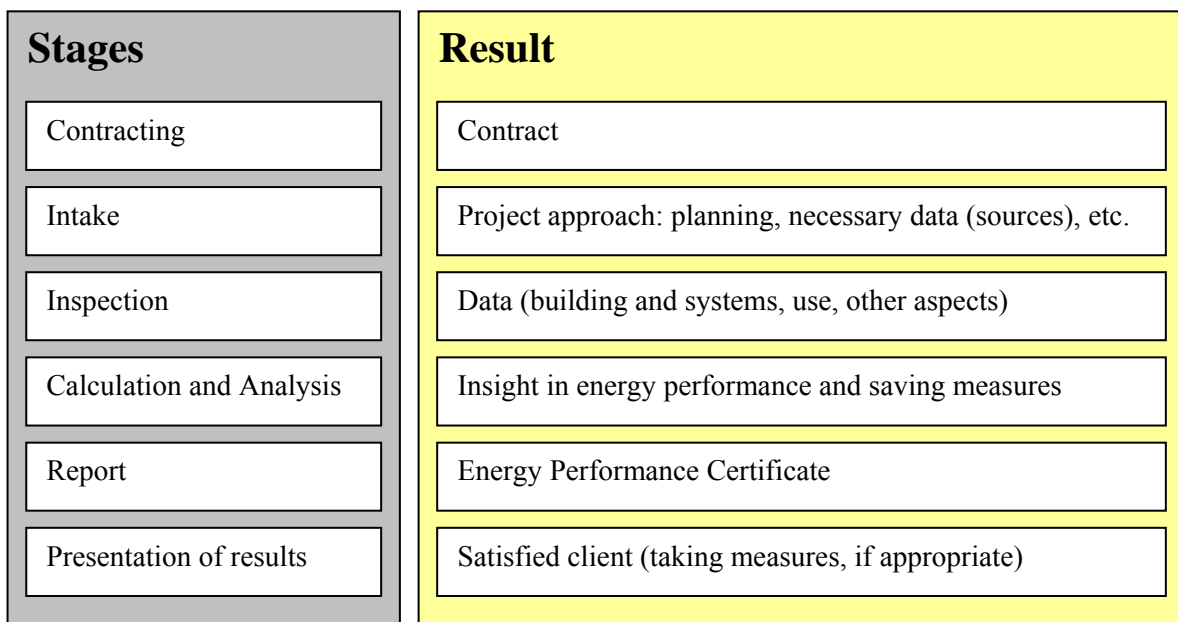


Figure 2. Overall scheme of the EPA procedures.

The EPA consultants inspect the buildings, calculate the energy performance and advice the owners for possible improvements. To achieve these goals, the consultant is provided with several tools including:

- (1) Intake / Inspection form: a list of all the required input data, which is completed during the audit. The collected data is closely related to the input parameters of the calculation tool.
- (2) Guidelines for inspection: a protocol that describes how the necessary input data is determined in a practical way, tuned to existing buildings. It gives a definition of the input parameters that can be standardized, used in the follow-up calculations, and a number of other aspects that the consultant should pay special attention to.
- (3) Calculation (software) tool: according to the EPBD, the energy performance calculation addresses the following: architecture (position and orientation, solar protection), building envelope thermal characteristics, heating installations, hot water production, air conditioning installations, ventilation, passive solar systems, natural ventilation, and indoor climatic conditions.

Since the EPA-NR method and tools are currently under development, the goal is to comply with the CEN-standards, at least the ones that are finalized; however, users will still be able to adapt the calculation routines to national requirements or new European and international standards. Similar flexibility is being offered by the EPA-ED tool, which was based on CEN WI-14 (Energy performance of buildings – Calculation of energy use for space heating and cooling). Accordingly, the methods are easily adjustable to the national context and the diversity in the market and further development and maintenance can be low cost. The EPA-ED method and instruments were tested through pilot projects in

several European countries, while EPA-NR will also be tested through a series of pilots with different end-use European buildings, including offices, schools and hospitals.

