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ANNEX 12

ANNEX

to the

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providing guidance on new or substantially modified provisions of the recast Energy Performance of Buildings Directive (EU) 2024/1275

Common general framework for the calculation of the energy performance of buildings (Annex I)

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Commission Notice providing guidance on new or substantially modified provisions of the recast Energy Performance of Buildings Directive (EU) 2024/1275

Common general framework for the calculation of the energy performance of buildings (Annex I)

1. INTRODUCTION

This document aims to provide guidance to Member States on the transposition of Annex I – Common general framework for the calculation of the energy performance of buildings ('the calculation methodology') of Directive (EU) 2024/1275[1] on the energy performance of buildings ('the recast EPBD'). It also aims to provide guidance on the relevant elements related to the calculation methodology throughout the recast EPBD, such as definitions in Article 2 and zero-emission buildings in Articles 7 and 11. The guidance covers all new provisions and modifications to existing provisions. In addition, it provides further recommendations on existing provisions where relevant.

2. POLICY AND LEGAL CONTEXT

The methodology for assessing the performance of buildings is a key element of the EPBD. It is used directly in several Articles on cost-optimal calculation, minimum energy performance requirements, energy performance certificates (EPCs), building renovation passports (BRPs), zero-emission buildings and databases for the energy performance of buildings. It is also used when carrying out renovations and it is necessary to identify the potential or actual improvement in performance due to subsidies or loans. Its relevance goes beyond the EPBD. For example, it is also widely used in building design (as a tool to identify and benchmark design solutions. The EU green taxonomy[2] also indirectly relies on its framework at national level to identify if an activity fulfils the requirements in place.

The calculation methodologies in use in all Member States rely on common and established physics, but their application must be able to adapt to the needs and particularities of different Member States. While climate is an obvious factor, there are other factors that may be considered, such as building typologies, technologies, the availability of renewable energy sources on-site or on the grid, and social and cultural aspects.

The energy performance of buildings has been improving significantly since the EPBD was first introduced in 2002. Modern buildings consume less than half of what was typical before 2002, and this is likely to continue improving in the coming years. As requirements are steadily becoming more ambitious, the calculation methodology needs to also improve and allow for a better representation of the energy performance of buildings at multiple levels: the building as a whole, its individual components and the building as part of the larger energy system.

The calculation methodology also needs to be able to adapt to new technologies and products, new practices in the construction sector, the evolution of the building sector itself (as it responds to different user needs) and the larger energy sector (e.g. the progressive introduction of renewable energy sources in the energy mix).

[1] Directive (EU) 2024/1275 of the European Parliament and of the Council of 24 April 2024 on the energy performance of buildings (recast).

[2] EU taxonomy for sustainable activities – European Commission.

Together with the Member States, the Commission established a set of standards (EPB standards) and accompanying technical reports to support the EPBD through Mandate M/480 to the European Committee for Standardisation, CEN 2012-2017. There is no obligation to adopt the standards and Member States may use their national calculation methodologies. However, the EPBD does require that Member States use a set of EPB standards to communicate the national calculation methodology to the Commission (see Chapter 4.6).

The calculation methodology aims to:

- provide a clear framework for the calculation of energy performance;
- identify the main energy needs of the building, including user needs and behaviour;
- represent the effects of the different building elements and systems;
- represent the integration of the building with the rest of the building energy uses (e.g. white goods or office equipment) and the larger energy grid;
- make it easier to introduce new technologies (e.g. energy storage).

3. SUMMARY OF OBLIGATIONS UNDER ANNEX I AND THE CALCULATION METHODOLOGY

Annex I builds upon and complements the provisions related to the calculation methodology already established in the original EPBD in 2002, its 2010 recast and the amending 2018 EPBD.

Table 1 presents an overview of the obligations related to the calculation in Annex I and elsewhere in the recast EPBD.

