Bulletin of the *Transilvania* University of Braşov • Vol. 8 (57) No. 2 - 2015
Series I: Engineering Sciences

# ENERGY EFFICIENCY. ENERGY PERFORMANCE IN THE BUILT ENVIRONMENT

**C.A. ILIE**[1] **I. VIȘA**[1]

***Abstract:*** *Energy is an essential pillar that feeds and stimulates economic growth and social welfare, thus there is a need to assess the future economic and social growth based on efficiency power consumption with lower costs. In this context, energy efficiency is carefully analysed in terms of the built environment, which is responsible for at least 40% of the total energy consumption. This paper includes a blueprint of the European legislative framework on energy efficiency and energy performance of buildings; it outlines the harmonizing strategies for issuing energy efficiency plans at the level of all Member States, and comparatively discusses the performance requirements for buildings based on the national energy plan in Romania.*

***Key words:*** *energy efficiency, energy performance for buildings.*

## 1. Introduction

The 2020 EU sustainable development strategy has several main objectives of: (1) 20% green house gas emissions (GHG) reduction; (2) 20% energy demand reduction through energy efficiency; (3) 20% energy needed to be met from renewable energy sources and (4) 10% from bio fuels [10]; this asks for innovative and competitive solutions that can be accepted and supported by citizens.

The initial EU Council formulated conclusions on the need to increase energy efficiency to meet the first objective considering the primary energy consumption by 2020. Subsequent conclusions of EC showed that this objective must be actually achieved by reducing primary energy by at least 368 Mtoe [12], as presented in Figure 1.

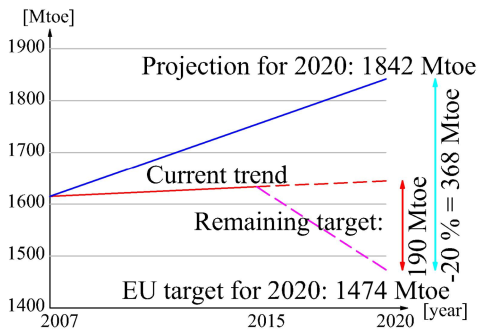


Fig. 1. *EU 20% energy efficiency target*

However, the near past and current development allow estimating that EU will reach energy savings only of around 18-19% until 2020 [15], thus missing the target set by 1-2%. Sustainability scenarios also show that, if countries would harmonize and implement EU legislation on energy efficiency, the 20% target could be achieved without additional measures [8].

[1] Centre "Renewable Energy Systems and Recycling", *Transilvania* University of Braşov.

The built environment is responsible for at least 40% of total energy consumption and 24% of EU $CO_2$ emissions [8], [5].

Meeting the EU target is therefore significantly linked to measures implemented at the buildings and community levels.

A new building consumes at least five times less energy than an old one and more than 35% of the EU constructions are older than 50 years [8]. So focus should be set on the quality of any new building, but highly important are the retrofitting processes, to significantly reduce energy consumption and greenhouse gas emissions.

The Energy Efficiency Directive (EED), the Energy Performance of Buildings Directive (EPBD) and the Renewable Energy Directive (RED) activated a set of measures supporting a dynamic and consistent transition towards the sustainable built environment [1].

Following the world targets and the rather different legal frames developed at national levels, this paper presents a synthesis of the energy performance parameters/indicators of the current built environment, in direct correlation with the actions and action plans. The data in this paper aims at contributing to the general effort towards standardization, as a pre-requisite for coherent strategies sustainable development implementation.

## 2. Legislative Framework

Strategies and plans were issued, both at European and at Member State levels, aiming at meeting the strategic objectives set by EU. Thus, a new energy model was formulated; sustainable and socio-economical acceptable, as defined by the European SET-Plan (The European Strategic Energy Technology Plan) [5], which together with the legal instrument, the European Directive 2009/28/EU offer concrete solutions for meeting the 2020 targets.

