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ALIGNING UKRAINIAN BUILDING ENERGY CODES WITH THE EPBD

Pacific Northwest National Laboratory

January 2024

PNNL-35597

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Aligning Ukrainian Building Energy Codes with the EPBD

January 2024

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ACRONYMS AND ABBREVIATIONS

CEN	European Committee for Standardization
CO_2	Carbon dioxide
DBNs	State Construction Norms of Ukraine
EEM	Energy efficiency measure
EPBD	Energy Performance in Buildings Directive
EU	European Union
GHG	Greenhouse Gas
kWh/m^2	Kilowatt hour per square meter
NEFCO	Nordic Environment Finance Corporation
NPV	Net Present Value
NZEB	Nearly Zero Energy Building
PEF	Primary Energy Factor
PNNL	Pacific Northwest National Laboratory

EXECUTIVE SUMMARY

The aim of this report is to support Ukraine in revising its building energy codes in line with regulations laid out by the Energy Performance in Buildings Directive (EPBD). The main objectives are to i) provide valuable information to help Ukraine align its building energy codes with EPBD requirements, ii) advance the capacity of key stakeholders in Ukraine to develop new regulations based on robust technical methodologies and analysis, iii) summarize building energy codes best practices using examples from the EU and elsewhere, and iv) recommend steps Ukraine can take to improve its building energy code regulations and implementation. This report summarizes EPBD requirements for new buildings, and buildings undergoing major renovations, related to cost-optimal and Nearly Zero Energy Building (NZEB) requirements. This report highlights Ukraine's progress in aligning it's building energy codes with the aforementioned requirements and best practices regarding those requirements from the EU and internationally. Based on best practices and Ukraine's current progress on requirements, recommendations are presented. A brief overview of the EPBD and building energy codes in Ukraine is also provided. Implementation related to building energy codes is touched upon as well. Potential next steps for Ukraine are outlined based on provided recommendations.

1. INTRODUCTION

1.1 GOAL AND STRUCTURE OF REPORT

This report serves to support Ukraine in revising its building energy codes in line with regulations laid out by the Energy Performance in Buildings Directive (EPBD). The main objectives of this report are to i) provide valuable information to help Ukraine align its building energy codes with EPBD requirements, ii) advance the capacity of key stakeholders in Ukraine to develop new regulations based on robust technical methodologies and analysis, iii) summarize building energy codes best practices using examples from the European Union (EU) and elsewhere, and iv) recommend steps Ukraine can take to improve its building energy code regulations and implementation. The report draws on literature, technical documents, and information and discussions presented during a webinar on July 20, 2023, *Aligning Ukrainian Building Energy Regulations with EPBD Requirements*.

This report will focus on the two significant EPBD requirements, cost-optimal building performance requirements and nearly zero energy building (NZEB) performance requirements, for new buildings and buildings undergoing major renovations. We note that the EPBD covers new buildings, existing buildings undergoing major renovations, and retrofits for existing buildings. However, we choose to focus primarily on new building energy code requirements and those applicable to buildings undergoing major renovations as Ukraine's building energy codes for existing building retrofits have already been covered in Ukraine's building retrofit strategy. This report is structured around several key topic areas i) background on building energy codes and the EPBD, ii) background on Ukrainian building energy codes, iii) cost-optimal building performance requirements, iv) NZEB performance requirements, and v) building energy code implementation. Cost-optimal building performance requirements, NZEB performance requirements, and building energy code implementation are discussed with regard to EPBD definitions and requirements, best practices, status in Ukraine, and recommendations. This report concludes with several main takeaways and an overview of potential next steps for Ukraine.

1.2 INTRODUCTION TO BUILDING ENERGY CODES

The Energy Performance in Buildings Directive (EPBD) promotes a highly energy efficient and decarbonized building stock in the EU by 2050 (European Commission Directorate-General for Energy, 2023a). Directive 2010/31/EU (consolidated version of the EPBD) sets forth requirements for cost-optimal building energy codes and defined Nearly Zero Energy Buildings (NZEBs) requirements. The most recent EPBD revision in 2018 (Directive 2018/844) reaffirmed the EU's commitment to modernizing the European building stock (European Commission Directorate-General for Energy, 2023a). Directive 2010/31/EU, as mentioned in this document, refers to the consolidated version of the EPBD not the 2010 version of the EPBD as it was originally recast. A proposal to revise the EPBD was released in 2021 and a provisional agreement on that recast was reached in 2023, with plans to go through the formal adoption process in 2024 (European Commission Directorate-General for Energy, 2023a).