Additionally, policy recommendations address all levels of authorities in Europe. The EPA methods take into account the local framework with respect to legislation, technical aspects, design and building maintenance processes and acceptance by actors in the market. The flexibility of the methods guarantees simple transfer to all EU Member States. The instruments are developed in such a way that adjustment to new or modified CEN-standards will be relatively easy.

3.1 The EPA Software

The general software structure is outlined in Figure 3. They consist of a standard calculation core, which can be used internationally (independent of local context), and eventually may fully comply with EPBD and CEN-standards. Around this infrastructure, future users will be able to build their own national or regional specific interface. The calculation core makes use of local weather files, construction libraries, nationally adaptable method constants, etc. Specific project data are provided through the input interface. The input and output interfaces can be easily adapted to local needs for different languages or other user needs.

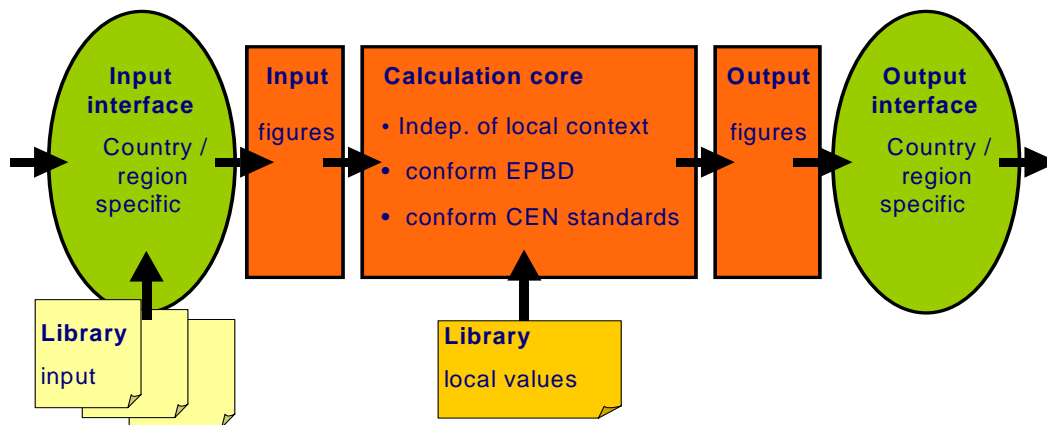


Figure 3. General software structure.

The software enables the user to:

- perform a calculation of the energy requirement for space loads, lighting, hot water, and equipment; depending on the building's end-use some of the energy calculations may not be applicable;
- document the energy consumption and CO₂ emissions;
- assess energy performance (EP);
- prepare an EP certificate;
- create scenarios to assess different energy conservation measures and calculate the pay-back time of the investments, in order to provide technical advise to the building owner(s).

The currently available EPA-ED software for existing dwellings was completed in 2004 as an international prototype tool (version 1.4.10.30) and consists of a calculation engine and a user interface for handling input and output. The calculation engine incorporates algorithms based on available European standards. The prEN 13790 (Thermal performance of buildings – Calculation of energy use for space heating) constitutes the main source for the formulas used, simplified or modified to meet the needs for existing dwellings (Table 1). For missing or not-suitable formulas for existing buildings, these were defined based on existing (and validated) models from other sources or average national values from libraries accessible through the user interface. In anticipation of the new EN standards the algorithms in the EPA-ED calculation tools were simplified as much as possible. However, the various algorithms are independently linked to the user interface. This way, future adaptations to meet national requirements or new norms that become available can be easily integrated in the software. Some of the software's algorithms were checked against the Building Energy Simulation Tests - BESTEST [21-23] and the entire

methodology and software was verified for its applicability through a pilot campaign in the participating countries (refer to the following section for the results from the pilot studies).

Table 1. Overview of EPA-ED calculations approach.