Meeting the energy efficiency goal of 20% by 2020 represents the central priority in the energy efficiency development plans; following this, a set of regulations have been formulated:

- The Energy Efficiency Directive (EED - D 2012/27/EU);
- The Energy Performance of Buildings Directive (EPBD - D 2010/31/EU);
- Minimum energy performance standards and labelling the information regarding energy performance (Eco-design Directive 2009/125/EC and the Energy Labelling Directive 2010/30/EU);
- Reducing $CO_2$ emissions for vehicles (Regulation EU No 333/2014 and Regulation EC No 443/2009);
- Increasing the availability of grants, the European emissions trading (The EU Emissions Trading System (ETS) - Directive 2003/87/EC).

## 3. Energy Efficiency

Energy efficiency is one of the most cost effective way to strengthen the energy supply security and to reduce GHG emissions and other pollutants. In many ways, energy efficiency can be considered the largest energy resource in Europe [8].

The main pillar for energy efficiency increase is represented by the 2012/27/EU Directive. By using more efficiently the energy, individuals can reduce the energy bills; globally, GHG emissions and the dependence on external supplies of oil and gas can be reduced [12].

Energy efficiency must be improved in all stages, starting from the energy production, all the way to the final consumer; however, feasibility asks for benefits that exceed the renovation investment cost [8].

Buildings have the largest energy efficiency potential; transport is ranked second while industry will be separately addressed with energy efficiency requirements for industrial equipment (e.g. by improving automation and IT in SMEs and through energy audits and energy management systems [8]).

EU promotes the idea that the public sector must set an example by speeding up the rehabilitation of public buildings through a mandatory target, and introducing energy efficiency criteria in public spending.

Article 24 of EED requires each Member State to compose a national action plan on energy efficiency (NEEAP) [8], every 3 years starting with 2014. As a first step, Member States will set indicative targets and the efforts of each state will be evaluated to assess the likeliness of achieving the global objective. A second phase foresees that after forecasting the global energy efficiency EC will impose a series of mandatory measures so that the target objective will be met.

To overcome a number of uncertainties and to create a strong direction regarding efficiency, the EU has already adopted a series of measures to improve energy efficiency in Europe; these include:

- 1.5% annual reduction in energy sales;
- annual energy efficient renovations of at least 3% of the buildings owned and occupied by the central governments;
- the obligation of issuing energy certificates for the buildings sale and rental;
- labelling and standardization in the spirit of energy efficiency for products such as thermal boilers, appliances, lighting equipment and televisions;
- supplementing National Energy Efficiency Action Plans (NEEAP) every 3 years;
- replacing more than 200 million electricity meters and 45 million gas meters by 2020;
- obligation for the large companies to carry energy audits once every 4 years;
- consumer's rights protection through easy and free access to history data on energy consumption.

## 4. Energy Performance of Buildings

Article 9 of EPBD requires that Member States have to ensure that starting on 31.12.2018 all new public buildings will be Nearly Zero Energy Buildings (NZEB) [1], [9]. Furthermore, the Directive establishes the obligation for standardization at Member State level of the minimum levels of the building's energy performance based on optimal investment cost.

Under the 2010/31/EU Directive on the energy performance in buildings, a series of measures are provided:

- mandatory use of energy certificates for the buildings sale and rental;
- Member States of the EU must impose inspection schemes for heating and air conditioning systems;
- all new buildings will be NZEB buildings starting December 31, 2020 (public buildings starting December 31, 2018);
- EU Member States are required to impose minimum energy specifications for most refurbishment items of buildings (heating and air conditioning systems, roofing, walls, windows etc);
- EU states will decide the funding scheme for promoting and improving energy efficiency in buildings.

## 5. Buildings in Terms of Energy Efficiency

The EU legislative framework requires Member States to adopt their own definitions for building performance [1], [3]. There is a huge potential for improving energy efficiency in buildings, starting from the initial consumption as it is shown in Table 1 [14] and Figure 2, and identifying opportunities for efficiency as will be further presented.