Building energy codes are a cost-effective tool for reducing greenhouse gas (GHG) emissions and increasing energy savings. Building energy codes set minimum energy efficiency requirements for new and existing buildings undergoing major renovations or retrofits (e.g., heating, cooling). They are implemented during building construction, providing emission and energy reductions over the long life of a building (Evans et al., 2021). They have a proven track record of cost-effectively saving energy on a large scale. For example, in Denmark, 1982 code requirements led to buildings that consumed around

120 kWh/m2 for heating, cooling, and hot water, whereas buildings built to the 2020 version of the code will consume just 20 kwh/m2 for these services. The Danish code has had five revisions since 1982 (Evans et al, 2021). Building energy codes are being revised on a more frequent basis and becoming more stringent across countries to achieve building energy efficiency targets (i.e., nearly zero energy buildings). This is an important effort as countries look to decarbonize energy grids and reduce emissions to meet international climate agreements and domestic climate targets. Building energy codes are a crucial tool in improving resilience of buildings by reducing energy demand and peak demand, particularly in light of the significant reconstruction and construction planned in Ukraine.

2. UKRAINIAN CONTEXT

2.1 IMPORTANCE OF ENERGY CODES ISSUES IN UKRAINE

Ukraine was accepted as a candidate for EU membership in June of 2022 and the European Council opened formal accession negotiations with Ukraine in December 2023 (General Secretariat of the Council, 2023). Part of Ukraine's efforts to become an EU Member State involve aligning its legislation with EU EPBD requirements on nearly zero-energy buildings (NZEBs) and cost-optimal solutions for building energy codes. Given that Ukrainian reconstruction efforts will involve a tremendous number of new buildings, it is important to revise building energy codes to ensure new buildings comply. Additionally, updated building energy codes will help improve energy efficiency and resilience in Ukraine. This will ease the burden on the grid in the future and help pave the way to a decarbonized energy system.

2.2 STATUS OF BUILDING ENERGY CODES IN UKRAINE

Building energy codes, for both new and existing buildings, in Ukraine have historically been regulated through the State Construction Norms of Ukraine (standard) (DBNs). Since 2007, Ukraine has had some sort of mandatory building energy code for buildings, set up by the DBNs (IEA, 2012). DBNs are prescriptive technical rules related to specific construction types, but they lack the same force as laws since they are not registered by the Ministry of Justice. The key DBNs related to energy efficiency are DBN V.2.6-31:2021 "Thermal insulation and energy efficiency buildings"; DBN V.2.5-67:2013 "Heating, ventilation and conditioning"; and DBN V.1.2-11:2021 "Energy conservation and energy efficiency". Each specific DBN must be met, which works to meet overall building energy performance requirements.

In 2017, Ukraine adopted the Law on Energy Efficiency of Buildings, which created a building energy rating system and defined a building rating calculation method aligned with the EPBD. The Law of Ukraine "On the Energy Efficiency of Buildings" and subsequent related Orders set minimum energy performance requirements. The adoption of the 2017 law marked the beginning of Ukraine's transition from the old system of building energy codes, the DBNs, to a new system created by government issued laws and Orders that aim to align Ukraine's building energy codes with the EPBD. Ukraine is currently in the middle of this transition and the two systems, DBNs and Orders, are working in parallel and in some instances are incompatible. This highlights the need for Ukraine to have a comprehensive building energy code system in place to avoid confusion regarding these parallel systems.

Ukraine has made several important steps towards improving the regulation of energy efficiency with regard to building energy codes. Recently, Ukraine has finalized it's long-term building retrofit strategy that aims to improve energy efficiency in existing buildings and bring regulations in line with EPBD requirements for retrofitting of buildings. The Ministry for Communities, Territories and Infrastructure Development of Ukraine is working on aligning its building energy efficiency regulations for new buildings and buildings undergoing major renovations with EPBD requirements in several key areas. The Ministry is currently working to define cost-optimal and nearly zero energy requirements for buildings, collaborating with outside stakeholders to develop the necessary analytical tools and legislative instruments to finalize these requirements. Cost-optimal measures and nearly zero energy buildings will be mandated for all new buildings in Ukraine. Some of these regulations also cover existing buildings, but we will focus on new buildings and buildings undergoing major renovation in this report as Ukraine's build retrofit strategy already deals with existing building retrofit regulations.

3. COST-OPTIMAL BUILDING PERFORMANCE REQUIREMENTS

3.1 EPBD REQUIREMENTS AND DEFINITION

The EPBD requires that Member States define cost-optimal levels of minimum energy performance requirements for new and existing buildings (both retrofits and buildings undergoing major renovations). The cost-optimal level is defined broadly as "the energy performance level which leads to the lowest cost during the estimated economic lifecycle" (Directive 2010/31/EU). The full definition of cost-optimal as written in the EPBD can be found in the Appendix of this document. Member states must calculate, compare, and report on efforts to determine cost-optimal levels using the Comparative Methodology Framework provided by the European Commission (Commission Delegated Regulation No 244/2012). The Comparative Methodology Framework and its accompanying guidelines (Guidelines accompanying Commission Delegated Regulation No 244/2012) outline how comparisons between minimum energy performance requirements and calculated cost-optimal levels should be executed (Aggerholm et al., 2011). Member States are to calculate a cost-optimal level using a macroeconomic and financial approach. Member States must compare the two results and decide which approach will be used to establish cost-optimal requirements (Commission Delegated Regulation No 244/2012).

