Contradictions of low-emission nZEB buildings

Severnyák K
University of Debrecen, Hungary

severnyakk@yahoo.co.uk

Abstract. Based on the EPBD 2010 directive and the mandated method of cost-optimum calculation the forthcoming national regulations require “nearly zero energy buildings” which have high energy performance, significant share of renewables in covering the low energy need and harmonizing the requirement system and the cost-optimum all over in Europe. Known intention of the EU Member States as well as some research reports create the impression that predominant use of biomass in the forthcoming years will be the right way to fulfil the above requirements of nearly zero energy buildings. Taking advantage of regulations in many Member States, the amount of yearly primary energy demand is favourably influenced by the low primary energy conversion factor determined by the very states; besides the delivered energy does not decrease. The CO$_2$ neutrality of biomass is not real. It is true that the emission of gas firing far exceeds that of wood firing, but emissions from the production of natural gas might be lower than that of the production of certain wood products. Overall, the lifecycle-based emission of biomass firing for the most converted fuels is already significant. In the case of wood combustion, the local pollutant emissions, which occur in cities, are significant, while the CO$_2$ constraint take place in the forests.

1. Introduction
Based on the European Parliament’s directive published in 2010[1], all new buildings built after 31 December 2020 within the EU should meet the requirements of nearly zero-energy buildings. According to the definition, these buildings must be characterized by low energy consumption and extensive use of renewable energy. The European Union has entrusted the Member States to set a maximum primary energy consumption requirement for nearly zero-energy buildings, which varies from one Member State to another. The maximum value of the energy consumption of nearly zero-energy buildings is determined per year and floor area in primary energy. The method of calculating the yearly energy consumption is determined by the Member States individually (figure 1).
Figure 1. The primary energy demand for NZEB buildings in some EU Member States BPIE [2] (including renewable energy use).

The regulation gives Member States a broad opportunity to define the criterion, and this criterion can be met in a number of favorable computational ways.

2. Primary energy calculation mode interpretation in the EU

Buildings use heat, electricity, or mechanical energy. Different forms of useful energy must be converted into primary energy for comparability. Renewable and non-renewable energy sources such as coal, crude oil, natural gas, water energy, wind, and solar radiation found in nature are so-called primary energy carriers. Most of them are not used directly, but after conversion. The conversion into a directly usable energy carrier, such as gasoline, diesel, electricity, involves energy use and losses. The magnitude of the loss depends on the degree of conversion and the technology used. In Hungary, for example, the primary energy conversion factor for electricity (e) equals with 2.5 determined by the current regulation, which means that by investing 2.5 kWh of primary energy we get 1 kWh of useful electricity.

Member States of the European Union use primary energy conversion factors (e) with different values for the same energy carrier, that is, they determine their primary energy consumption individually depending on the energy, loss and other factors of the conversion of energy carriers [3]. At the same time, these conversion factors may conceal central subsidies or other incentives that may cause energy consumption results to be subjectively distorted in individual Member States. The e-factor is set by the Member States on a subjective basis, mostly according to their own energy policy [4]. However, this should be an energy statistics parameter that could be determined by statistical measurements by tracking energy paths to territorial and / or consumer groups.

Most decision-makers in the EU are convinced that the nZEB requirement could be met with a widespread use of biomass [5]. As an example, the conversion factor for biomass energy is 0.6 in Hungary, 1.08 in Austria and 0.2 in Slovakia. Considering an example building, the same amount of fuel on the opposite sides of the border shows a completely different level of total primary energy consumption in Hungary, Austria and Slovakia. In many Member States, the primary conversion factor for biomass is surprisingly low (figure 2), which results in low total primary energy consumption simply by conversion factors. This way only the total primary energy use is reduced, not the heat demand.
Let us calculate [6] [7] and compare the primary energy need of identical buildings on the opposite sides of the Hungarian-Austrian and Hungarian-Slovak borders. The sample building is a one-storey single-family house with a floor area of 100 m² made from manually built building blocks, widely used in Hungary between 1960 and 1980. Assuming the same environmental conditions the primary energy demand for heating the building is not the same in the three countries if biomass is used. The buildings were just a few meters away from each other on the opposite side of the border, and locally processed forest tree was used as fuel, which requires minimal processing (figures 3, 4).