As the above data show, there is a broad variety in the reported values of the EU country; there are some objective reasons, related to the climatic profile and the economic development (GDP per capita), along with a set of factors linked to traditions, culture or education (thus acceptance). The key issue stated by the EU legal frame is the *affordability* of the proposed measures that is considered the main supporting factor for immediate acceptance and future actions.

*Average consumption* Table 1

| Country/Cons. in buildings [kWh/m²/y] | | | | | | |
|---|---|---|---|---|---|---|
| **AT** | **BE** | **BG** | **CY** | **CZ** | **DK** | **EE** |
| 259 | 346 | 142 | 144 | 281 | 191 | 353 |
| **FI** | **FR** | **DE** | **EL** | **HU** | **IE** | **IT** |
| 302 | 214 | 238 | 201 | 261 | 248 | 189 |
| **LV** | **LT** | **LU** | **MT** | **NL** | **PL** | **PT** |
| 332 | 200 | 522 | 101 | 236 | 243 | 120 |
| **RO** | **SK** | **SI** | **ES** | **SE** | **UK** | **HR** |
| 266 | 296 | 219 | 151 | 258 | 265 | 210 |

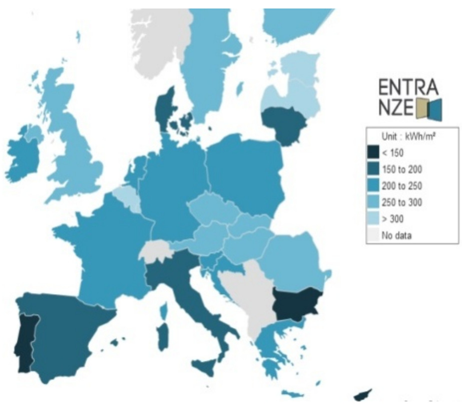


Fig. 2. *Average consumption* [14]

In a first step, EU targeted a 20% increase in the energy efficiency by 2020, as compared to the provisioned consumption for the same milestone (equivalent to closing 400 power plants). As this target proved to be feasible, during the October 2014 summit, the Member States agreed upon new targets formulated for 2030, to at least 27% energy efficiency decrease (while the European Commission proposal was for 30% [8]).

## 6. Energy Requirements for Buildings

A NZEB building is defined as *"a building that has a very high energy performance, as determined in accordance with Annex I. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby"* [11].

In Member States where there is an official definition of Low Energy Buildings (LEB), the calculation is made according to the EPBD Directive to which national applicable standards are added.

An analysis at Member States' level on the acceptable and affordable performance criteria for every state shows obvious deviations from a matrix - which makes difficult to compare the performance of each state's buildings. Some of these differences for defining the calculation of the energy performance of buildings in the EU are:

- using the built surface in the calculating methodology of heating/cooling;
- variations between internal standards of comfort;
- including unheated areas in the calculating methodology;
- the flow considered as primary energy;
- different conversion factors for thermal agents used in transport systems;
- different climatic conditions [6].

The energy performance of the buildings must be expressed in terms of primary energy as requested in the EPBD. However, to reflect the relevance of emissions consumption, $CO_2$ emissions should be added as additional information to ensure energy performance with climatic targets [4].

***Comparison indicator - primary energy***

European laws require the energy performance indicator to be expressed as primary energy used by a building and it reflects the equivalent fossil fuel consumption that can be converted into percentages of polluting emissions; EPBD Directive is defining this term as: *"energy from renewable and non-renewable sources which has not undergone any conversion or transformation process"* [11].

Specifically, it is very important that the calculation method of the conversion from final to primary energy to be based on actual parameters and uninfluenced by politics, through inaccurate in approximations and assessment. Furthermore, energy conversion factors should be continuously taken for the system energy situation [4].

Defining and consequently calculating the primary energy consumption is strongly influenced by the calculation limits. Figure 3 shows several possible limits, consistent with the methodology specified in EPBD and its standards support, establishing at least three calculation methodologies as follows:

(1) *Net energy demand:* the primary energy is calculated considering the extraction point, directly from the source, before any transformation or loss [6];

(2) *Delivered energy:* most countries have defined the calculation limit as being somewhere between the point of extraction and the point where the energy enters the building. Losses during energy conversion are thus part of the calculation for primary energy. This limit is not perfectly clear in terms of power consumption, since the electric consumption is covered by a conversion factor (which differs from country to country), to appreciate the power plant conversion losses [6];

(3) *Thermal envelope:* the limit considers the building's thermal envelope but this only gives the energy demand, not the energy consumption [6].

