Energy-Efficient Building in European States

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National legal and political regulation in the field of energy efficiency is closely connected to minimizing energy consumption in buildings. Within the framework of implementing Directive 2018/844/EU on the energy performance of buildings in Europe, the practice of its application differs from country to country. To achieve the sustainable development scenario, all countries of the world must switch to mandatory building energy efficiency laws by the year 2030. Improvements in the energy efficiency of buildings and sustainable development of renewable energy are a must in terms of overcoming the ever-growing energy consumption and the consequences of climate change.

Keywords: energy class ; energy efficiency ; Buildings

1. Introduction

Modern buildings have come to be the third-largest group of consumers of fossil fuel after industry and agriculture. What is more, 30–40% of all key global resources are consumed by none other than the construction sector [1]. The building sector is considered the main and largest energy consumer on the global scale, and 40% of all primary energy (PE) generated in the US and the European Union (EU) is consumed in buildings [2][3]. With the economy growing and urban development picking up pace, one can look forward to a further increase in the building sector and a parallel surge in energy consumption, to be boosted by the accelerating climate change as well.

It is a widely known fact that greenhouse gas (GHG) emissions are the number one reason behind climate change and the global warming that follows, as well as extreme weather [4]. Obviously, buildings also have a role in driving climate change: 19% of all GHG emissions occur through energy processes decarbonization in buildings [5]. It is the matter of building decarbonization that has been the focal point of attention over the past few decades, as achieving energy efficiency in buildings and switching to renewable energy has a large potential in reducing GHG emissions in the future [6].

In a bid to improve the energy performance of buildings, in 2018 the EU adopted Directive 2018/844/EU, partially amending Directive 2010/31/EU on the energy performance of buildings [7]. The latest EU directive is geared towards improving the energy efficiency of buildings, ensuring the right indoor climate, and reducing the use of fossil fuel whilst increasing the availability of renewable energy. This directive aims to contribute to the EU's goal of decarbonizing the building sector by 2050 [8]. The results of an analysis conducted by the European Commission (EC) in 2011 have shown that GHG emissions in the building sector can be cut by a staggering 90% by 2050 [9]. The EU goal of becoming a climate-neutral zone is also seeing a contribution from the building sector with nearly zero-energy buildings (NZEB), which were supposed to become the benchmark in the EU residential building market as of 2021 [7].

EU member state documents provide varying definitions of energy-efficient buildings, yet their underlying feature is defined as follows: these buildings consume little energy, and any energy consumption is done in an efficient way [10]. Some of Europe's first high-energy class buildings were introduced in German: these are the so-called passive houses and buildings bearing the Minergie seal of quality in Switzerland [1].

Following the adoption of the updated Building Energy Performance Directive [7], European countries and Member States had to amend their national legislation to include legal solutions in connection with NZEB. The main requirements for the primary energy consumption, total annual heating, and cooling demands, envelope heat transfer indicators, airtightness, and infiltration of buildings differ from one European country to another. However, these are just some of the differences that affect an effective entrenchment of NZEB in Europe.

A review by the Institute for Energy Efficiency has backed the information presented in the amendment to the European Commission regulation (Directive (EU) 2018/844) that differences in climatic conditions preclude the application of a single NZEB efficiency value suitable for all European countries [11]. Therefore, in the EU (and Norway) these buildings are covered by different national regulations and requirements, which makes a consistent increase in the availability of such buildings in different economies more difficult.

The latest political strategies by the Building Performance Institute Europe (BPIE) has highlighted the key differences when it comes to implementing the requirements of Directive 2018/844/EU among the EU states. According to the BPIE, (1) the timing of hands-on application of the NZEB concept varies among the states (some of the Member States have complied with the requirements for implementation ahead of time while others are lagging behind); (2) Member States use different definitions and approaches to determine national NZEB definitions; (3) approaches to calculation and performance levels to be achieved by NZEBs under construction are variegated; (4) a portion of the energy consumed to be replaced by renewable energy varies from country to country. Another important aspect is that some of the Member States had developed (and have never updated) their approaches to NZEB years before such buildings became mandatory. As a result, the national standards of these buildings are not aligned with the EU's goal of becoming a climate-neutral zone by [12].