Table 1: Summary of obligations in Annex I (including new, modified and existing)

Scope	**Member State (MS) obligation**
Reflect typical energy use	• MS to identify the typical energy uses for buildings (existing)
Use of metered energy in calculation methodology	• MS to define the boundaries for the use of metered energy in the calculation methodology (new option)
Use of indicators	• MS to define primary energy use (modified) • MS to define additional indicators, including greenhouse gas emissions (modified)
Use of primary energy or weighting factors	• MS to define primary energy factors or weighting factors for energy carriers (modified) • MS to consider the integration of the building into the energy grid and its evolution over time (modified)
Consideration of building and system aspects	• MS to lay down the methodology considering at least the aspects identified in Annex I(4) (including new aspects in the recast) (modified) • MS to consider the positive influence of multiple aspects identified in Annex I (5) (including new aspects) (modified)

Classification of buildings in categories	• MS to classify buildings according to classes identified in Annex I (6) (existing)
Reporting of calculation methodology	• MS to report their calculation to the Commission using the national annexes of the standards identified in Annex I (modified)

4. IMPLEMENTATION OF OBLIGATIONS UNDER ANNEX I

4.1. Determination of energy use

4.1.1. Energy uses identified in the EPBD

To calculate the energy performance of a building, the energy needs must first be defined (for example by EN ISO 52016-1 (Article 1, Annex I)). They refer to the amount of energy (regardless of its source and efficiency of systems) to be supplied or extracted in order to maintain the requirements for indoor environmental quality (IEQ). This gradually expands the system boundary from energy needs to delivered energy and finally to primary energy use.

To fulfil the building's requirements for IEQ, the EPBD identifies the 'services related to the energy performance of buildings' or 'EPB services' (Article 2(56)). These services comprise heating, cooling, ventilation, domestic hot water, lighting and others. These are the systems applicable in most buildings, although in some cases additional services may be needed. For example: humidification or de-humidification in specialised rooms or uses, specialised cooling in server rooms, domestic cold water pumping, parking or external lighting, internal mobility, etc.

Member States should decide themselves if additional energy needs from the broader definition of technical building systems are to be considered when calculating the energy performance. The Commission recommends that Member States consider the needs of these other technical building systems when these are responsible for controlling the IEQ of a building[3]. This should help differentiate between systems that have an effect on IEQ (e.g. printers or cooking appliances) from those that control IEQ (e.g. humidity and purification devices).

EPB services exclude energy uses that are also typical in buildings, but that are not directly related to maintaining IEQ. This applies for example to the energy loads of white goods, home electric appliances,, office equipment or industrial processes. However, because these (non-EPB) energy loads have a significant effect on (EPB) energy needs, it is important to identify them and take into consideration their effects on EPB services. For example, the energy use for office equipment (because of its internal heat gains) will play a key role in the calculation of heating and cooling needs in office environments.

Electricity for charging e-vehicles is not considered an EPB service. However, renewable energy generated on-site may be exported to the vehicle. This would have the advantage of avoiding losses related to extraction, refinement, conversion and transport, which could be reflected in the calculations (see Chapter 4.3). It would also make it easier to represent the integration of buildings into smart energy grids, and would enable smart grid integration.

[3] For the definition, see the Guidance on Technical Building Systems, Indoor Environmental Quality and inspections in Annex 10..

4.1.2. Key definitions

Clarification on definitions available in the EPBD

EPB uses or EPB services – Article 2(56) defines the uses that are relevant for the energy performance assessment of buildings. Services such as heating, cooling, ventilation, domestic hot water and lighting are directly mentioned and must therefore be included in the assessment. Member States should also include other services if relevant. Article 1 establishes the relationship between energy performance and among other things the requirements of IEQ. Based on this relationship, other services that have an impact on IEQ should be considered by Member States where relevant. This could include, for example, services related to treating outside air in specific cases (e.g. humidifiers or purifiers for specific room uses which differ from the typical conditions). Additional building services could also be considered (e.g. escalators or elevators).