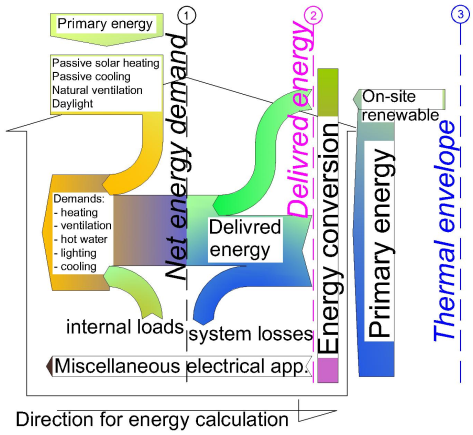


Fig. 3. *Primary energy calculation limits*

Energy flows included in the energy performance requirements may vary from one country to another and consequently direct comparison is hardly possible. Buildings are designed for various use (residential, public) and may have very different sizes, thus have different profiles of the energy consumption, [6]. Therefore, Member States have developed their own definitions for low energy consumption buildings, establishing also the performance levels, as requested in Article 9 of the EPBD Directive. These levels, expressed in primary energy, are shown in Table 2, broken down for each country, to the extent that they were completed [7], [2], [13]. These values are self-imposed by each Member State, as result of a complex analysis of the current energy demand, available energy sources (amount, costs) and based on realistic development scenarios. An effort towards rationalizing the calculations is done, using a unique algorithm; however, this standardization effort is far from being finalized.

Table 2

*The performance levels of low energy consumption buildings. Status: September 2015*

| Country | Calculation mode | Primary energy [kWh/m²/y] | | | | Type of energy included in calculation method (EPBD basic) | Additional |
|---|---|---|---|---|---|---|---|
| | | New buildings | | Existing buildings | | | |
| | | Residential | Non-residential | Residential | Non-residential | | |
| AT | (3) | 160 | 170 | 200 | 250 | H,C,W,AC + L for NRB | +AP |
| BE | (3) | 45 | 90** | 54 | 108** | H,C,W,AC + L for NRB | |
| BG | (3) | ~30-50 | ~40-60 | ~30-50 | ~40-60 | H,C,W,AC + L for NRB | |
| HR | (3) | 30-41 | - | - | - | H,C,W,AC + L for NRB | |
| CY | (3) | 100 | 125 | 100 | 125 | H,C,W,AC + L for NRB | |
| CZ | (2) | 75-80%* | 90%* | 75-80%* | 90%* | H,C,W,AC + L for NRB | |
| DK | (2) | 20 | 25 | 20 | 25 | H,C,W,AC + L for NRB | |
| EE | - | 50-100** | 90-270** | - | - | H,C,W,AC + L for NRB | +AP |
| FI | - | - | - | - | - | - | |
| FR | (2) | 40-65** | 70-110 ** | 80 | 60%* | H,C,W,AC + L for NRB | |
| DE | (3) | 40%* | - | 55%* | - | H,C,W,AC + L for NRB | |
| EL | - | - | - | - | - | - | |
| HU | (3) | 50-72** | 60-115** | - | - | H,C,W,AC + L for NRB | |
| IE | - | 45 | ~60%* | 75-150 | | H,C,W,AC + L for NRB | |
| IT | - | - | - | - | - | H,C,W,AC + L for NRB | |
| LV | (3) | 95 | 95 | 95 | 95 | H,C,W,AC + L for NRB | |
| LT | (3) | A++*** | | A++*** | | H,W,AC + L for NRB | |
| LU | (3) | A-A-A*** | | - | - | H,C,W,AC + L for NRB | |
| MT | (3) | 40 | 60 | - | - | H,C,W,AC + L for NRB | |
| NL | (3) | en. perf. ceof. =0 | | - | - | H,C,W,AC + L for NRB | |
| NO | - | - | - | - | - | - | |
| PL | - | 60-75** | 45-70** | - | - | H,C,W,AC + L for NRB | |
| PT | - | - | - | - | - | - | |
| RO | (3) | 93-217** | 50-192** | - | - | H,C,W,AC + L for NRB | |
| SK | (3) | 32-54** | 34-96** | - | - | H,W,AC + L for NRB | |
| SI | (3) | 40-75** | 70 | 70-90** | 100 | H,C,W,AC + L for NRB | |
| ES | - | A*** | - | - | - | H,C,W,AC + L for NRB | |
| SE | - | 30-75** | 30-105** | - | - | H,C,W,AC + L for NRB | |
| UK | (2) | 44 | - | - | - | H,C,W,AC + L for NRB | |