One stipulation of Directive 2018/844/EU is the mandatory inclusion of the numerical indicator of primary energy (kWh/m^2/year) in the national plans of Member State NZEB strategies. Considering that the energy efficiency of a building is affected by different climatic conditions and the building's typology, geometry, location, engineering mechanical systems, and so on, many Member States (with the exception of Austria, Flanders, Germany, Italy, Luxembourg, and Portugal where PE values are calculated on the basis of benchmark buildings) have set a certain range of primary energy consumption [12]. In its 2016 recommendations and guidelines for ensuring the good NZEB practice in the Member States, the EC indicated the comparable limit values of primary energy differentiated by four key climatic zones: Mediterranean, Oceanic, Continental, and Nordic [13][14]. According to a report by the International Energy Agency (2018), there is a global slowdown in the progress of energy policy, indicating that the evolution of building energy codes is failing to keep up with the growth of the economies of rapidly developing countries [14]. In 2018, two-thirds of countries worldwide were short on building energy efficiency codes and legal regulations. It means that in 2018 more than three billion square meters of useful building area were built without any mandatory energy performance requirements.

2. Climate Change on Residential Buildings in Europe

To achieve the sustainable development scenario, all countries of the world must switch to mandatory building energy efficiency laws by the year 2030 [14]. Improvements in the energy efficiency of buildings and sustainable development of renewable energy are a must in terms of overcoming the ever-growing energy consumption and the consequences of climate change [8]. Climate change and building energy processes share a paradoxical bond: these days, the processes that take place in buildings contribute to climate change; according to a number of studies (**Table 1**), the consequences of climate change will drive the energy consumption for building cooling purposes up. Scientific studies conducted decades ago noted that climate change would have a direct impact on the energy and thermal properties of buildings [15][16].

Table 1. A summary of previous studies pertaining to the effect of climate change on residential buildings in Europe.

Country	Period	Climate Scenario	Conclusion	Reference
Sweden	**2050–2100**	**RCP [1] scenario 4.5 (the radiative forcing of GHG is reduced to 4.5 W/m²) and RCP scenario 8.5 (GHG increases, its radiative forcing going up to 8.5 W/m²) [17]**	**A 13–22% drop in the demand for heating, a 33–49% increase in the demand for cooling**	[18]
Finland	**2030–2050–2100**	**Drafted on the basis of the CMIP3 global climate model [19]**	**A 20–40% drop in the demand for heating, a 40–80% increase in the demand for cooling**	[20]
Switzerland	**2100**	**It is assumed that the average annual air temperature will increase by 4.4 °C compared to the climatologic standards of 1961–1990**	**A 33–44% drop in the demand for heating (cooling is not considered)**	[21]
Germany	**2060**	**It is assumed that the average annual air temperature will increase by 1–3 °C**	**A 44–75% drop in the demand for heating and a 28–59% increase in the demand for cooling**	[16]
Greece	**2100**	**Three scenarios by the Intergovernmental Panel on Climate Change are used [15]**	**A 44–75% drop in the demand for heating and a 28–59% increase in the demand for cooling**	[22]

All kinds of research have been undertaken around the globe over the past few decades in order to analyze the effect climate change has on buildings. **Table 1** shows the results of simulation studies of residential buildings in Europe highlighting the impact of climate change on the energy needs of buildings.

Depending on the climatic data of different countries, climate change scenarios, and other assumptions, the summary of studies in **Table 1** shows that when the building's demand for heating drops by roughly one-half, the demand for cooling may go up by a massive 80%. Isaac and van Vuuren have estimated that climate change will drive the need for heating energy by more than 30% worldwide by 2010, while the demand for cooling energy will go up by nearly 80% [23].

3. The Current Situation in the European Zones Covered by the Analysis

Based on the values established by the EC, countries with prevalently milder (Mediterranean) climates must ensure the lowest demand for net primary energy and the largest share of energy from renewable sources [12]. Still, considering the primary energy of a building and notwithstanding whether it is supplied from renewable sources, the range of primary energy across all four European climate zones is much narrower: the PE demands of a single-family home must fall within the recommended 50–90 kWh/m^2/year (**Table 2**) [13].

