CONCERTED ACTION
ENERGY PERFORMANCE OF BUILDINGS

(CT2) Building Code

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1. Introduction

Core Team 2 (CT2) 'Building Code' is responsible for sharing the experience of Member States and identifying and discussing the most important issues related to setting the energy performance requirements for new and existing buildings within the Energy Performance of Buildings Directive (EPBD). Implementation of energy performance requirements is through national primary and secondary legal documents – usually called building codes. Legislation covers new building construction and the significant renewal of existing buildings if operationally, technically and economically feasible. Both areas are covered by Directive 2010/31/EU[1] on the energy performance of buildings and amendments included in Directive 844/2018/EU[2]. These were to be transposed into national legislation by 10 March 2020.

This report provides an overview of the work undertaken by CT2 in the fifth phase of the Concerted Action (CAV) on Energy Performance of building Directive (EPBD). Dedicated 'Building Code' sessions focused on relevant EPBD articles that were to be transposed and adopted by Member States. CT2 prepared the topics for discussion in collaboration with other CTs or CCTs and representatives from Member States. Some of the technical experts volunteered to support the work of a working group focused on EPBD Standards.

There is more detailed information on the individual topics related to CT2 that were the subject of discussion at plenary meetings in reports published on the CA EPBD website[3].

2. Objectives

Legislation is the most essential part of the process of the adoption and transposition of the requirements and conditions set by the EPBD. The objective of this report is to provide particular information about the following points:

- State of adoption of the minimum requirements for buildings to achieve the Nearly Zero Energy Buildings (NZEBs) level;
- Conditions and requirements to be included in the Building Code related to energy performance of buildings (having an impact on building structures and building technical systems);
- Implementation and use of the 2^{nd} generation of EPB standards;
- Health, indoor air quality and comfort levels; and
- Need for changes or adjustments to requirements of building codes (construction and renovation).

The exchange of experiences was designed to help develop building regulations for all categories of buildings and support countries in achieving NZEB as a common standard in new construction as well as adoption of the mandatory requirements for existing buildings. Building Code CT2 topic focuses on levels of energy performance requirements set in primary and secondary legislation rather than recommending procedures to apply tools and processes such as step-by-step renovation, Building Renovation Passports, Energy Performance Certificates, etc. These topics are covered by other parts of the reporting, in particular teams CT3, CT5 and CCT1.

3. Analysis of Insights

3.1 State of implementation of the minimum requirements for buildings

The implementation of the minimum requirements for buildings and building units is affected by the time when they come into force and the type of buildings they apply to. Directive 844/2018/EU was published in May 2018, with an implementation date as of 10 March 2020. By 31 December 2020, Member States had to ensure that all new buildings were NZEB. After 31 December 2018, new buildings occupied and owned by public authorities were to be constructed as NZEB. This represented a tightening of energy performance of buildings requirements as well of requirements on building components. While some countries have already implemented the new requirements of the EPBD, many countries are still in the process of implementing new building codes.

3.1.1 State of implementation the minimum requirements up to 2020 and the view to 2021

In line with Article 4 of the EPBD, CT2 set out to investigate how Member States differentiate between new and existing buildings and between different categories of buildings, as well as to explain how ‘functionally, technically and economically feasible’ for the renovation of existing buildings has been included in the regulations. These elements are implemented to a different level in the Member States.

Different requirements on primary energy are set for residential and non-residential buildings and/or different categories of buildings. Tightening of primary energy requirements was required since 2019 at the latest for public buildings and for other buildings by 31 December 2020.

EPBD provides the definition of NZEB. Most Member States intend to adopt the definition without any changes. It is assumed that the NZEB definition applies to both public buildings as well as other buildings. However, in many Member States, there are different requirements set for residential and non-residential buildings.

Often, minimum requirements are set for the U-value (measure of thermal resistance) of building envelope structures – such as external walls, windows, roofs – for whole country or for regions, taking into account the climatic conditions as well as requirements related to the indoor environment. There are large differences between Member States in the requirements for U-values of individual building structures, whether they are required at the present time, or recommended after 2020. Southern countries tend to have much higher U-values, but the differences are not just between the southern and the northern countries.

Often, values for technical systems are handled as part of the overall performance.

3.1.2 What does 'functionally, technically and economically feasible' mean when renovating buildings

The minimum requirements for renovation of existing buildings should reflect different conditions compared to new construction, accounting for identified obstacles and extra costs. There are two possible ways to fulfil requirements in the renovation of existing buildings: the first is to take the energy requirements based on primary energy; the second is based on meeting the U-value requirements for the renovated building elements (walls, windows, roof, floors).

In the context of renovation, the term 'functionally, technically and economically feasible' ensures that the requirements outlined in the EPBD are not excessive, and that they only apply when cost-effective. The notion of feasibility applies to the existing Article 7 (EPBD) as well as the revised Articles 8, 14 and 15. These articles cover the major renovation of buildings and improvements of individual building elements, Technical Building Systems (TBS), Self-Regulating Devices (SRD), and Building Automation and Control Systems (BACS). The specific conditions for feasibility can currently be specified only in national legislation together with types of exemptions which are acceptable. The methods of implementing Article 7 and 8 (EPBD) vary considerably across the Member States.

Economic feasibility considers the proportionality of the costs of a planned intervention to the benefits. The use of performance thresholds is still important, but the financial resources of the building owner should be considered. The measures should not be considered as feasible if there is lack of finance by the owners. There should also be an assessment of whether the technical characteristics of the system prevent the requirements from being applied or whether the changes would impact the operation of the system or the usage of the building. All these factors would depend on the type of work being undertaken. As every renovation is unique and strongly dependent on the particular building conditions, rules governing renovations cannot be as simple and straightforward as they are for new construction. At the building level, there are individual requirements for building elements and parts, allowing a staged approach. Ultimately, it is up to Member States' public authorities to establish clear guidelines and standard procedures that will determine where meeting energy requirements is not feasible. This could often depend on an individual assessment or, in individual cases, an assessment of the need for exemption. However, in the case of a major renovation, the overall need for energy performance should always be assessed.