The calculation approach laid out in the Comparative Methodology Framework can be outlined in several steps (Commission Delegated Regulation No 244/2012 Annex 1):

1. Identify National Reference Buildings. Reference buildings are real or virtual buildings that are representative of the building stock in a Member State. Reference buildings must be defined for three building categories: single-family buildings, apartment blocks and multifamily buildings, and office buildings. In addition, reference buildings should be established for other building categories for which specific energy performance requirements exist (Zangheri et al., 2022).
2. Identify energy efficiency measures (EEMs) and renewable energy measures, including packages and variations of measures, for each reference building. EEMs are measures applied to a building that reduce the buildings primary energy needs and packages are sets of EEMs and/or renewable energy measures applied to a reference building. EEMs must be defined for all energy performance calculation input parameters. Member States can bundle measures into packages or variants (i.e., measurements of different levels). Renewable energy measures, packages, and/or variants should be identified as well. EEMs/packages/variations used in the cost-optimal calculation must include measures to meet the minimum energy performance requirements applicable.
3. Calculate the primary energy demand of EEM packages that are applied to reference buildings. Primary energy is the energy from renewable and nonrenewable sources "which has not undergone any conversion or transformation process" (Directive 2010/31/EU). Energy produced on-site shall be deducted from the building's primary

energy demand and delivery energy. The energy performance calculations should be made using current CEN standards or an equivalent national calculation method that is in line with Annex I to Directive 2010/31/EU. Results of the energy performance calculation should be expressed in primary energy demand per square meter of useful floor area of a reference building kWh/m^2 per year. The general framework for energy performance calculations can be found in Annex I of Directive 2010/31/EU. Annex I outlines the requirements for calculation and establishes the framework conditions that should be defined such as climate data, Primary Energy Factors (PEFs), performance of energy systems, and indoor air quality (Zangheri et al., 2022). PEFs are the basis for primary energy demand calculations used to establish minimum energy requirements for new and renovated buildings and are defined by each Member State. PEFs represent the efficiency when converting primary energy sources, such as fossil fuels, into secondary energy carries, such as electricity, delivered to buildings that provide services, such as heating or cooling, to end users (Firląg et al., 2020; translated from the original Polish work with Google Translate). They may be based on national, regional, or local information on an annual, seasonal, or monthly basis. PEFs of energy carriers are multiplied by delivered energy to calculate primary energy demand of the building (Seinre et al., 2020).

4. Calculate the global cost for each reference building in terms of net present value (NPV). The calculation of global costs should be done twice, once using a financial approach, and again using a macroeconomic approach. The macroeconomic approach considers the costs and benefits of energy efficiency investments for society, while the financial approach considers only the investments themselves. The main differences between the financial and macroeconomic approaches are the discount rates and costs included in the calculation. The macroeconomic approach includes greenhouse gas emission costs, while the financial approach includes taxes (Zangheri et al., 2022). Member States must establish the following cost categories: initial investment costs, running costs, energy costs, disposal costs, and cost of CO_2 emissions (only for the macroeconomic approach). Use of CEN standard EN 15459 is recommended for evaluation of global costs associated with a chosen combination of building elements (Zangheri et al., 2022).
5. Test sensitivity of the results. Sensitivity analysis is undertaken to identify the most important parameters of the cost-optimal calculation. It is recommended that sensitivity analysis be conducted for all crucial cost input data, but sensitivity analysis is required for energy prices and discount rates.
6. Describe the derivation of cost-optimal levels of energy performance requirements for each reference building. Member States should compare the global cost calculation results for different EEM packages and identify the cost-optimal levels for each reference building, expressed as kWh/m^2 per year. The cost-optimal range is identified in Figure 1 below. Once a Member State decides on the macroeconomic or financial approach for the national benchmark, cost-optimal results can be compared with the current minimum energy performance requirements for each building category. If the difference between existing energy performance requirements and calculated cost-optimal levels is higher than 15%, then Member States must outline a plan to reduce the gap or provide an explanation as to why the gap should be allowed (Zangheri et al., 2022). If no minimum energy performance requirements currently exist for a building category,

Member States should adopt the cost-optimal levels of minimum energy performance calculated for that building category.

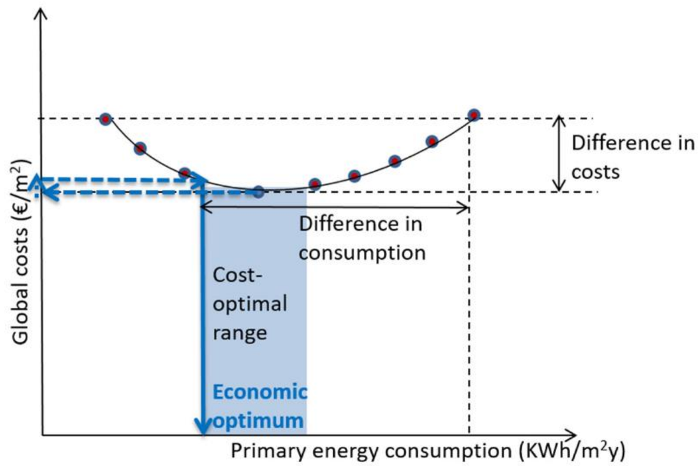

Figure 1. Different variants within the graph and position of the cost-optimal range. Figure reproduced from "Review of the Cost-Optimal Methodology Implementation in Member States in Compliance with the Energy Performance of Buildings Directive," by P. Zangheri, D. D'Agostino, R. Armani, and P. Bertoldi, 2022, Buildings, 12(9), Figure 1, (https://doi.org/10.3390/buildings12091482). CC BY 4.0.