Table 2. European Commission standards of building performance and renewable energy resources for different climate zones [13].

Climate Zone	Demand for Net PE, kWh/m^2/year	Energy from Renewable Energy Sources, kWh/m^2/year	PE Ceiling, Including Energy from Renewable Sources, kWh/m^2/year	Renewable Energy Sources as a Percentage of Total PE
Mediterranean	**0–15**	**50**	**50–65**	**87%**
Oceanic	**15–30**	**35**	**50–65**	**61%**
Continental	**20–40**	**30**	**50–70**	**50%**
Nordic	**40–65**	**25**	**65–90**	**32%**

Based on a review by the BPIE (2021), regulations of 13 Member States point to primary energy values that fall within the limit of 50–90 kWh/m^2/year as recommended by the Commission. Denmark, Croatia, and Ireland are more stringent in their requirements, and their recommended values are below those laid down in the EC guidelines. Whereas countries such as Bulgaria, Latvia, Cyprus, Hungary, the Czech Republic, Finland, and Romania are disregarding the guideline recommendations and have set primary energy values above those recommended by the EC [12]. The differences in PE demand in European states and the gap between the national values and the EC requirement for the demand in countries covered by the analysis are shown in **Figure 1**.

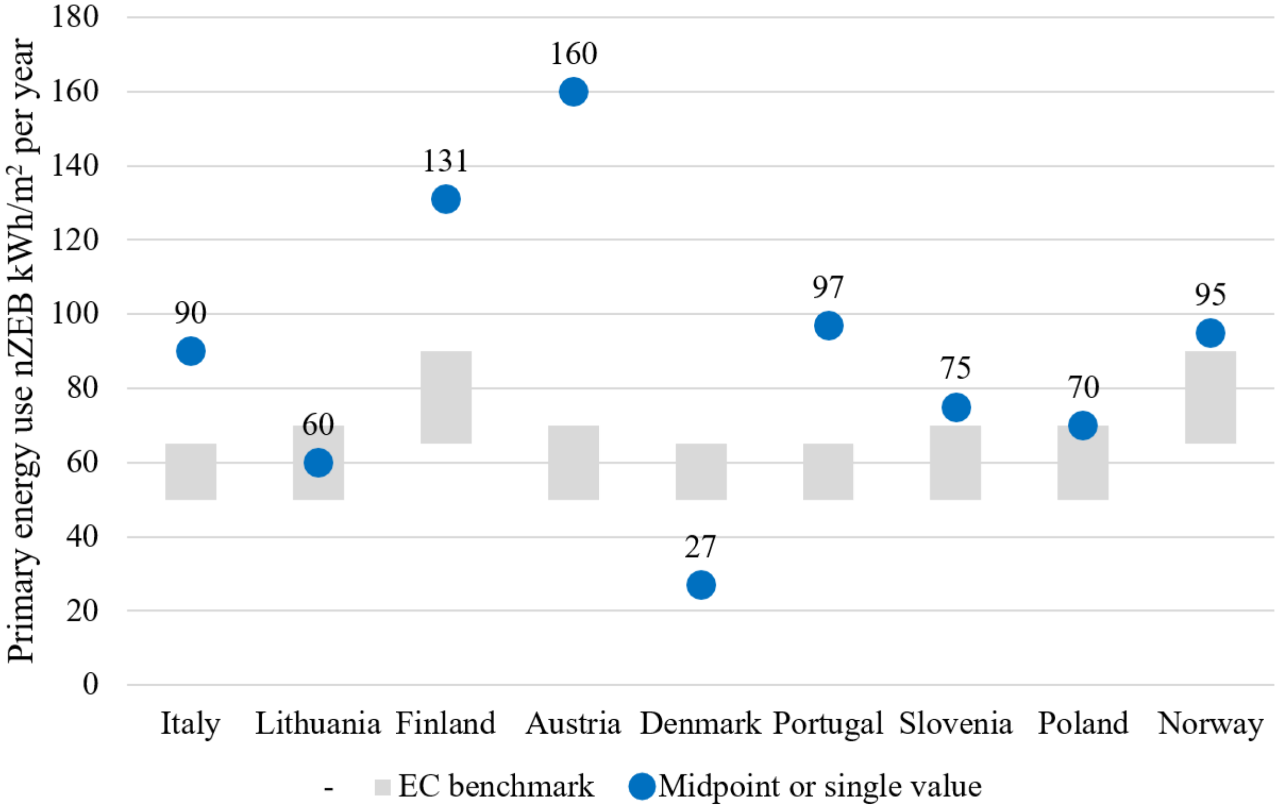

Figure 1. NZEB values (kWh/m^2/year) for single-family homes in European countries analyzed.

A more precise breakdown of the values established by the countries analyzed and those recommended by the EC are presented in **Table 3**.

Table 3. PE values in the countries covered by the analysis and those recommended by the European Commission.

Country Analyzed	PE Value as Recommended by the EC, kWh/m^2/year [1]	Source
Italy	65	PE value determined based on an assumption (considering the results of projects completed) [24]
Lithuania	70	[25]
Finland	90	[12]
Austria	70	[26]
Denmark	65	[12]
Portugal	65	[27]
Slovenia	70	[12]
Poland	70	[12]
Norway	90	[28]

Evidently, only Lithuania and Poland make it to the EC's brackets of primary energy demand. Denmark's national regulations stipulate a PE value that is nearly three times below the EC recommendations. For Norway (it is assumed that Norway is appraised on a par to the EU countries) and Slovenia, the PE limits are close to what the EC recommends.

References

1. Chel, A.; Kaushik, G. Renewable energy technologies for sustainable development of energy efficient building. Alex. Eng. J. 2018, 57, 655–669.
2. Allouhi, A.; El Fouih, Y.; Kousksou, T.; Jamil, A.; Zeraouli, Y.; Mourad, Y. Energy consumption and efficiency in buildings: Current status and future trends. J. Clean. Prod. 2015, 109, 118–130.