3.1.3 Primary energy factors, weighting factors for renewable and non-renewable sources

The choice of values for primary energy factors (PEFs) to calculate the primary energy content of energy delivered by different energy carriers is at the discretion of Member States. From a physical perspective, some differences between PEF values of Member States for the same energy sources are inevitable because of local conditions. In addition, there are several internationally recognised conventions for the primary energy content of electricity from renewable or nuclear sources. The published PEF values and Member States' responses to the session questionnaire revealed that reported PEF values do indeed vary by more than the purely physical differences for the aforementioned reasons. The reliability of primary energy savings (or consumption) in buildings and the consistency between cost-optimisation of national regulations and definitions of Nearly Zero Energy Buildings (NZEB) is dependent on the quality and transparency of the PEF calculations.

Primary energy factors or weighting factors per energy carrier may be based on national, regional or local annual, and possibly also seasonal or monthly, weighted averages or on more specific information made available for individual district heating systems.

3.1.4 CO_2 emission assessment and requirements in building regulation

While building codes regulate performance for primary energy indicators, national energy efficiency goals will also require a CO_2 emissions indicator.

Member States require the implementation of measures to reach net zero greenhouse gas emissions by 2050 and, specifically, to decarbonise the building stock, which is responsible for approximately 36% of all CO_2 emissions in the EU. National requirements for the energy performance of buildings are included in building codes including primary energy indicators; but to reach the national indicative milestones, objectives, and actions for energy efficiency, it is necessary to define specific CO_2 emissions indicators. An agreed approach to reducing CO_2 emissions is a priority for Member States, notably in relation to National Energy and Climate Plans (NEPCs). A bottom-up methodology (from the energy source to the overall energy balance) for estimating energy demand is needed to fully understand the energy consumption of buildings. This should be closely followed by the footprint analysis of GHG emissions. Residential buildings are an important aspect to this as they produce a significant share of CO_2 emissions compared to the rest of the building stock.

The session aimed to assess the possibilities and conditions to evaluate and rate the CO_2 emissions of buildings and to discuss the experiences of Member States on the path to fulfil the future requirements. The session explored the changes needed to bring national building codes in line with the objectives of the European Green Deal and the 'Fit for 55' package and, more broadly, how the EU can meet its 2030 climate targets. It focused on CO_2 emissions requirements in national building regulations and the steps to impact CO_2 emissions levels through the energy performance of buildings.

3.2 Implementation and use of 2nd generation of EPB standards

The energy performance of a building must be determined on the basis of the calculated or the actual energy use of the building which must reflect all its typical energy uses. The amended EPBD requests Member States to describe and report to the EC their national calculation methodology following annex A of the overarching standards, namely ISO 52000-1 (Overarching EPB assessment), 52003-1 (Indicators, requirements, ratings and certificates), 52010-1 (External climatic conditions), 52016-1 (Energy needs for heating and cooling), and 52018-1 (Indicators for partial EPB requirements). The main focus of the CA EPBD is to exchange ideas on the reporting of the national calculation methodology following the annexes of the EPB Standards. The deadline for the reporting to the EU was by the EPBD transposition date of 10 March 2020.

Annex I of the EPBD has been revised in order to improve transparency and consistency and it provides the common general framework for the calculation of the energy performance of buildings. To meet the objectives of energy efficiency policy for buildings, the transparency of Energy Performance Certificates (EPCs) should be improved by ensuring that all necessary parameters for calculations – both for minimum energy performance requirements and for certification – are set out and applied consistently. Directive (EU) 2018/844 amends Annex I to update the general framework for the calculation of the energy performance of buildings accordingly. It allows for national adaptation and flexibility for adaptation to local and climatic conditions. It also allows more emphasis on health, indoor air quality and comfort levels as well as considering primary energy factors and the treatment of on- and off-site renewables.

Performance should be based on calculated or actual energy use, depending on the end uses, e.g., space heating, space cooling, domestic hot water and lighting. The energy performance of a building must be or usually is expressed in primary energy use per square meter per year. Additional indicators, e.g., greenhouse gas emissions, may also be reported and these can be used for other purposes, e.g., building compliance checks. The changes introduced by Directive 844/2018/EU also add the need to account for the positive influence of factors, e.g., local solar conditions and district heating. Member States must adopt these changes by revising their building codes.

As stated above, Member States must also report to the EC their national calculation methodology following annex A of the overarching standards. The EC has developed guidelines for this, but it is up to the Member States to implement. A service contract is in place to help Member States through the reporting process along with Frequently Asked Questions. It should be noted that this is to support Member States, not to control the process.

Some specific changes included the consideration of the calculation of primary energy factors. The definition of the method to be used to calculate the factors was left up to Member States to decide and the option to use national/local or annual/monthly factors, for example, is left open.

The nearly zero or very low amount of energy required for NZEB buildings should to a very large extent be covered by energy from renewable sources, including renewable energy produced on-site or nearby. In the calculation of the primary energy factors for the purpose of calculating the energy performance of buildings, Member States may take into account renewable energy sources supplied through the energy carrier, and renewable energy sources that are generated and used on site, provided that it is used in a non-discriminatory basis – meaning that if systems are equivalent then they must be treated in the same way, e.g., on-site and off-site systems. Overarching standards EN ISO 52000-1 and TNI CEN ISO/TR 52000-2[4], clause 9.5.1, present and explain the location of renewable energy sources and related calculations. The on-site boundary or perimeter used is critical when considering renewable energy sources.

The calculation of primary energy should be based on primary energy factors or weighting factors per energy carrier, which may be based on national, regional or local annual, and possibly also seasonal or monthly weighted averages or on more specific information made available for individual district heating systems. Primary energy factors or weighting factors are defined by Member States. In the application of those factors to the calculation of energy performance, Member States shall ensure that the optimal energy performance of the building envelope is pursued.