For the cost-optimal calculations, the European Commission determines the starting year, cost categories, calculation period, need for sensitivity analysis, defines the term "reference building", and sets rules for selecting EEM packages. However, it is up to the Member States to determine its own PEFs, estimated economic lifecycle, cost input data, discount rate, reference buildings, and EEM packages. Member states are to report all assumptions and data involved in cost-optimal calculations to the European Commission (Aggerholm et al., 2011). National minimum energy performance requirements are to be revised every five years, in line with cost-optimal requirements, and strengthened if those national requirements are "significantly" less ambitious than national benchmark cost-optimal levels (Commission Recommendation 2016/1318).

3.2 BEST PRACTICES

The framework for calculation of cost-optimal levels is set by the Comparative Methodology Framework (Commission Delegated Regulation No 244/2012) and must be followed by Member States. However, each Member State may differ in exactly how it carries out this framework. There are several different approaches Member States have taken in adopting a national cost-optimal benchmark. Countries can start from scratch using the outlined framework and conduct each step according to its unique needs. However, starting from scratch is often time consuming and expensive as a comprehensive parametric analysis of all building energy components and systems is required. Alternatively, countries can adopt an existing building performance framework that has already been created by a peer Member State or internationally. This route is much quicker and less expensive but will likely not capture the issues and unique characteristics of the country it is applied to. For example, an existing cost-optimal building performance framework of a peer Member State, like Poland, could be utilized. Some countries opt for a hybrid approach in developing a cost-optimal level. Countries start with an existing building performance framework, then finetune the framework using targeted analysis of equipment and systems based on the country-specific building stock and EPBD criteria. This approach still produces quicker results than starting from scratch while accounting for country-specific needs that may be overlooked by strictly using an existing framework.

Many countries have taken a hybrid approach, using existing reference buildings from countries like the United States and adjusting those reference building's characteristics to reflect the country's own building stock attributes and assumptions. In Vietnam, for example, PNNL protypes were adjusted to fit Vietnamese building assumptions (USAID, 2017). Some countries have taken the first approach and developed national cost-optimal benchmarks from scratch, defining cost-optimal levels of energy performance through comprehensive analysis. For example, in Estonia, modeling capabilities (Building Information Models and dynamic modeling for energy performance calculations) were developed by institutions over 3-5 years to help establish cost-optimal levels with regard to NZEB requirements (T. Kalamees, personal communication, July 16, 2023). This emphasizes the need to invest in education, research, and development to produce the tools necessary to calculate a national cost-optimal benchmark if a country wants to take a "from scratch" approach. It also highlights the time investment necessary to achieve these results. The approach a Member State uses is highly dependent on the level of resources available and time constraints (Tillou, 2023).

3.3 STEPS TO DATE IN UKRAINE

Ukraine has taken several steps to comply with the cost-optimal building performance requirements outlined by the EPBD. Ukraine has established a methodology for determining cost-optimal levels in line with the Comparative Methodology Framework provided by the European Commission. Ukraine's cost-optimal methodology is defined by Order No. 170 (2018), outlining the following steps:

- definition of reference buildings;
- drawing up a list of initial data and their values for each reference building;
- calculation of energy efficiency indicators of each reference building;
- creation of a list of energy efficiency measures for each of the buildings;
- calculation of energy efficiency indicators for each of the reference buildings taking into account energy efficiency measures;
- calculation of the value of discounted costs;
- drawing up schedules and determining the economically feasible level of energy efficiency.
- determination of minimum requirements (within 15% of economically feasible).

Minimum energy efficiency requirements for buildings have already been defined in Order No. 260 (2020). These minimum energy efficiency requirements are calculated based on the methodology laid out in Order No. 169 ("On the approval of the methodology for determining the energy efficiency of buildings", 2018) and in line with cost-optimal levels, as mandated by the Law of Ukraine "On Energy Efficiency of Buildings" (2017). The minimum level of energy efficiency in buildings requirements are to be revised every five years, in line with EPBD rules. The minimum energy efficiency requirements are available for 7 types of buildings.