The truth is when different fuels are used, consumption of the sample Hungarian building shown in figure 5, taking into account the efficiency of the system, and the primary energy conversation factors more primary energy carrier is needed when using biomass.
3. Fulfilment of nZEB building criteria in EU member states

Biomass use is expected to be the key to solving the problem of high renewable share of nZEB buildings. Biomass as an energy source can be renewed, but it has limitations. If we only look at the heat demand of buildings, it is likely that the growing demand for biomass poses a risk to resources and will result in rising prices (not to mention the biomass needs of thermal power plants, which is an important source of green electricity in Europe) [8].

Scientists, looked at the dynamic simulations of a single-family house and an office building in four representative European climates [2]. The results of each study put biomass use in the centre. This approach is reflected in the plans of some Member States which includes the share of the various renewable energy sources planned to be used in the future.

With some simplification, Member States distinguish renewable sources for heat production for example: solar, geothermal, biomass, heat pump, (the amount of heat or electricity generated above the needed auxiliary power).

Although this classification is not considered consistent, these data are available (figure 6).

![Figure 6. The planned share of different renewable energy sources in some member state [9]](image)

However the acquisition of biomass fuel in the European Union is difficult for many Member States, e.g. GB imports from the USA, whilst Denmark from the Baltic States. [8].
4. Cost optimum requirements within the EPBD

“EPBD Recast” sets additional criteria for increased energy efficiency. EU Member States were asked to draw up action plans by 2020 and radically reduce energy consumption according to specific milestones. Member States shall regulate their own national energy criteria, which should be reviewed every five years. The Commission has published its regulation in support of the review and the Member States were asked to take into account the methodology and the criteria [10].

The methodology requires the identification of cost-optimal energy criteria for buildings and building elements. The primary energy consumption of buildings found in the energy certificate and the global cost of buildings, which consists of the sum of the present value of the initial investment costs, sum of running costs, and replacement costs (referred to the starting year), as well as disposal costs if applicable, are considered as the basis for the determination of the optimum.

Based on this method, the Member States calculated the costs of building renovating and maintaining optimum-including operation costs. The calculations had to take into account the national legislation in force in the Member States. Under the EPBD Regulation, the national minimum energy performance requirements should not deviate from the cost-optimal calculations by 15%. The cost-optimal level shall lie within the range of performance levels where the cost benefit analysis calculated over the lifecycle is positive [11] figure 7.

![Figure 7. Cost optimum range by the EC](image)

Based on the results, biomass use was highlighted by several advisory organizations supporting the Commission. Hungarian calculations also showed that progressive passive renovation and the complex renewal of engineering system to biomass use should be optimal. [6]

5. Cost aspects

In Hungary, the calculation underlying the report was prepared by Energiaklub Climate Policy Institute and Applied Communications; we studied a total of 15 reference buildings. [6]

The biomass fuel based optimum of nearly zero-energy buildings is shown through the cost optimum analysis of one of the reference buildings.

This type of building is typically a cube-shaped building constructed of B30 blocks, so-called “Kádár kocka” or “Kádár cube” (Hungary’s leader between 1956(1961)-1988) based on the survey of the Energiaklub Negajoule2020 [11]. Built between 1960-1980, two-bedroom house with gas convector heating, gas-boiler hot water producing equipment. The typical annual energy consumption of the building is 38,520kWh / year, the CO2 emissions are 7.82t / year, calculations based on the 7/2006 Decree by the Minister without Portfolio of Hungary. [12]

The B30 block was a modern building unit in the Hungarian building materials market from 1960 to 1980. According to the data of the Hungarian Central Statistical Office based on the 2011 census data, of the stone, masonry unit buildings (2.48 M), more than 800,000 buildings could be built masonry units, therefore it can be considered a typical type of building in Hungary’s single-family housing stock (figure
According to the result of the analyses, the optimum renovation of this building will result in an nZEB building.