3.3 Health, indoor air quality and comfort levels

The Energy Performance of Buildings (EPB) standard EN 16798-1:2019[5] specifies requirements for indoor environmental parameters for thermal environment, indoor air quality, lighting and acoustics. It specifies how to establish these parameters for building system design and energy performance calculations. The human health impacts of indoor air quality depend on multiple variables, such as the internal temperature and humidity. Annex B of the standard includes the recommended default criteria for the indoor environment and outlines the levels of expectation the occupants may have (high, medium, moderate and low). A normal level would be 'Medium'. A higher level may be selected for occupants with special needs (children, elderly, persons with disabilities, etc.). A lower level will not provide any health risk but may decrease comfort. Criteria for the thermal environment in heated and/or mechanically cooled buildings shall be based on the thermal comfort indices PMV-PPD (EN ISO 7730[6]). These will be used alongside assumed typical levels of activity and thermal insulation for clothing (different for winter and summer). Based on the selected criteria, a corresponding design operative temperature interval shall be established. The criteria may be different for different building types (flats, offices, schools, etc.) and the requirements for indoor air quality can differ for Member States. The requirements should vary between the minimum required level and the maximum level allowed. There is a link between the indoor environmental parameters and the properties of the individual building structures of the building envelope that affect the energy needs for heating and cooling.

The requirements for indoor air quality of different use spaces can differ depending on the building. The session focused on the possibilities and conditions for the evaluation and rating of the building's energy performance, considering indoor air quality (related to the EPBD, Annex I, 1. c) and practice and experience in Member States. Indoor air requirements are also related to avoiding occupant health problems, to thermal comfort and to reduce energy consumption. Data from the questionnaire and presentations from Member States will provide more information regarding possibilities and conditions for obtaining a deeper insight into the extension of EPB indicators and their evaluation.

In the context of the current pandemic situation, there was an overview of the link between COVID-19, ventilation, energy and energy performance regulations. The issue of aerosol concentration indoors, which can result in an increased risk of catching COVID, is very important. This can be corrected in many ways, through increased air ventilation in buildings and/or the use of air cleaning systems. Often air cleaning systems utilise a lower energy consumption than new ventilation systems.

3.4 Need for changes or adjustments to requirements for building codes

The implementation of Directive 2002/91/EC started the process of decreasing the energy use in buildings by outlining targets within national building codes. Implementation of Directive 2010/31/EU introduced the definition of major renovation as an essential measure related to meeting the global indicator requirement and introduces the concept of NZEB. The amendment of Directive 2018/844/EU outlines the definition of NZEB and its achievement by carrying out a deep renovation. This amendment in the directive has led to a tightening of the minimum energy performance requirements for buildings and building components, set by calculating their cost-optimal level.

In order to decarbonise the building sector by 2050, net GHG emissions must be cut by at least 60% by 2030 compared to a 1990 baseline. A large proportion of the buildings that exist today will still be standing in 2050. Therefore, buildings built and renovated today will continue to have an impact on the energy consumption for many years. As announced in the European Green Deal and presented in the Renovation Wave, in order to meet the objectives, there need to be more renovations annually that are significantly more ambitious than today's renovations on average. A phased introduction of mandatory Minimum Energy Performance Standards (MEPS) must be considered for different types of buildings, especially focusing on the worst performing.

As a result, following the implementation of EPBD into national building codes there will be a need to reflect further and to investigate whether changes and modifications are needed, considering the real building stock quality (e.g., extension of assessment indicators, how to deal with previously renovated buildings and minimum energy performance standards).

4 Main Outcomes

4.1 State of implementation the minimum requirements on buildings

The Directive 844/2018/EU which amended the EPBD was to be transposed in national legislation by 10 March 2020. It implies a tightening of the minimum requirements for energy performance of buildings to achieve the 2030 and 2050 milestones. At the time of the survey, the determination of minimum energy performance of buildings requirements laid down in the Building Codes and related regulation showed the following results:

- The majority of Member States are not expecting to change the NZEB definition in 2020. They expect to add, tighten and/or change the requirement to be fulfilled starting in 2019 for public buildings.
- Buildings of similar use and type should have a similar NZEB definition. There should be a distinction between public offices and private offices as well as between public schools and private schools, but not for all public buildings versus all privately owned (non-residential) buildings.
- Minimum requirements are typically set for the whole country, for regions or climate zones.
- Minimum requirements are in most cases stated in terms of numerical values, a formula or in comparison with a reference building.
- Different requirements for primary energy are set for residential and non-residential buildings and/or different categories of buildings.
- Tightening of primary energy requirements was expected in 2019 at the latest.
- Thermal bridges are taken into account in calculations, following standards EN ISO 14683, EN ISO 10211 or including ΔU in W/(m^2.K) based on national standards.
- There is a wide range of requirements (from 15 to 55%) for the proportion of energy supplied by RES.
- There are large differences in the required U-values of individual building structures between Member States, whether those are required at the present time, standardised or recommended after 2020. U-values set in southern countries are higher than in central Europe or northern countries. In some countries, the required values depend on the internal temperature of the building spaces.
- The lowest temperature recommended for Domestic Hot Water (DHW) is 55 °C, due to the risk of Legionnaires´ disease.
- Requirements for Building Automation and Control Systems (BACS), significant for improvements, are not commonly addressed individually but as part of the overall performance.

In the context of renovation, the term ‘functionally, technically and economically feasible’ ensures that EPBD requirements for specific provisions are not excessive, and that the cost-effectiveness of application should be considered as well as that unproven improvements' should not be required. There could be a judgment call by experts to accept what is technically feasible. There are different ways to analyse if the system requirements for upgrading technical building systems are economically feasible. The simple payback method is one option.