Energy needs – Article 2(57) defines energy needs as the energy supplied (or extracted) from a conditioned space to maintain intended conditions. These are the requirements of a given building space or building before the efficiencies of technical building systems or primary energy factors are considered.

Energy use and energy consumption – Defined in Article 2(58) as the input to a technical building system, including the inefficiencies of the system. Both terms (use and consumption) are interchangeable for the purposes of the EPBD. Energy use may be calculated in primary energy use or in final energy use.

Primary energy – Defined in Article 2(9) as the energy from a renewable or non-renewable energy source that has not undergone any conversion. It is calculated by applying a primary energy factor to the final energy use. Depending on the energy source, this can be: renewable primary energy, non-renewable primary energy or total primary energy (the result of adding renewable and non-renewable).

Clarification on terms used in the EPBD, but not defined in the legal text

Typical energy use – This represents the conditions used as a baseline in the calculation methodology. They often include patterns and profiles of use that reproduce how buildings are generally used. For example: pre-warm up period, opening hours, temperature settings or use of temperature set-back conditions in the case of demand-controlled systems. Typical energy use should be representative of the building stock for a given building category, although this may result in differences between an individual building and the specific energy use. Typical energy use is the opposite of specific energy use, which would apply to an individual building under distinct circumstances.

Final energy use – This represents the energy use of a building and its system, taking into consideration the inefficiencies of the system, but before primary energy factors are applied. Final energy use can be understood as being applied to the whole buildings, or it can be applied to a single system (e.g. final energy use for the domestic hot water system). Because the primary energy factor is applied to energy carriers, final energy use should be recorded separately per energy carrier.

Energy delivered – This represents the energy supplied (delivered) to a system or a building through the building assessment boundary per energy carrier.

Energy exported – This represents the energy supplied (delivered) from the building to the grid through the building assessment boundary per energy carrier.

4.1.3. Building categories

Buildings are very different from one another and respond to very different needs. However, they can be broadly grouped into the categories identified in paragraph 6 of Annex I.

(a) single-family houses of different types;

(b) apartment blocks;

(c) offices;

(d) educational buildings;

(e) hospitals;

(f) hotels and restaurants;

(g) sports facilities;

(h) wholesale and retail trade services buildings;

(i) other types of energy-consuming buildings.

The aim of the categories is to group similar buildings that share similar energy uses and patterns.

Member States may identify additional categories of buildings or subdivide the categories already identified in the EPBD. For example, they could define a subcategory for primary schools and secondary schools.

4.1.4. Typical energy use and user behaviour

For the calculation of energy performance, it is important to determine the typical use of a building. Typical energy use includes aspects directly related to energy (e.g. operating temperature), but also how users behave and use a building (e.g. operating hours).

It is common for buildings to actually have multiple uses (e.g. a multi-residential building with retail shops on the ground floor). In this case, the calculation must be based on the typical use per building category of space. Benchmarks and minimum energy performance requirements should be applied based on the weight of the different spaces (e.g. based on floor area).

The EPBD requires that typical energy use is representative of actual operating conditions in the building categories identified. This is a key element in ensuring that the calculation methodology can be applied consistently throughout the building stock and allows for benchmarking between buildings.

The EPBD indicates that typical energy use and typical user behaviour should, where possible, be based on available national statistics, building codes and metered data. Member States may use additional methods such as sampling, questionnaires or interviews with professionals in the given sector. The aim is to ensure that the defining elements are representative.

Typical use and behaviour may vary over time, for the whole building stock or for individual building categories. For example, the COVID-19 pandemic saw a significant increase in the use of teleworking, even when workers were allowed to return to the office. The gradual introduction of computers in schools has also seen changes in energy patterns (e.g. higher internal gains).

The evolution and changes in the use in buildings should be represented in the typical use and behaviour when calculating the performance of buildings.