3. Cao, X.; Dai, X.; Liu, J. Building energy-consumption status worldwide and the state-of-the-art technologies for zero-energy buildings during the past decade. Energy Build. 2016, 128, 198–213.
4. Berardi, U.; Jafarpur, P. Assessing the impact of climate change on building heating and cooling energy demand in Canada. Renew. Sustain. Energy Rev. 2020, 121, 109681.
5. Pachauri, R.K.; Allen, M.R.; Barros, V.R.; Broome, J.; Cramer, W.; Christ, R. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change; IPCC: Geneva, Switzerland, 2014.
6. Larsen, M.A.D.; Petrović, S.; Radoszynski, A.M.; McKenna, R.; Balyk, O. Climate change impacts on trends and extremes in future heating and cooling demands over Europe. Energy Build. 2020, 226, 110397.
7. Directive 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the Energy Performance of Buildings and Directive 2012/27/EU on Energy Efficiency, 2018; European Parliament: Strasbourg, France, 2018.
8. Tanasa, C.; Dan, D.; Becchio, C.; Corgnati, S.P.; Stoian, V. Cost-optimal and indoor environmental quality assessment for residential buildings towards EU long-term climate targets. Energy Sustain. Dev. 2020, 59, 49–61.
9. A Roadmap for Moving to a Competitive Low Carbon Economy in 2050. In Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions; European Commission: Brussels, Belgium, 2011.
10. Andaloro, A.P.F.; Salomone, R.; Ioppolo, G.; Andaloro, L. Energy certification of buildings: A comparative analysis of progress towards implementation in European countries. Energy Policy 2010, 38, 5840–5866.
11. D'Agostino, D.; Mazzarella, L. What is a Nearly zero energy building? Overview, implementation and comparison of definitions. J. Build. Eng. 2019, 21, 200–212.
12. BPIE. Nearly Zero: A Review of EU Member State Implementation of New Build Requirements. 2021. Available online: https://www.bpie.eu/wp-content/uploads/2021/06/Nearly-zero_EU-Member-State-Review-062021_Final.pdf.pdf (accessed on 1 April 2022).
13. Guidelines for the Promotion of Nearly Zero-Energy Buildings and Best Practices to Ensure that, by 2020, all New Buildings are Nearly Zero-Energy Buildings, C/2016/4392; Publications Office of the European Union: Brussels, Belgium, 2016.
14. IEA. Available online: https://www.iea.org/reports/tracking-buildings-2020 (accessed on 1 April 2022).
15. Nakicenovic, N.; Alcamo, J.; Davis, G.; Vries, B.D.; Fenhann, J.; Gaffin, S. Special Report on Emissions Scenarios. 2000. Available online: https://escholarship.org/content/qt9sz5p22f/qt9sz5p22f.pdf (accessed on 1 April 2022).
16. Olonscheck, M.; Holsten, A.; Kropp, J.P. Heating and cooling energy demand and related emissions of the German residential building stock under climate change. Energy Policy 2011, 39, 4795–4806.