As expected, all minimum requirements for the energy performance of buildings should be changed and the amended EPBD be transposed into national legislation. The 2020 survey provides information on how Member States set requirements for effective thermal protection of building envelope structures; technical systems taking into account needed requirements for the indoor environment; and RES applications.

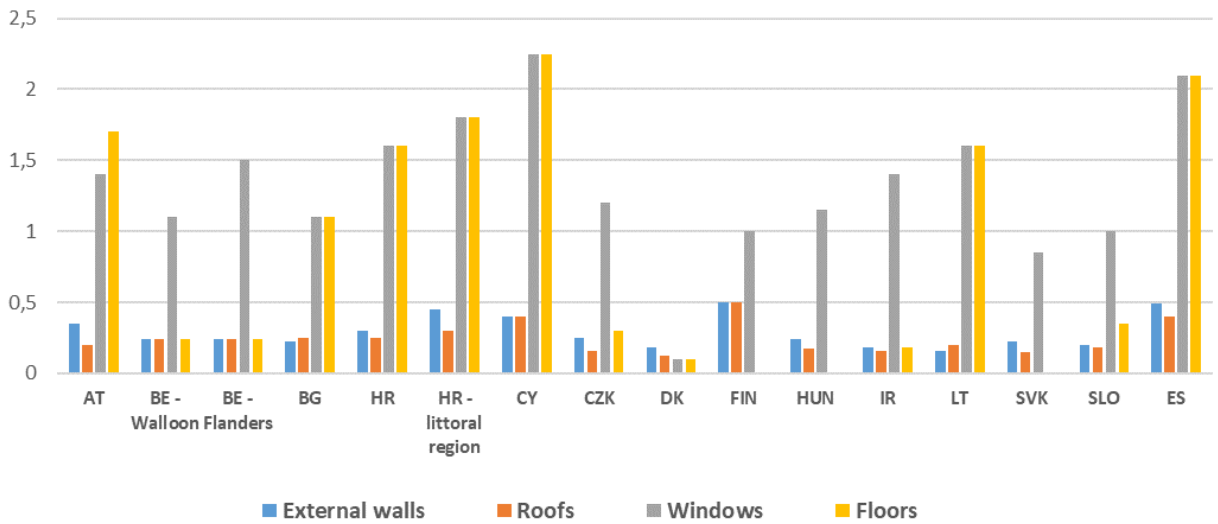

Figure 1. Minimum requirements on building envelope structures U-values; major renovated buildings after 2020.

The implemented requirements must take into account the results of the cost-optimal calculations of the minimum energy performance requirements, and the differences in requirements for existing majorly renovated buildings compared to new buildings (U-values, requirements on technical systems, and global indicator). The tightened standardised U-values for external walls set after 2020 are expected to be between 0.15 – 0.5 W/(m^2.K), for roofs between 0.1 – 0.4 W/(m^2.K) and for windows different for southern, central and northern countries between 0.8 – 2.0 W/(m^2.K).

Countries representing different European climates were selected for presentations, i.e., countries with a predominant heating season, with a predominant cooling season and with a need for both heating and cooling.

Posters were prepared providing information on each Member State's requirements on envelope structures and technical systems, as well as on the primary energy indicator.

4.2 Primary energy factors, weighting factors for renewable and non-renewable sources

From a physical perspective, some differences between PEF values in Member States for the same energy sources are inevitable because of local conditions. In addition, there are several internationally recognised conventions for the primary energy content of electricity from renewable or nuclear sources. It was found that the PEFs are not regularly updated. They are typically only reviewed when updates are deemed necessary. Member States responses to the session questionnaire revealed that reported PEF values do indeed vary greatly for many reasons:

- For conventional carriers such as fossil fuels, PEFs do not vary greatly (between 1-1.2) whereas for less established and centralised carriers such as biomass and biofuels much greater variations are observed (between 0.0-1.3).
- Electricity also presents great PEF variations (between 0.0-3.0) as renewable energy sources become more prevalent.
- District heating PEFs vary significantly (0.0-1.6) across Member States as they are influenced by parameters such as cogeneration, type of source (renewable or not), waste heating or district heating.
- Most Member States do not use different primary energy factors for some particular sectors or technologies, e.g., photovoltaic systems.
- Most Member States base their primary energy factors on national standards.

The survey found that the majority of Member States were expected to update their PEFs in 2020 or it was not yet confirmed.

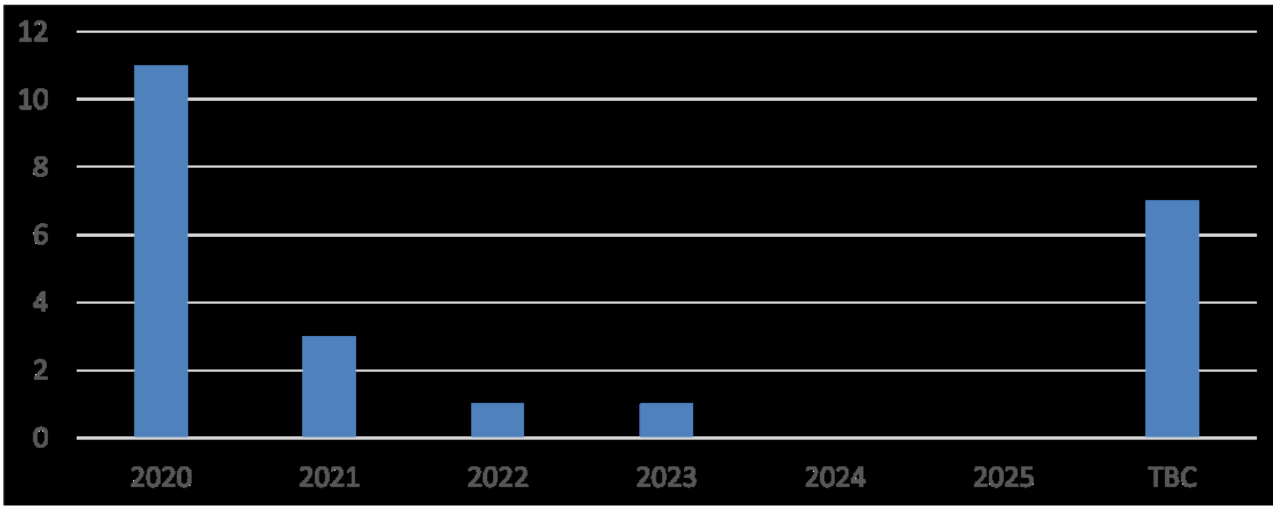

Figure 2. When the Primary Energy Factors will be updated by Member States.