Ukraine has run into several problems regarding the standardization of building energy efficiency requirements. Firstly, the Ministry does not have the necessary energy performance and reference building models to develop and calculate minimum energy efficiency requirements. Secondly, there is no detailed information on the characteristics of representative buildings according to which modeling and determination of minimum requirements were previously carried out and established by Order No. 260. Because of these gaps, it is not possible to properly assess the impact of changes in minimum building energy performance requirements compared to current requirements that is required by the EPBD (Step 6 in the outlined EPBD Comparative Methodology Framework). The building database, as a potential source of statistical information on the building stock, is in initial stages of development. Thirdly, the requirements for the energy characteristics of the components of the building established by various acts (DBN, DSTU, Orders) are not consistent (i.e., require different levels of energy performance). This reflects the fact that Ukraine is still in transition from its old system of individual prescriptive standards for building energy performance to a new standard on estimating whole building performance (in line with the EPBD), but the current framework doesn't explicitly link those two.

3.4 RECOMMENDATIONS

Ukraine has already outlined its cost-optimal methodology in Order No. 170. However, given that there is a lack of reference buildings with representative characteristics available for further cost-optimal calculations, more work is needed. In deciding an approach for establishing reference buildings, and furthermore, a national cost-optimal benchmark for energy performance, Ukraine can take any of the outlined approaches (i.e., starting from scratch, using an existing framework, or a hybrid approach). However, starting from scratch may prove time consuming and expensive as a comprehensive parametric analysis of all building energy components and systems would be required to create new reference buildings and calculate cost-optimal levels. As mentioned previously, data availability may also be an issue in conducting an analysis of that scale. Instead, it may benefit Ukraine to utilize an existing framework as a template and tailor it to its needs. Existing reference building prototypes could be adapted to better reflect the Ukrainian building stock. Best practice EEM packages could be utilized for a cost-optimal analysis, finetuning the level of rigor to account for Ukrainian criteria (i.e., construction practices, availability of materials and equipment, climate, culture).

Based on Ukraine's desired schedule for adopting a cost-optimal analysis framework, taking a hybrid approach is recommended as that will reduce the time and costs associated with the process, while still allowing Ukraine to adjust the framework to fit its buildings. PNNL has a free database of reference buildings that could be of use to Ukraine in applying to its own building stock. One option is to start with one building at a time and prioritize building types that are most prevalent in Ukraine's building stock.

4. NEARLY ZERO ENERGY BUILDING PERFORMANCE REQUIRMENTS

4.1 EPBD REQUIREMENTS AND DEFINITION

Since 2020, the EPBD requires that Member States ensure all new buildings are nearly-zero energy (Directive 2018/844). Member States are also required to develop long-term strategies to facilitate the renovation of existing buildings to NZEBs.

Article 2 and 9 of the EPBD defines a NZEB 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" (Directive 2010/31/EU).

EPBD requires that a national application of the NZEB definition should specify a very high energy performance of the building, a very low amount of energy required by the building, and a numerical indicator of primary energy in kWh/m2 per year (Erhorn-Kluttig & Erhorn, 2018). This definition should also contain a very significant contribution of renewable energy to cover the remaining energy use. Essentially, the EPBD sets the framework for a NZEB definition, but it is up to each Member States to determine how it will apply that framework in defining its "very high energy performance" and setting a recommended significant contribution of "energy from renewable sources" in its building energy codes (Commission Recommendation 2016/1318). Additionally, the type of primary energy (total, non-renewable, or renewable) to be used in the numerical indicator of primary energy and what constitutes "nearby" for renewable energy production must be defined in the national application of the NZEB definition (D'Agostino & Mazzarella, 2019). However, the Commission recommends that "the primary energy use must be calculated using primary energy factors specific to each energy carrier (e.g., electricity, heating oil, biomass, district heating and cooling)" (Commission Recommendation 2016/1318). Member states can choose to use total primary energy (the sum of non-renewable and renewable primary energy consumption) or non-renewable primary energy when determining the amount of primary energy consumed by a building, for the purposes of the EPBD (Firląg et al., 2020; translated from the original Polish work with Google Translate).

NZEB requirements must be cost-optimal. The cost-optimal methodology outlined by the European Commission is flexible enough to allow a Member State to define a range of NZEB requirements in line with cost-optimal levels (Commission Recommendation 2016/1318). As stated in the cost-optimal requirements for EPBD, Member States have to define primary energy factors per energy carrier. These primary energy factors should account for the renewable energy content of the energy supplied to the building, including from nearby sources, in order to place on-site and off-site renewable energy sources on equal footing. This EPBD provision is meant to drive the use of energy from renewable sources, as on-site renewable energy production reduces the primary energy associated with delivered energy to a building and the share of renewable energy in an energy carrier will be reflected through the primary energy factor for that delivered energy (e.g., when electricity is the energy carrier) (Commission Recommendation 2016/1318).