Figure 8. According to the data of the Hungarian Central Statistical Office, the census data prepared in 2011: by the building material of residential homes

According to the published methodology, Member States had to determine energy performance requirements for buildings in order to optimize costs. Examination was mandatory both at the level of the annual energy consumption of buildings and that of building elements.
Table 1. Building shell and energy system versions for a reference single family house

The examination followed the next steps:

In the first step, the heating demand was reduced from the moderate to the progressive level by modernizing the energy performance of the building shell (wall, attic, cellar thermal insulation and replacement of windows), by building elements and their combination, and then such combinations were examined. Following the reduction of heat demand, combined alternatives were analyzed with various engineering solutions and the use of mandatory renewable energy sources. Calculations based on the 7/2006 Decree by the Minister without Portfolio of Hungary. [12]

In the reference single family house, we looked at 24 really feasible alternatives for modernization. For combinations, see Table 1. The results of the analysis are given in figure 9. The optimum solution No.20 is a complex refurbishment, based on wood heating.

![Global cost / primary energy ratio](image)

**Figure 9.** Global cost (EUR) in function of building shell and energy system combinations. Numbers identify the combinations in Table 1.

However, the life-cycle CO2 emission examination of biomass firing, it can be established that it is by no means CO2 neutral. Depending on the fuel, fuel production and transport may show significant CO2 emission values which might be even higher than those of the production of natural gas.

During our research, we have examined whether life-cycle CO2 emissions show higher values for biomass or natural gas use, considering different transport distances.

Harmful emissions of buildings calculated by life cycle have been determined in two parts.

5.1. Emissions from fuel production and transport

a. CO2 emissions during biomass production and transport (pellet, chip) was calculated on the basis of the Solid and Gaseous Biomass Carbon Calculator 2.0. [13] The calculator uses the Life Cycle Analysis defined in Renewables Obligation Order [14] and in the Renewables Obligation, in the Ofgem Sustainability Criteria Guide [15].

Our calculations were carried out with the delivery of the fuel to the house included.

During the calculation, the following phases can be considered in the user chain:

- Chip production:
- 1. Corp production (fully for firing)
- 2. Harvesting
- 3. Drying (artificial, natural)
- 4. Raw material transport (by land to place of processing)
- 5. Biomass processing / conversion to chip
- 6. Fuel transport (by land to storage)
7, Storage
8, Fuel transport (by land to place of use)

Pellet production
1, Corp production (fully for firing)
2, Harvesting
3, Raw material transport (by land to place of processing)
4, Drying (artificial)
5, Biomass processing / conversion to pellet
6, Fuel transport (by land to storage)
7, Storage
8, Fuel transport (by land to place of use)

In the production of chips and pellets, the following CO₂ emission values were received taking into account the production-specific production chain. (figure10).

![CO₂ emissions during production](image)

**Figure 10.** CO₂(g) emission of biomass production

b, Emissions from the production and transport of natural gas come from the SHALE GAS UPDATE FOR GHGENIUS study by (S&T)2 Consultants Inc. [16]. The emission value given in the report is as in Table 2.

| Natural Resources Canada | g CO₂eq / MJ fuel |
|--------------------------|-------------------|
| Natural gas upstream emissions | 7, 25 |

The method of calculating the emission values of natural gas production and the size of the final result vary by country, but for comparability, the above two results are accepted because of the available and traceable calculation method.

5.2. Annual CO₂ emissions of the reference building according to EPBD calculations

a, When using chip
b, When using pellet
c, For natural gas

The calculation methodology is based on the EPBD directive. The amount of carbon dioxide produced during the combustion of wood was constraint during the growth of tree. This constraint in the forest has improved the air quality of the environment. During combustion, emission happens in a residential environment (if not power plant use), so that the emitted pollutants return to the living environment and pollute it. The final results are aggregated to give CO₂ emissions values for producing natural gas and biomass during 30 years lifetime of the sample building (figure 11) as it is calculated in Table 3.
Table 3. Emission value for producing natural gas

| Fuel type | Energy demand E(MWh/y) | Energy demand E(MJ/30yrs) | Fuel carbon intensity (g CO\textsubscript{2}eq / MJ fuel) | CO\textsubscript{2} emission of fuel production of sample building during 30 years (g CO\textsubscript{2}eq) |
|-----------|------------------------|---------------------------|---------------------------------------------------------|-------------------------------------------------|
| chip      | 16.19                  | 1748520                   | 2.33                                                    | 4 074,020                                      |
| pellet    | 18.42                  | 1989360                   | 23.80                                                   | 47 346,768                                     |
| gas       | 12.1                   | 1306800                   | 7.25                                                    | 9 474,300                                      |