4.3 CO_2 emission assessment and requirements in building regulation

Discussions focused on the possibilities and conditions for the evaluation and rating of building performance through CO_2 emissions (related to EBBD, Annex I, 1. c), reviewing the practice and experience in Member States, and assessing different ways to support future requirements to reduce GHG emissions and the assessment of primary energy.

A questionnaire provided more information on the options for the evaluation and rating of buildings through CO_2 emissions, current practices, and experiences. The questionnaire and results include:

- 16 Member States currently utilise CO_2 emissions calculations for energy performance assessments, with Germany indicating that this was expected to be implemented.
- Only three (3) Member States utilise CO_2 equivalent emissions (CO_{2eq}) in calculations to determine GHG emissions, with six (6) Member States confirming that this is something they were expecting to implement.
- Seven (7) Members States use a simplified calculation of CO_2 emissions when reporting GHG emissions savings in the building sector.
- 18 Member States confirmed they have set a CO_2 emissions coefficient for gas. On average, this value was 209 KCO_2 g/kWh, with the highest coefficient being 252 KCO_2 g/kWh (Spain) and the lowest coefficient being 160 KCO_2 g/kWh (Portugal). Six (6) Member States confirmed that this coefficient for gas is expected to change.
- 12 Member States confirmed they have set a CO_2 emissions coefficient for electricity, with an average value of 302 KCO_2 g/kWh. Although it should be noted that these values ranged greatly, with the highest coefficient being 644 KCO_2 g/kWh (Belgium – Wallonia and Flanders) and the lowest being 49 KCO_2 g/kWh (Slovenia). Six (6) other Member States confirmed that this coefficient for electricity was expected to change.
- Nine (9) Member States confirmed they have set a CO_2 emissions coefficient for district heating. On average, this value was 281 KCO_2 g/kWh, with the highest coefficient being 400 KCO_2 g/kWh (Germany) and the lowest coefficient being 154 KCO_2 g/kWh (Finland). Four (4) other Member States confirmed that this coefficient for district heating was expected to change.
- Only two (2) Member States confirmed that they plan to monitor the CO_2 for each building category separately.
- Six (6) Member States confirmed they currently monitor the CO_2 emission savings after the renovation of buildings from public sources. Three (3) Member States expected this to be implemented.
- Lastly, only one (1) Member States confirmed that, in the future, they expected to monitor PM2.5 and PM10 particulate emissions after renovation.

NZEB are low energy buildings that primarily use energy from renewable sources produced on-site or nearby. The reduction of energy consumption also allows for the reduction of CO_2. The methodology for calculation of primary energy is set out in Part 1 of the overarching EPB assessment standard EN ISO 52000-1 and calculations for the global indicator are depicted in the TNI 52000-2, although no examples for the calculation of CO_2 emissions are provided. For both primary energy and CO_2 emissions, the calculation is based on the delivered energy, utilising PEFs or CO_2 emission coefficients. The PEFs and CO_2 emission coefficients are set either in the EPB standard EN ISO 52000-1 or within the national regulations.

General descriptions of the methods and choices related to PEFs and CO_2 emission coefficients are set out in the EN 17423 standard. To decrease the PEF or CO_2 emission coefficient values, the ratio of renewable sources must be increased, although a specific ratio of renewables has not been set within EU or national regulations. The mix of energy carriers is also important to determine the CO_2 emissions coefficient factor for electricity from the grid and for district heating.

Based on the Member States responses on CO_2 emission requirements to the next session questionnaire, the main conclusions are:

- With regard to the different energy carriers Member States/ regions have set CO_2 emission coefficients for, there was a notable difference in the information received and there is a varied mix between countries and also between different regions. For gas, most Member States reported that the current value for the CO_2 emission coefficient remains the same as it did before 2021 or is expected to be changed by 2030. For electricity, the majority of Member States reported that the current coefficient will remain the same as it was before 2021, with most Member States expecting a change significantly before 2030. This means there will be an end to coal use and an increase in the share of renewable energy sources (RES). Lastly, Member States confirmed that the coefficient for district heating is based largely on the energy carriers that are being used, the specific cases and the type of production.

- In terms of the key measures that have an influence on reducing CO_2 emissions in the renovation of buildings, Member States/regions ranked the renovation of the building envelope and heat recovery first, followed by the upgrade of technical systems and boilers, the availability of different kinds of renewables on site and nearby, then the importance of control and automation systems. Member States/regions also highlighted the importance of:

    - necessary legislative measures, financial support, lifecycle analysis (LCA) / circular economy approach;
    - skills / technical competence of consultants / designers.

- Lastly, Member States/regions were asked how the GHG emission requirements were expressed in each Member State/region. Responses indicated that currently, requirements are only set on energy use and primary energy, there are no CO_2 emission requirements set, CO_2 is calculated and outlined within the EPC of some Member States/regions, and the impact on emissions is indirectly expressed via the analysis of the primary energy and RES share.

4.4 Implementation and use of 2nd generation of EPB standards

The deadline for the reporting to the EU about the state of implementation of the overarching EPB standards and setting the default values for the calculation and assessment of energy performance of buildings was 10 March 2020. At the time of the first survey, the state of transposition was as follows:

- Most MS had either not started the process of reporting or had only begun planning.