Work item	prEN 13790	Modified prEN 13790	Other	Comments
Internal and external temperature		X		Θ_i and θ_e standardized for labeling; free input for other calculations
Transmission	X			
Weighting factor b for unheated zones		X		Method in prEN 13790 can be used, but user input is also possible
Sunspaces		X		Formula from prEN 13790, with geometrical assumptions
Ventilation			X	Formulas not applicable for existing stock
Solar gains	X			Solar heat gain factor into calculation; $F_w \cdot g$ as input from interface; I_{sol} (solar radiation) available for 8 orientations and 3 tilt angles (from libraries). Effect of movable shading devices is modeled with an extra FM factor (different for heating/cooling period)
Internal heat gains		X		Neglect gains in unheated zones
Heat gain utilization factor	X			Heat capacity c given in interface; no detailed calculation for each structure
Installation efficiency			X	Differentiate between the efficiency of generation and distribution (defined in user interface)
Solar contribution (other than sunspaces)	X	X	X	Collector systems: simplified method
Cooling			X	Method from Dutch Std NEN 2916
Domestic Hot Water			X	DHW demand volume is an input variable (per occupant or gross floor area)
Auxiliary energy			X	Part of the user interface (national values)
Lighting (common spaces)			X	Part of the user interface
Photovoltaics			X	System efficiency to calculate the energy contribution.
CHP			X	Differentiate between heat and electricity production efficiency
Energy consumption			X	For different source fuels: split as a percentage of demand. Corrections from Dutch EPA method
CO ₂ emissions			X	Conversion from energy consumption (national values)
Renewable energy			X	Converted to primary energy using the efficiencies of the installation and conversion factor of the fuels.
Energy Indicator			X	EI is calculated as a simple performance value, e.g. energy per m ² . Other indicators can be determined through the user interface
Indoor climate			X	Dutch non-residential calculation scheme
Financial calculations			X	Simple pay-back time and net present value pay-back time (national libraries)

The input parameters vary from a description of the dwelling to weather data and investment costs, derived from country specific data. The user can also modify the input in the software interface, which is specified in the software libraries. Currently, national libraries are available for Austria, Denmark, Hellas and The Netherlands. The user interface of the EPA-ED software consists of: Main window (define the

actual energy consumption from various sources, and climatic data), Dwelling (define general input data, i.e. heated floor area, internal heat gains, ventilation), Thermal envelope (define opaque constructions and glazings using libraries, unheated spaces etc), Passive solar systems (define geometries and construction of sunspaces, etc), Installations (define HVAC equipment using libraries), Active solar systems (define solar collectors, PVs using libraries).

The user can create and assess different renovation scenarios by modifying the dwelling's thermal envelope elements (constructions, glazing), the installations or the passive and active solar systems. The calculation scheme proceeds as follows:

- First, the existing situation is described and the energy consumption is calculated.
- Then, the building is adapted by applying a number of measures. This leads to a variant building description and a new calculated energy consumption.
- Next, the savings are calculated as the difference in energy consumption between the current and the variant situation.
- The costs of the measures are calculated in a separate calculation.
- The results of the calculations are integrated to calculate the pay back time.

The EPA-ED software output tables (Figure 4) include:

- (1) Energy consumption: calculated monthly energy consumption for heating and cooling
- (2) Heating, Cooling and Domestic Hot Water: calculated energy demand
- (3) Summary: calculated savings (fuel consumption, electricity, CO₂ emissions, Energy Indicator) and cost (investment cost, payback period).