Figure 11. CO\textsubscript{2} emission of fuel production of sample building during 30 years

6. Summary
Cost-optimal calculations, as defined by the European Commission, have in many cases resulted in a biomass renewal version as cost-optimal, on the basis of which EC advisors recommend the use of significant biomass at nZEB buildings.

These studies do not take into account that:
Biomass production has territorial limits in many EU countries.
Taking advantage of regulations in many Member States, the amount of yearly primary energy demand is favorably influenced by the low primary energy conversion factor determined by the very states; besides the annual heat demand does not decrease in naturals. Therefore, nZEB buildings may use more energy through biomass firing than in gas heating.

The Commission advisers suggest that biomass fuel should be used to reduce CO\textsubscript{2} emissions, even if the availability of this fuel is limited in Europe. The CO\textsubscript{2} neutrality of biomass is not real. It is true that the emission of gas firing far exceeds that of wood firing, but emissions from the production of natural gas might be lower than that of the production of certain wood products. Overall, the lifecycle-based emission of biomass firing for the most converted fuels is already significant. In the case of wood combustion, the local pollutant emissions are significant, while the CO\textsubscript{2} constraint occurs in the forests.

Acknowledgements
This article presents the results of my PhD research leaded by Professor András Zöld at the University of Debrecen's Doctoral School of Earth Sciences.

References
[1] EPBD recast 2010. Directive 2010/31/EU of the European parliament and of the council of 19 May 2010 on the energy performance of buildings (recast). Official journal of the European Union
[2] BPIE, 2011a. Principles for nearly zero-energy buildings. Paving the way for effective
implementation of policy requirements. Brussels: Building Performance Institute Europe

[3] EPBD DIRECTIVE 2010/31/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 May 2010 on the energy performance of buildings (recast) - Annex I.

[4] R Hitchin, K Thomsen, K Wittchen: Primary Energy Factors and Members States Energy Regulations Concerted Action EPBD,

[5] information on: https://www.navigant.com/news/energy/2019/biomass-remains-largest-contributor

[6] Severnyák K, Fülöp O, 2013. Determination of the cost-optimal building energy requirements - background calculations (in Hungarian). Energiaklub

[7] Guidelines accompanying Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements

[8] Carvalho, L – Wpopienka, E. – Pointner, C. Lundgren, J. – V. K. – Haslinger, W. – Schmidt, C: Performance of a pellet boiler fired with agricultural fuels. Applied Energy 104 (2013) pp. 286-296

[9] Hermelink A, et al. 2013. Towards nearly zero-energy buildings. Definition of common principles under the EPBD. Ecofys

[10] Commission delegated regulation No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements

[11] Fülöp Orsolya Energy efficiency potential of Hungarian residential buildings, Energiaklub 2011

[12] 7/2006 Decree by the Minister without Portfolio of Hungary

[13] Solid and Gaseous Biomass Carbon Calculator 2.0. on: https://www.ofgem.gov.uk/publications-and-updates/uk-solid-and-gaseous-biomass-carbon-calculator

[14] The Renewables Obligation Order, in: http://www.legislation.gov.uk/ukdsi/2015/9780111138359/pdfs/ukdsi_9780111138359_en.pdf

[15] Ofgem Sustainability Criteria Guide on: https://www.ofgem.gov.uk/karokkapkodni.publications-and-updates/renewables-obligation-sustainability-criteria

[16] SHALE GAS UPDATE FOR GHGENIUS study by (S&T)2 Consultants Inc. 2011