- There was a mixed response on how Member States intended to report with some planning to fill in annex A, some using annex A as a template and some using a mixture of the two.

- Most Member States intended to only report to the EU.

Due to the differences across countries, the reporting cannot be the same for all Member States. For more countries the default values in Annex A umbrella standards of the 2nd generation are not yet available to a sufficient extent and were not relevant to their national calculation methodology. In other cases, some of the national requirements are not met by EU standards and that is why national requirements were added to the required in EU standards.

Later on, the results of the survey in 2020 showed, that only one Member State had already implemented the overarching EPB standards. Four (4) Member States were in the process and expected to implement the EN standards within 2-3 years.

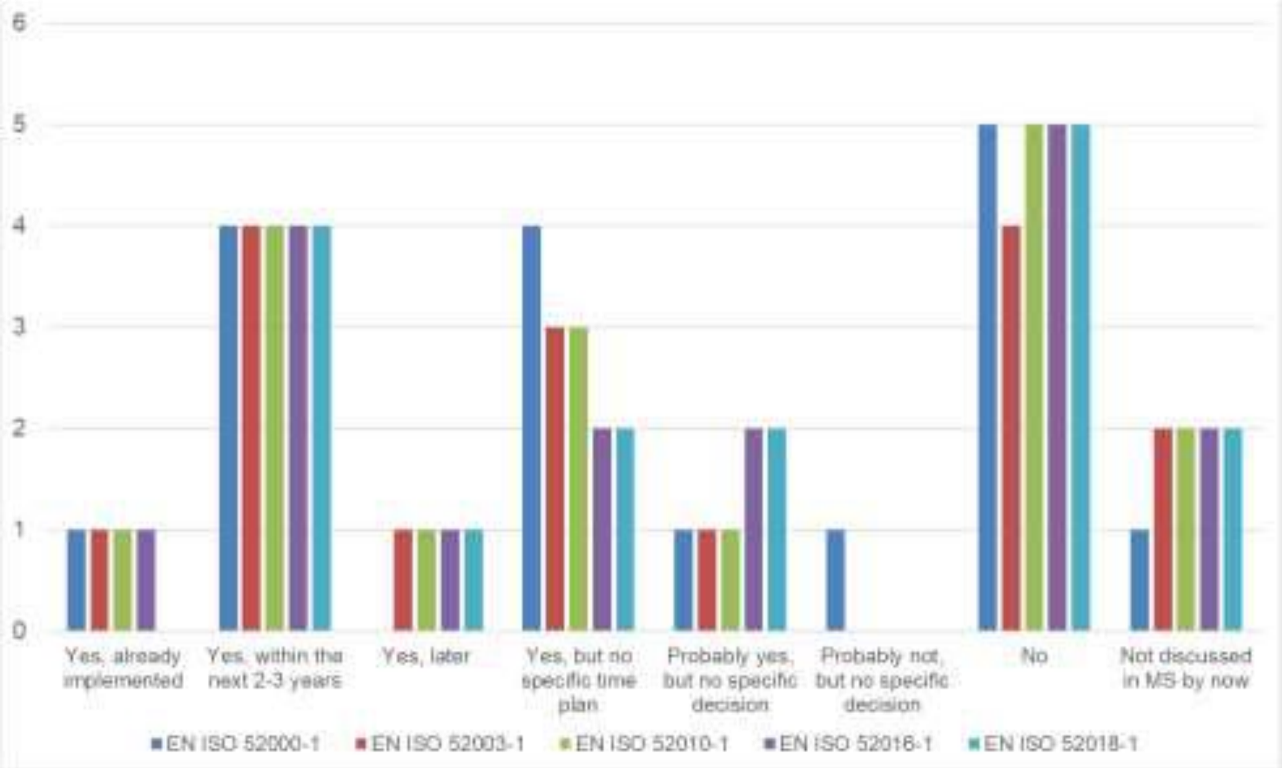

Figure 3. When Member States expect to have implemented ISO 520XX-1 for regulation purposes.

4.5 Health, indoor air quality and comfort levels

4.5.1 Optimising health and indoor air quality

A questionnaire was prepared on options for gaining deeper insight into the extension of energy performance of building indicators and their evaluation. The main results are:

- Eight (8) Member States or regions confirmed that they have implemented the EN 16798-1 standard, with four (4) confirming that it is expected to be implemented.
- 18 Member States or regions confirmed that they set requirements for the indoor temperature (operative temperature) of residential buildings during the winter season, four (4) confirmed they do not. In some Member States, the standards differentiate indoor temperatures for different types of spaces, e.g., bathroom 24°C, bedroom 18°C, living room 21°C. Only in some Member States there are requirements on the indoor air relative humidity. Requirements are typically set between 40 – 65%. Ventilation rates are also outlined in some Member States, although sometimes rates apply to the whole building, or they differ per room.
- 16 Member States or regions confirmed that they set requirements for the indoor temperature (operative temperature) of residential buildings during the summer season, four (4) confirmed they do not, whilst one (1) MS confirmed that they expect to set temperature requirements.
- For non-residential buildings, 18 Member States confirmed that they set requirements for the indoor temperature (operative temperature) during the winter season, 10 Member States

confirmed that they set requirements for the relative humidity and 19 Member States confirmed they set requirements for the ventilation rates. It was noted that, depending on the Member State, ventilation rates were set differently, some focused on the levels of CO_2.

- 16 Member States also confirmed that illuminance levels were set for the wintertime. Requirements are typically in accordance with EN 1264-1, but the levels can vary depending on the environment and the visual task. The medium illuminance level is around 500 lux.

- Nine (9) Member States confirmed that the control of indoor environmental parameters is mandatory after the construction of a new building, whilst seven (7) Member States confirmed that it is mandatory after the renovation of an existing building.