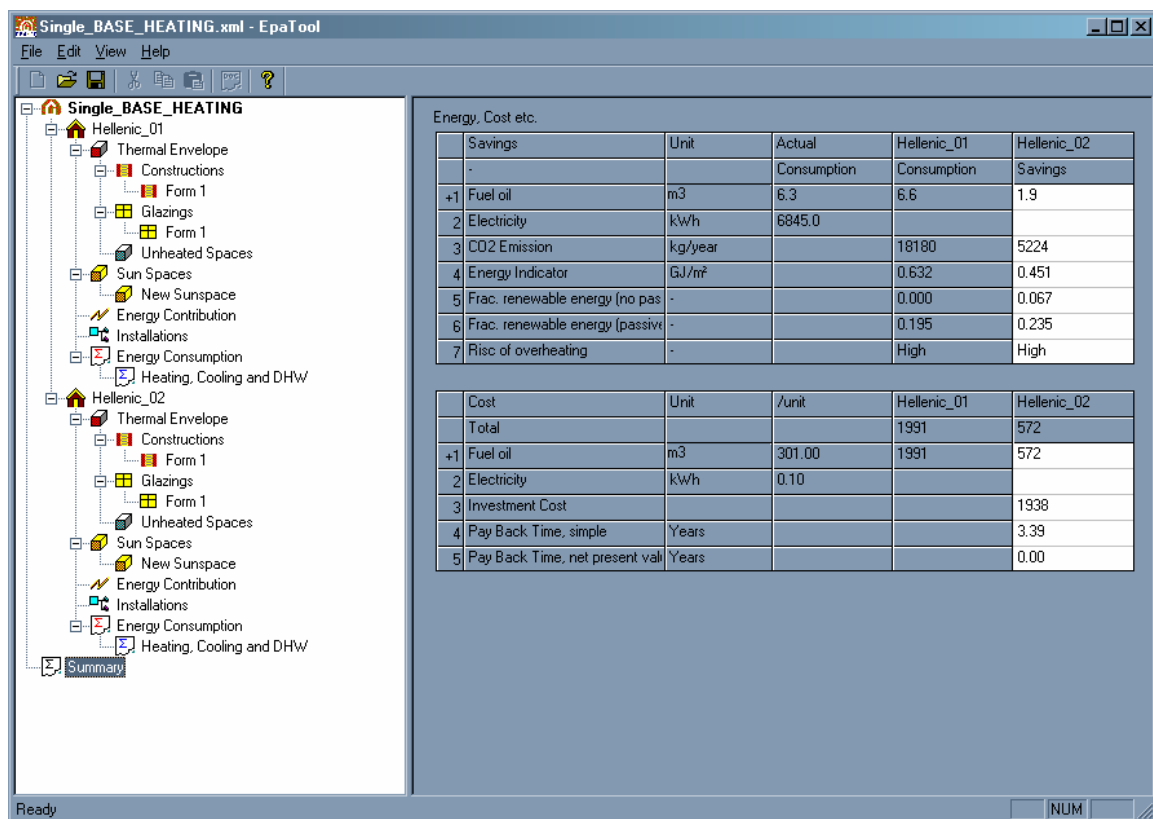


Figure 4. EPA-ED software savings (results) screen.

The EPA-NR software for existing non-residential buildings is currently under development and the beta version will be available by the end of 2005. It follows a similar structure with EPA-ED, but since many CEN standards are now becoming available, they are being exploited as much as possible. Other sources are also being used in order to bridge gaps or avoid increased complexity for energy performance calculations (i.e. the Dutch standard for energy performance of new non-residential buildings, which has also been the basis for the CEN/ISO standard / WI-14).

The EPA-NR software will focus on certification of non-residential buildings (integrating standard calculations for the EP certificate), using standard national climatic data and assuming a fixed national asset rating. According to CEN WI-1+3, this rating is based on calculations of the energy used by a building for heating, cooling, ventilation, hot water and lighting, with standard input data related to internal and external climates and occupancy. It represents the intrinsic energy potential of the building under standardized conditions of weather and occupancy. This rating quantifies the calculated energy intensity of the building under standardized conditions for a given set of energy end uses. To a limited extent, specific calculations will also be available for obtaining results to be used for providing owners with recommendations and advise on energy savings. The software will also include the necessary infrastructure (providing the possibility to add or elaborate on a limited advise module) to assist the user to perform a tailored benchmark, customized to individual buildings using real local climatic data to fit the calculated energy use to the measured energy use, over a specific period of time.

Calculations will take into account space heating and cooling, ventilation, humidification and dehumidification, lighting, sanitary hot water, along with pumps, fans and other equipment. The input and output interfaces will be standardized and independent as much as possible from the algorithms in the calculation engine, following the structure proposed by the CEN standards. National databases, including climatic data and other average values will be available, at least for the participating countries in the project. The calculations will be possible for multizone buildings, performed on a monthly basis. For hourly calculations, the user will need to alter the time step in the input interface and provide the necessary new module in the calculation engine. The interaction between conditioned building zones is neglected.