17. Swedish Meteorological and Hydrological Institute Klimatscenarier (Climate Scenarios). Available online: https://www.smhi.se/en/climate/future-climate/advanced-climate-change-scenario-service/met/sverige/medeltemperatur/rcp45/2071-2100/year/anom (accessed on 1 April 2022).
18. Dodoo, A.; Gustavsson, L.; Bonakdar, F. Effects of future climate change scenarios on overheating risk and primary energy use for Swedish residential buildings. Energy Procedia 2014, 61, 1179–1182.
19. Meehl, G.A.; Covey, C.; Delworth, T.; Latif, M.; McAvaney, B.; Mitchell, J.F. The WCRP CMIP3 multimodel dataset: A new era in climate change research. Bull. Am. Meteorol. Soc. 2007, 88, 1383–1394.
20. Jylhä, K.; Jokisalo, J.; Ruosteenoja, K.; Pilli-Sihvola, K.; Kalamees, T.; Seitola, T.; Mäkelä, H.M.; Hyvönen, R.; Laapas, M.; Drebs, A. Energy demand for the heating and cooling of residential houses in Finland in a changing climate. Energy Build. 2015, 99, 104–116.
21. Frank, T. Climate change impacts on building heating and cooling energy demand in Switzerland. Energy Build. 2005, 37, 1175–1185.
22. Asimakopoulos, D.A.; Santamouris, M.; Farrou, I.; Laskari, M.; Saliari, M.; Zanis, G.; Giannakidis, G.; Tigas, K.; Kapsomenakis, J.; Douvis, C.; et al. Modelling the energy demand projection of the building sector in Greece in the 21st century. Energy Build. 2012, 49, 488–498.
23. Isaac, M.; van Vuuren, D.P. Modeling global residential sector energy demand for heating and air conditioning in the context of climate change. Energy Policy 2009, 37, 507–521.
24. Green Building Council Italia. Energy Efficiency of Buildings in Italy. 2019. Available online: https://c2e2.unepdtu.org/kms_object/green-building-council-italia-gbc-italia/ (accessed on 20 March 2022).

25. STR 2.01.02:2016 Pastatų Energinio Naudingumo Projektavimas ir Sertifikavimas 2019. Available online: https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/15767120a80711e68987e8320e9a5185/sEHkqghNMX (accessed on 20 March 2022).
26. OIB Guidline Energy Conservation And Thermal Protection. Cost Optimality OIB-330. 6-005/18-001; Austrian Institute of Construction Engineering: Vienna, Austria, 2018.
27. Laustsen, J.; Warming, N.B. New Building Codes for NZEB. Key Elements and Overall Picture in EU Countries. Joint Workshop Presentations. Session 7, NZEB Building Code. 2019. Available online: https://www.ca-res.eu/fileadmin/cares/PublicArea/Joint_workshop_presentations/Session_7_NZEB_Building_Codes.pdf (accessed on 1 April 2022).
28. Kurnitski, J. NZEB requirements in Nordic countries. REHVA Eur. HVAC J. 2019, 56, 8–12.