The European Commission has proposed to revise the EPBD to align with longer-term climate goals, such as the European Green Deal, and is planning on moving from NZEBs to zero-emission buildings by 2030 (European Commission Directorate-General for Energy, 2023b). Zero-emission buildings are defined by their high energy performance, with any small amount of energy needed coming only from renewables and no on-site carbon emissions from fossil-fuels (European Commission Directorate-General for Energy, 2023b). A provisional agreement has been reached to revise the EPBD and forthcoming formal adoption of this agreement will enter the revised legislation into force. The revision will make zero-emission buildings the standard for all new buildings as of January 2030, but requiring new publicly owned buildings to adopt this new standard by 2028 (European Commission Directorate-General for Communication, 2023). There are also plans to ensure new buildings are able to host solar energy installations (European Commission Directorate-General for Communication, 2023). It is important to keep this in mind as Ukraine works to align its regulations with the current iteration of the EPBD.

4.2 BEST PRACTICES

Member States must address the four requirements of NZEBs in a national NZEB definition: i) a very high energy performance, ii) nearly zero or very low amount of energy required, iii) a numerical indicator of primary energy, and iv) a very significant extent of renewable energy to cover remaining energy use. However, the EPBD does not establish a uniform approach for implementing NZEBs in Member State building energy codes (D'Agostino et al., 2021). A 2018 overview of national applications of NZEBs in the EU highlighted common Member State approaches to satisfy EPBD requirements in a national NZEB definition (Erhorn-Kluttig & Erhorn, 2018). The data collected for the report showed that Member States met the "very high energy performance" requirement of the NZEB definition mostly though tighter energy performance requirements (e.g., primary energy requirements, heating energy demand, final energy, mean U-value of building envelope, etc.) compared current requirements. Most countries fulfilled the "nearly zero or very low amount of energy required" requirement by setting limits on primary energy, but a few also set limits on component U-values. At the time of the report, most countries defined a "very significant extent of renewable energy" directly through renewable energy source requirements for NZEBs; usually set by minimum share of energy use, minimum renewable energy contributions in kWh/m^2 per year, or choice of defined "exemplary" renewable energy source measures.

As NZEB requirements must be cost-optimal, NZEB requirements are created using a similar framework previously outlined in the cost-optimal methodology. An example of the process Poland used to establish NZEB requirements in line with cost-optimal levels is outlined below (K. Witczak, personal communication, July 20, 2023).

1. Definition of reference buildings.
2. Definition of set of energy efficiency measures.
3. Calculation of yearly primary energy demand.
4. Calculation of NZEB according to financial and macroeconomic approach.
5. Establishment of NZEB standards based on minimum global cost.
6. Establishment of energy efficiency related requirements based on NZEB standards.

The reliance of NZEB requirements on the cost-optimal methodology highlights the need to establish a solid cost-optimal methodology before NZEB calculations can be undertaken. It is also worth noting that stakeholder engagement can be an important step in establishing NZEB requirements. For instance, in Poland, establishing the NZEB requirements required extensive public consultation with industry, technology providers, and designers (K. Witczak, personal communication, July 20, 2023).

In addition, given the importance of PEFs in the energy performance calculation, it is important for Member States to provide transparent determinations of PEFs. As a supplement to CEN standard EN ISO 52000-1:2017, which provides the general framework for assessing the energy performance of buildings, EN 17423:2020 provides a framework for reporting on the choices related to the determination of PEFs and CO_2 emission coefficients (Zirngibl, 2020). EN 17423:2020 proposed a harmonized methodology for determining PEFs to address the lack of transparency and reliability of Member States PEFs (Zirngibl, 2020; Bilardo et al., 2022). While Member States are not required to adhere to the CEN standards, Member States must describe the calculations and information used in their national calculation methodology (EPB Center, 2024). Thus, CEN standards can serve as helpful guides for Member States to follow in constructing and describing their methodology for building energy performance calculations (Bilardo et al., 2022).

4.3 STEPS TO DATE IN UKRAINE

Ukraine has yet to approve a set of NZEB requirements, but a draft is in development. Currently, Ukraine has advisory requirements on NZEBs that will be incorporated into regulatory requirements. There are also plans to add NZEB parameters to building energy certificates.

The Nordic Environment Finance Corporation's (NEFCO) NZEB project developed two reference buildings for NZEB calculations that provide cost-efficient NZEB solutions (VTTb, 2022). Specifically, reference buildings for a Ukrainian school and apartment building were modeled and simulated for climates in Kyiv and Odesa. The project also studied countries with similar climates to Ukraine (e.g., Poland) that have implemented NZEB EPBD requirements, examining those country's parameters for building characteristics to guide Ukrainian estimates (VTTa, 2022).

4.4 RECOMMENDATIONS

As stated previously, NZEB requirements must be established in line with cost-optimal requirements. Therefore, a cost-optimal framework should be determined first so that NZEB references buildings can be established in line with cost-optimal levels. If given measures are not cost-optimal, then they should not be included in NZEB requirements or explanation should be provided as to why they deviate from cost-optimal levels.

Another step necessary in defining NZEB requirements for Ukraine is to establish PEFs for energy carriers in Ukraine. As primary energy is the foundation of both the cost-optimal and NZEB calculation, the importance of this step cannot be understated. PEFs can significantly alter the outcome of building energy performance calculations, so it is important to choose appropriate PEFs and report the methodology that establishes those PEFs. CEN EN 17423:2020 can offer a starting point for determining PEFs in Ukraine.