[*] = percentage of the reference building; [**] depending on climate zone; [***] according to energy classification of buildings;

H = heating; C = cooling; W = domestic hot water; AC = air conditioning; L for NRB = non-residential buildings lighting; AP = appliances.

Calculation mode of primary energy limits: (1) Net energy demand, (2) Delivered energy, (3) Thermal envelope.

## 7. Energy performance in Romania

Romania, as a Member State of EU, adopted a series of laws to harmonize the national legislation with the EU directives on energy efficiency, energy performance in buildings but also to create financing schemes able to support the targeted parameters and objectives.

Moreover since 2015, Romania presents a National Energy Efficiency Action Plans (NEEAP) developed for domestic consumption of energy and built environment, setting performance thresholds for energy depending on the building type and representative climatic zone, as the data in Tables 3 and 4 shows [13].

Table 3

*Energy performance objectives of Romanian buildings*

| **Primary energy [kWh/m²/y]** | | | |
|---|---|---|---|
| **Single family building** | | **Apartment building** | |
| new | existing | new | existing |
| 110-190 | 160-280 | 92-113 | 90-135 |

Table 4

| **Primary energy [kWh/m²/y]** | | | | | |
|---|---|---|---|---|---|
| **Offices** | | **Schools** | | **Hospitals** | |
| new | exist. | new | exist. | new | exist. |
| 45-60 | 60-80 | 35-75 | 67-122 | 75-200 | 175-275 |

As the data in Table 4 show, already existing residential buildings have to comply with apparently “mild” threshold values; however, considering the current values (with specific energy consumption ranging between 400…650 kWh/m$^2$/year) it may be understand that the refurbishing investments are actually rather high and should comply with the major EU recommendation: affordability.

Additionally, in Romania, only 2% of the building stock is represented by new buildings, thus the expected effort involves a large part of population. To comply with the energy efficiency objectives, effective refurbishing should be done, well adapted to the onsite climatic conditions. For the existent public buildings, the imposed values are even lower, but the burden may not be so high, as most of the buildings are no older than the ‘70s.

For the new buildings the targeted values are, as expected, low; this asks for coherent and novel construction and architectural concepts, able to fulfil at least two prerequisites: efficiency and low-cost.

## 8. Conclusions

The problem of energy efficiency and the development of national standards represent a permanent focus of the European states and of EU as a whole. However there is not an unitary concept defining the types of energy that allow to assess the performance criteria and energy efficiency.

“Trend setters” can be observed in terms of power thresholds imposed by the states of Central and Northern Europe who tends to set thresholds for consumption close to zero (e.g. Denmark, The Netherlands, Belgium) in counterbalances with Southeast European countries (e.g. Estonia, Romania or Cyprus).

Interpretations on the energy performance indicator in primary energy terms are differently viewed by Member States. The legislative framework and supporting documents do not define clearly the primary energy *vs.* final energy, and there is not a clear definition of the energy produced from renewable sources reported to primary energy. Therefore, a unitary concept must be defined, aiming at formulating the energy indicators in order to efficiently implement strategies for the new built environment until the deadline (2019/2021).

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