The input parameters of the EPA-NR and EPA-ED softwares will be similar, including libraries with typical national data for building construction, weather data and investment costs. In addition, other applicable systems like combined heat and power, will also be considered. Again, the EPA-NR software algorithms will be checked against BESTEST and the entire methodology and software will be verified for its applicability through a pilot campaign in seven European countries, including offices, schools and hospitals.

4. PILOT STUDIES

Pilot studies following the EPA-ED methodology were performed in Austria, Denmark, Hellas and The Netherlands. The goal of these pilots was to provide useful insight information about the intake/inspection process and the software, collect feedback on the time required by the consultants to complete the entire process, assess the reliability of the calculations, evaluate the practical value of the results to the building owners and identify any necessary adjustments to the prototype for the different countries. The six pilots were carried out in different age houses, dwellings and apartment buildings, representative of the national typologies.

Several problems and possible interventions were identified based on the information collected during the audit, the interaction with the occupants and analysis of the available data. The first step was to evaluate all the different interventions independently. In a following step, selected individual actions were combined and evaluated together to obtain the corresponding cumulative results that provide a global overview of their impact on improving the building's energy performance (Figure 5). Emphasis was given on elaborating the practical aspects of the results with the client. The time required to perform the inspection and complete the process varies from two to four days, depending on the size of the building and availability of the necessary input data.

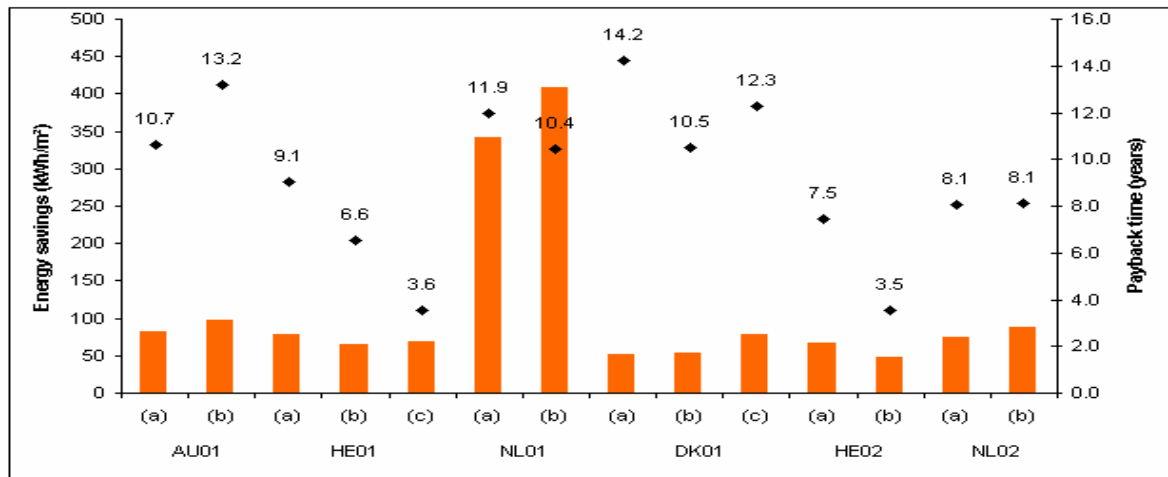


Figure 5. Energy savings (bars in kWh/m²) and payback time (bullets in years) of the different scenarios evaluated with the EPA-ED software during the pilots, in four countries (AU: Austria, HE: Hellas, NL: The Netherlands and DK: Denmark). The first three pilots correspond to apartment buildings and the last three to houses. The evaluated scenarios were for AU01: (a) Double glazing; (b) Thermal insulation. HE01: (a) Wall insulation, new boiler (NB), insulated heat distribution pipes (IHDP), solar collectors (for DHW and space heating); (b) Roof insulation, piloti insulation, NB, IHDP, solar collectors; (c): Double glazing, NB, IHDP, solar collectors. NL01: (a) wall and roof insulation, high efficiency windows; (b) wall and roof insulation, high efficiency windows, efficient lighting, combi boiler. DK01: (a) Roof insulation; (b) solar collectors, (c) High efficiency windows. HE02: (a) Insulate load bearing structure, weather stripping; (b) weather stripping, solar collectors. NL02: (a) Roof insulation; (b) double glazing.