5. IMPLEMENTATION FRAMEWORK: INSPECTIONS AND COMPLIANCE CHECKS

5.1 EPBD REQUIREMENTS

The EPBD does not specify Member States set up a specific system of building performance inspections and compliance checks related to building energy codes. In terms of implementing the EPBD in general, there are a few requirements laid out. Article 20 of the EPBD requires that Member States must train and provide guidance to relevant stakeholders (those implementing the directive) "in particular regarding the optimal combination of improvements in energy efficiency, the use of energy from renewable energy sources, and the use of district heating and cooling when planning, designing, building and renovating industrial or residential premises" (Directive 2010/31/EU).

To support effective implementation, Article 21 of the EPBD requires that Member States "consult the stakeholders involved, including local and regional authorities, in accordance with the national legislation applicable and as relevant". Specific emphasis is placed on the consultation with regard to Article 9 (NZEB) (Directive 2010/31/EU).

5.2 BEST PRACTICES

Though the EPBD does not mandate specific systems for implementation of building energy codes, we note here that effective implementation is crucial for achieving the positive outcomes possible through improved building energy codes. Once building energy codes are established, it is important to create systems that ensure compliance with codes. Compliance with building energy codes is most effective when adequate support systems are put in place (i.e., resources, technical expertise, administrative capacity). Other countries have taken various approaches to addressing code compliance with methods of code enforcement varying based on location and needs. Code enforcement may be handled at the national government level, regional/local government level, or through private/third party enforcing institutions or a combination of those organizations (hybrid enforcement approach).

National, state, and local institutions are important in code implementation as they often have the power to adjust code requirements. For Ukraine, the level of involvement at different levels of government will depend on at what level code regulations are established. Government institutions can be limited in their resources to address code compliance. Therefore, third-party enforcing institutions are a good way to ensure enforcement and code compliance while easing the burden on Member State resources. Third party institutions can be tasked with conducting inspection and compliance checks, reporting back to government offices in charge of enforcement (Yu et al., 2013).

A variety of countries use a third-party system to ensure compliance with building energy codes. Third parties can be licensed by the state to conduct inspections and compliance checks. Third parties can not only help enforce energy codes but improve overall compliance with codes. In China, the use of third-party professionals to conduct on-site inspections and plan reviews has increased the level of building energy code compliance in the country while allowing government institutions to conduct limited compliance checks. The government entities instead rely on the reports from third parties to ensure compliance. Though these third parties are hired and paid by building developers/owners, they are not without oversight from the Chinese government's authority. Third-party professionals are subject to required trainings, licensing, and penalties for violation of building energy codes to ensure a balanced system of building energy code enforcement (Yu et al., 2013).

A hybrid third-party approach would involve third parties performing limited inspections, with government officials taking on the bulk of compliance checks. For example, in the United States, Wisconsin uses the third-party approach where certified building designers must sign the occupancy permit, indicating that the construction matches the design. Designers who do not properly verify construction in this jurisdiction can lose their license, which provides a strong incentive. Similarly, in Washington State, United States, there is a program that encourages localities to use qualified professionals for plan review and inspections. Although this program is voluntary, it has increased compliance in the state from 55% to 94% (Makela et al., 2011). In either third-party system, hybrid or full, a key aspect is ensuring there are strong checks and balances in place for third-party assessors. This can include requirements, such as in China, for third parties to attend trainings and pass an exam to obtain a license. There should be penalties for assessors who commit violations relating to building energy codes, such as a loss of the assessor's license (Yu et al., 2013). It is important to create a strong system to hold third parties accountable and ensure they are carrying out building energy code compliance checks appropriately.

5.3 STEPS TO DATE IN UKRAINE

In Ukraine, engineer designers, engineer technicians, and engineer consultants are certified professionals who are responsible for designing and constructing new buildings and major renovations to meet minimum energy efficiency requirements. These are third-party professionals who obtain certification, not government officials. Engineer designers are responsible for designing to minimum energy performance standards in the building design stage. Building designs must be permitted before construction. Currently, buildings are primarily designed to meet DBNs and there is some review in the permitting stage to ensure the building design meets these minimum requirements. However, in terms of checking compliance with building energy codes after the design stage, that is done post-construction by energy auditors. Overall, there is a need to improve control in the permitting phase of new buildings to ensure building energy code compliance.

In Ukraine, energy auditors are certified to oversee building energy code compliance in new buildings. The Law of Ukraine "On Energy Efficiency of Buildings" (2017) assigns responsibility to energy auditors to conduct energy efficiency certifications and inspections of technical instillations in buildings to ensure minimum requirements are met. Energy auditors are third-party professionals who obtain certification from qualification centers accredited by the National Qualifications Agency, not government officials. The Law of Ukraine "On Energy Efficiency of Buildings" (2017) defined the procedure and minimum requirements for energy auditor certification. Professionals must have a master's degree and at least one year of experience in a relevant field to be considered for certification. Higher education institutions and self-regulatory organizations in the building energy efficiency field are tasked with training energy auditors. The law also established that an energy auditor's certification expires after five years. There are some consequences for third-party professionals who commit violations related to building energy code requirements. An energy auditor can lose his or her license, but this involves a lengthy process.