Some examples of implementation of internal environment requirements were presented. The Finnish Land Use and Building Act states that '*When undertaking a building project, it is to be ensured that the building is designed and constructed in such a way that it is healthy and safe with regard to indoor air, humidity, temperature and lighting conditions*'. This concept is also repeated in other decrees and is applicable to renovation projects. A summary of the environmental parameters for residential and office buildings that have a set of requirements is outlined within regulations. In Finland, only requirements for temperature and ventilation rates are outlined. Some guidance is provided on humidity and lighting but the values for these are not clear.

Figure 4. Summary of environmental parameters for residential and office buildings in Finland (set limits within the regulations).

Different types of temperature indicators are used in Member States, among which the ambient air temperature, the radiant temperature and the operative temperature. Each of these is different not only in their physical definition, but also in the way they are measured. The humidity indicator is a common and measurable indicator, although by itself it says little about comfort. This indicator is typically tied with the temperature. Other indicators include the air flow velocity and air pollutants indicators. Pollutants include volatile organic compounds (VOCs), nitrous oxide, carbon monoxide, carbon dioxide, or solid particular matter which can impact human health. For example, Croatian regulations set basic requirements for buildings in all important areas and pertaining to a range of topics, but two of the topics 'hygiene, health and environment' and 'energy management and heat retention' are directly related to general air quality. Despite this, Croatian regulations only define air quality as either the ambient air temperature, or the minimum air flow/ minimum air change rate.

4.5.2 Link between COVID-19, ventilation, energy and energy performance regulations

Special attention was given to the COVID-19 situation. It is not possible to measure the concentration of COVID in the air; however, the number of aerosols is proportional to the number of people in a room, because every time a person breaths out, aerosols are released into the air. The activity level of a person also plays a role, if an infected person was active, they would exhale more, producing and releasing a larger amount of the virus particles. A person who is relaxed having undertaken minimal activity, produces approximately 20l CO_2/hour. It is generally accepted that by measuring the CO_2 concentration within a space, this provides a good indicator of the relative risk of getting infected. The greater the volume of CO_2, the greater percentage of fraction re-inhaled air, and the greater the risk of a person is to develop COVID. So, if the ventilation rate is increased, this will reduce the CO_2 concentration. For example, if the concentration of CO_2 in the indoor air is 500 ppm, a person is 5 times less likely to catch it.

Two key questions linked to the discussion of COVID-19 and its relation to energy were highlighted:

- Is there an increased infection risk in energy efficient buildings?

  Energy efficient buildings generally have a better airtightness than old buildings. If a zero-energy building was to be constructed without a ventilation system, the ventilation rate in the building would be lower than in older buildings. This would increase the risk of infection. It would also not be a good strategy to address the indoor climate.

- How to combine COVID-19 aerosol strategy with energy efficiency concerns?

  The general advice in the context of COVID-19 is to try to maximise the ventilation rates of the existing systems. Certain standards address the recommended rates and how systems can do this, e.g., ASHRAE. In terms of energy, there are two types of energy efficient strategies:

  - demand controlled ventilation;
  - heat recovery systems.

4.6 Need for changes or adjustments to requirements for building codes

A short questionnaire was used to structure the discussion on changes or adjustments to requirements for building codes.

In one question, delegates were asked if they supported the EC´s intention to set an exact standard of deep renovation within the EPBD. The responses were relatively equal, with 12 Member States stating that they supported the EC's intention, whilst 10 Member States stating they did not support it.

Concern was raised that it might be too early for Member States to answer this question due to the limited knowledge on the topic. The next question looked at whether Member States' national building codes require the reporting of total GHG emissions for buildings after their renovation. Only two (2) Member States confirmed that their national code requires this, whilst 22 Member States stated that they did not. Finally, the last question asked delegates if their administration had any plans to introduce such an obligation at the next amendment / change of the law. Five (5) Member States agreed that plans are in place, whilst 17 Member States confirmed there were no plans at the moment.

Based on the responses and comments received as part of the questionnaire, recommendations for both new buildings and the renovation of existing buildings were compiled. The main suggestions included:

- monitoring of GHG emissions across the life cycle of a building. This could be through the use of Level(s) core sustainability indicators for office and residential buildings;

- imposing a CO_2 indicator and make the indicator for primary energy optional;

- introducing an LCA indicator;
- installing automatic devices for monitoring of indoor air quality (IAQ);
- reviewing U-values and summer comfort requirements; and
- using a renewable resources ratio, CO_2 indicator and overall minimum U-values.

In addition, measures for refurbished buildings were recommended, including:

- the provision of an NZEB concept suitable for renovation; and
- to prefer and promote deep renovations via subsidies; however, if the minimum performance after renovation is set too high, this could become a barrier to renovations.

Regarding the adjustments to the requirements for building codes, there are a number of recommendations that have been outlined for both new and existing buildings. For new buildings, the existing building regulations and guidelines stipulate a high degree of efficiency in the building envelope. In order to achieve the energy and climate targets, it will be necessary to consider the use of resources and energy per unit. To do this, focus needs to be placed on raw materials for new building products, emissions and harmful environmental impacts. The measures necessary to drive forward a coherent climate and energy policy should also be implemented alongside the municipalities and regions. This will increase the potential of the measures utilised by the province itself and make these measures easier for citizens to relate to.

5 Lessons Learned and Recommendations

Over the course of several months, new requirements have been introduced. At the same time, new legislation should set the requirements and the process to meet the 2050 targets. Better understanding of the implementation process, together with changes in technical and technological solutions related to energy performance of buildings, have influenced the requirements on topics to be discussed.

Member States should prepare all the conditions to start the process of NZEB construction as well the renovation of existing buildings. Most Member States base requirements on the date of starting the design process. It is difficult to base requirements on the completion date because development may have started before the NZEB regulations and thus clear definitions were in place. Funding was considered the biggest challenge. It was noted that, as public budgets operate under strict rules, implementing NZEB measures can be a problem for small public authorities because they often do not have the required finances and capacity.