The intake/inspection process and use of the software was successfully implemented by third parties, not directly involved in the development, in order to have an unbiased assessment of the overall approach and software. The results were also positively evaluated by building owners. No major adjustments to the prototype software were necessary, to account for the different national characteristics.

5. CONCLUSIONS

The building sector uses about one third of all the raw materials and energy produced in Europe and over half of the electricity. As a result of improved legislation (i.e. building codes and insulation standards), the use of new building materials and more efficient equipment, much progress has been achieved in energy efficient and environmentally friendly new buildings over the past decade. On the other hand, higher living and working standards, along with the introduction of new equipment and appliances, including air conditioning, may counterbalance these savings and actually increase the average energy consumption in buildings and create considerable problems at peak load. Thus, the effort for energy conservation, while maintaining an optimum indoor environment, is a continuous struggle in order to minimize the dependency on conventional fuel sources, secure the energy balance and reduce the environmental impact from fossil fuels.

Energy efficiency in buildings can result to a multitude of positive effects, among which decrease the use of fossil fuels, alleviate the burdens of energy imports, and reduce GHG emissions. The implementation of the EU Directive on the Energy Performance of Buildings (EPBD) as of January 2006 is expected to play a determinant role. EU member states are introducing national laws, regulations and administrative provisions for setting minimum requirements on the energy performance of new and existing buildings that are subject to major renovations, and for energy performance certification of buildings. Additional requirements will include regular inspection of building systems and installations, an assessment of the existing facilities and to provide advice on possible improvements and on alternative solutions.

National efforts for the implementation of the EPBD vary significantly between the different EU member states. Based on available information, all member states have initiated their efforts for the national implementation of EPBD. Some have fallen behind and will probably take advantage of the 3year delay

period for full implementation of EPBD for existing buildings. Overall, more advanced in the national implementation of the EPBD are: Germany, Denmark, Czech Republic, and UK.

The new Energy Performance Assessment (EPA) methods for Existing Dwellings (EPA-ED) and non-residential (EPA-NR) buildings include software and tools addressing the needs of both policy makers and consultants with respect to Energy Performance Certificates for existing buildings, in line with the EPBD.

Specifically, the main results for the EPA-ED project which was completed in 2004 include:

- For policy makers: a **benchmark report** describing the status and context of the existing dwelling stock, penetration of energy saving measures and actual policies, housing market and actors, energy market, buildings and installation technologies in Denmark, the Netherlands, Austria and Greece. A **report on new policies** presenting the framework of policies, actors and stakeholders that EPBD is to be implemented in, to support on-going efforts throughout the European Union. Various **national brochures** that describe how EPA-ED can affect Energy Performance Assessment at national level. **Thematic brochures** cover some specific issues like a short description of the method, issues regarding energy labelling and the process of energy performance assessment.
- For consultants and researchers there is a **guide** describing the EPA-ED method. More detailed information on how to apply the method in the market is described in the **report on application strategies**. To facilitate the consultant during the process a **checklist** for performing the building audit and collecting the necessary input, complemented with an **inspection protocol** that presents information and guidance about adequate data acquisition. The **EPA-ED software** is a beta version, focuses on energy related issues and is suitable for issuing an Energy Performance Certificate of an existing dwelling. It supports the consultant throughout the process for collecting the necessary data, the building audit, calculations and analysis of different energy conservation scenarios. The consultant can then provide owners with specific advice for measures that can improve the energy performance of the dwelling or building. The interface of the tool can be easily adapted to meet national requirements, while the calculation engine can be modified to include new European norms as they become available.

The EPA-ED method and prototype software were successfully used for a number of pilots performed in four European countries. Follow-up work is currently underway to prepare a suitable methodology and a new software for non-residential buildings in the framework of the EPA-NR European project.

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