5.4 RECOMMENDATIONS

Recognizing that Ukraine currently uses a third-party system, the primary recommendation would be to put checks and balances in place to ensure the strength of this system. This would allow Ukraine to improve code compliance while building off the system already in place. Ukraine is already working to create a strengthened training and licensing program to ensure expertise of its certified energy auditors and this effort should be continued. This system could be further enhanced by peer-to-peer training and support. One example of such a program is the Energy Code Ambassadors Program of the International Code Council in the United States. This program helps recruit, train, and certify professionals to carry out building energy code inspections and compliance checks, usually in coordination with state energy offices (Building Codes Assistance Project, n.d.; Building Codes Assistance Project & International Code Council, 2016). Trainings and certification requirements for energy auditors could be compared to certifications in other counties to ensure best practices are being employed. As seen in successful third-party systems, third-party professionals should be subject to penalties for violation of building energy codes to ensure a balanced system of building energy code enforcement. Ukraine has already set some penalties, but these could be expanded beyond loss of professional license to include fines. This process could also be improved upon to ensure timely repercussions for individuals who commit violations. It is recommended that the system in charge of licensing and/or monitoring third-party individuals conduct random checks of assessors work to ensure compliance.

Bridging the gap between enforcement and compliance assurance in the pre- and post-construction phases could be another area of focus. Onsite inspections by energy auditors could be conducted throughout the construction of a building to help ensure correct implementation of codes, as seen in other international third-party programs such as China (Yu et al., 2013).

6. CONCLUSIONS

Overall, the aim of this report is to i) provide valuable information to help Ukraine align its building energy codes with EPBD requirements, ii) advance the capacity of key stakeholders in Ukraine to develop new regulations based on robust technical methodologies and analysis, and iii) summarize building energy codes best practices using examples from the EU and elsewhere. The information in this report can be summarized in several key takeaways. These takeaways are areas of potential action for Ukraine.

Firstly, regarding Ukraine's alignment with cost-optimal EPBD requirements, a hybrid approach to setting a cost-optimal framework would work best for Ukraine as it would reduce costs and meet the necessary timeline. The biggest hurtle here is developing a set of reference buildings, and collecting the necessary data for those reference buildings, to be able to run a cost-optimal analysis. A hybrid approach, utilizing already existing reference buildings, would allow Ukraine to utilize work that has been done by peers and apply it as best fits it's needs without devoting too many resources to developing reference buildings from scratch. There exist free resources that Ukraine officials can utilize to establish reference buildings and run open-source software to simulate building energy performance.

Secondly, a key step in defining Ukraine's NZEB requirements is the establishment of a national cost-optimal benchmark, as NZEB requirements must be in line with cost-optimal levels. Clear methodology in line with the cost-optimal Comparative Methodology Framework laid out by the European Commission is necessary to accurately represent NZEBs. Clear data and assumptions should be collected to fulfill reporting requirements of the EPBD. This is especially important when documenting assumptions and calculations used in the establishment of PEFs since they are the backbone of the NZEB determination.

Thirdly, implementation of building energy code requirements should be considered in order to achieve the positive outcomes possible through improved building energy codes. Utilizing a third-party system of code enforcement and compliance would build off of Ukraine's already-existing system. However, a system of checks and balances should be put in place to ensure that third parties are properly carrying out code enforcement and compliance checks. Required trainings, certifications, and penalties for violations have been shown to create a strong third-party system in other countries.

In the way of next steps, the most important first piece is establishing reference buildings for Ukraine. It should be determined if there are reference buildings developed by other countries that could applied to building stock in Ukraine or how existing reference buildings from places, such as the United States, can be adjusted to better account for Ukrainian building stock. In addition, primary energy factors for different carrier energies, including renewables, should be determined for Ukraine, as Ukrainian values may differ from the EU baseline and other EU Member States. Further collaboration on utilizing PNNL reference buildings database and fitting it to Ukraine building stock has been discussed.

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APPENDIX

Article 2 of the EPBD defines a cost-optimal level to be "the energy performance level which leads to the lowest cost during the estimated economic lifecycle, where:

a) the lowest cost is determined taking into account energy-related investment costs, maintenance and operating costs (including energy costs and savings, the category of building concerned, earnings from energy produced), where applicable, and disposal costs, where applicable; and
b) the estimated economic lifecycle is determined by each Member State. It refers to the remaining estimated economic lifecycle of a building where energy performance requirements are set for the building as a whole, or to the estimated economic lifecycle of a building element where energy performance requirements are set for building elements.

The cost-optimal level shall lie within the range of performance levels where the cost benefit analysis calculated over the estimated economic lifecycle is positive" (Directive 2010/31/EU).