It was suggested that although RES is desirable for NZEB, in general, it should be considered if the generated energy would be useful to the building itself. The majority of Member States thought that there should not be different requirements for public and private buildings; all buildings should be at the same level (subject to technical and economic feasibility, etc.).

At the beginning of CA V EPBD further work, there was a need to clarify the definitions of 'RES on site and nearby;' and 'functionally, technically and economically feasible' when renovating existing buildings. The group discussions indicated the importance of striking a balance between creating simple boundary conditions for exemptions and introducing conditions that are stringent enough to incentivise more nearly-zero energy buildings leading to the provision of a zero emission building. It was recommended to deal with approaches setting minimum requirements for building envelope structures and minimum requirements for technical systems.

Furthermore, it would be valuable to continue the dialogue amongst Member States and examine in more detail what these boundary conditions are and how the legislation to enact them should be developed. It was considered very important to determine how RES locations should be taken into account and to define requirements for the ratio of RES for heat supplied from district heating.

The reliability of primary energy savings (or consumption) in buildings and the consistency between cost-optimisation of national regulations and definitions of NZEB depend on the quality and transparency of the PEF calculations. Most Member States want to update the primary energy factors more regularly.

Currently, there are explicit requirements or thresholds for CO_2 emissions in the majority of Member States. There are examples in Member States where EPB regulations are currently being reviewed with the intention to update. Updates could include the addition of a specific CO_2 emissions indicator with threshold, the inclusion of an equivalent CO_2 principle to take into account missing and neutral data. It is clear that there is a necessity to set a requirement for CO_2 emissions as one of the options to assess the energy performance presented in EPCs. This CO_2 indicator should be an additional element to accompany the primary energy factor. To achieve the additional CO_2 target, it will be necessary to include an equivalent CO_2 principle and a yearly review of the electricity CO_2 factor. Different requirements for CO_2 emissions should be set for new construction projects and renovation projects.

Moving forward, it will be important to continue to monitor how Member States are addressing the monitoring of CO_2 emissions and what requirements are integrated into national regulations. It will be necessary to find the relation between primary energy and CO_2 emissions to ensure the EPC rating reflects both. Attention should be placed on thermal protection efficiency, technical system quality, building automatisation and control systems, to ensure they meet the preconditions for achieving a reduction in energy use and CO_2 emissions.

The energy performance of a building must be determined on the basis of the calculated or the actual energy use of the building, which must reflect all its typical energy uses. A national methodology is required following the national annexes of the 2nd generation of EPB standards. A separate session was recommended to look at the second generation of EPB standards. In 2018, only one (1) country implemented the overarching EPB standards. After 2020, the situation changed only a little. Most Member States have not implemented the standards. It was proposed that further work be undertaken to focus on setting the default values (e.g., structures/materials, technical systems and PEFs). It was also recommended to focus more on health, indoor air quality and comfort levels. A summary of the requirements needs to be based on performance, calculated or actual energy use based, end uses such as space heating, space cooling, domestic hot water and lighting. Additional indicators, such as GHG emissions, may also be reported and these can be used for other purposes such as building compliance checks. The changes also add the need to account for the positive influence of factors such as local solar conditions and district heating.

Future discussion could look at tools that some Member States could use to translate the standards. Additional questions concerned whether all Member States should be using a monthly or hourly model and how to incorporate measured data into calculation.

Following EN 16789-1 and the experience in different Member States, the aim was to standardise the parameters on winter and summer conditions for optimising indoor quality and comfort level. Eight (8)

Member States or regions confirmed that they have implemented the EN 16798-1 standard. Eighteen (18) Member States or regions confirmed that they set requirements for the indoor temperature (operative temperature) of residential buildings during the winter season. Sixteen (16) Member States or regions confirmed that they set requirements for the indoor temperature (operative temperature) of residential buildings during the summer season. Seven (7) Member States confirmed that it is mandatory after the renovation of an existing building. Only temperature and ventilation rate requirements are outlined in regulation, with some guidance provided on humidity and lighting. Dynamic simulation has been deemed the way forward to ensure accurate modelling of temperatures and effective building design going forward.

Additionally, an overview of the links between COVID-19, ventilation, energy and energy performance regulations was provided. It was concluded that aerosols are a source of infection and can increase the spread of the virus; occupancy related aerosol concentration indoors is typically much higher than outdoors, because outdoor air gets diluted. Good ventilation systems can substantially reduce the infection risk, and CO_2 is a good indicator of the relative risk. Heat recovery systems are the most effective technique for reducing energy consumption of ventilation systems; and finally, air cleaning systems can be a valid alternative and are easier to install in existing buildings.

There was also attention on the need for changes or adjustments in requirements for building codes (new building and renovated existing buildings). These topics were further explored in a Poll Everywhere survey taken during the session. To summarise, the poll found that 13 out of 23 participants believed that Minimum Energy Performance Standards (MEPS) should be set. All participants felt that a combination of measures should be identified for different categories of buildings. The majority of participants (95%) thought that heritage buildings required their own requirements. However, 19 out of 26 participants felt that energy demand indicators should not be introduced separately for each technical system nor the energy demand of the building. 20 out of 26 participants felt that the assessment should be extended to introduce CO_2 emission classes for new and refurbished buildings. Lastly, 21 out of 24 participants felt that a requirement to reduce CO_2 emissions should be introduced for a combination of percentage recovery measures.

Moving forward, to improve current energy requirements for new and for existing buildings, specifically looking at recent technical developments and changes in the building stock, areas to consider include:

- The inclusion of a NZEB renovation requirement expressed as a percentage of improvement.
- Harmonisation on an EU level to ensure current NZEB requirements are comparable.
- The enabling of new technologies within the Building Code. This might include neither explicitly listing the allowed technologies nor indirectly preventing new technologies from being implemented.

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