Member States should revise these parameters at regular intervals. For example, they could revise them before each cycle or every two cycles of the cost-optimal methodology (equivalent to revising them every 5 or 10 years). See Chapter 4.7 on changes to the framework for the calculation of energy performance.

4.1.5. Energy use in an individual building and user behaviour

The main uses of the framework for the calculation of energy performance are to allow for the evaluation of compliance of minimum energy performance requirements and the issuance of EPCs. For these purposes, the calculation methodology must use the typical energy use and behaviour.

The energy performance calculation framework could also be used to provide tailored information about the performance of an individual building. For example: energy audit or to identify design parameters. In order to do so, the use and behaviour would need to be modified and tailored to suit the actual or expected conditions. For example, a developer may be interested in benchmarking different options for a building where it is known that its use will be substantially different from a typical building (e.g. an office building that will be used 24/7). In this case, it is relevant for developers to be able to better model these conditions in order to identify the best system or solution.

In order to facilitate this flexibility in the calculations, Member States should allow the framework and any related calculation engines (i.e. software) to modify the operating condition for the production of specific and tailored calculations.

The results of these specific calculations should not be used to demonstrate compliance with energy performance requirements. In some very specific cases, where the building use characteristics are clearly identified, are different from typical patterns and cannot be modified without substantial changes to the building, it may be advisable to use specific calculations. Such uses should be authorised through specific waivers provided by the relevant authorising body in the Member State.

The results of these specific calculations cannot be used to issue an EPC, which must always be dependent on the building category in order to allow for benchmarking.

4.1.6. Energy use when a system is not present

It is common for an EPB need to not have a system associated to it in a building. For example, many buildings or building units in southern European Member States do not have central heating systems installed, and instead rely on portable space heaters. Similarly, many buildings rely on natural ventilation or passive means to provide thermal comfort in summer, while others may have cooling systems installed. In addition, some buildings may rely on natural ventilation to provide fresh air, while others may rely on mechanical ventilation.

The EPBD requires that IEQ in buildings is maintained. This is associated with the various energy needs (e.g. heating to maintain the temperature in winter, ventilation rate to ensure sufficient fresh air).

When there is no fixed system directly associated to an energy need, Member States should allocate a notional service to the energy need. This service should enable the fulfilment of building requirements (e.g. minimum temperature settings) be representative of typical solutions used in such cases, have a performance associated to it and an energy source, which would in turn require a primary energy factor (or weighting factor).

The following are three examples of how most typical scenarios could be approached:

- **Building without a fixed heating system** – In this case, it would be safe to assume that the building would rely on space heaters to supply the necessary heating. They would have an efficiency rating associated with them (e.g. 98%) and would rely on electricity (e.g. PEF 2.5 for grid electricity). This artificial system would then be used to calculate the building performance.
- **Building with natural ventilation** – In this case, buildings with good airtightness would rely on the manual opening of windows or dedicated passive ventilation devices to ensure sufficient fresh air. Manual openable windows usually offer less control over the flow of fresh air, but they can still provide the necessary service. Therefore, Member States must assume that the comfort air exchange rate is provided anyway. Member States might consider reflecting the lack of control in the calculation methodology, for example through the application of control coefficients. Member States should differentiate between alternatives. For example, dedicated passive ventilation devices (e.g. grilles in windows or walls designed to allow for small volumes of air) are usually better at performing their role compared to a large window given that they are purposedly designed for a limited but constant flow of air. If windows or passive ventilation devices rely on automated control (e.g. automated windows), it would be safe to assume that the ventilation rates are also better controlled and therefore the improved performance should be reflected.
- **Building with undersized systems** – In this case, it is safe to assume that the existing system would carry out the proportion of the load[4] corresponding to its size. The remaining load would still need to be covered, in which case the calculation could use the same approach as for buildings without a fixed system.

The assumed system approach is not mandatory. If used, it should be clearly visible in the EPC as important information for the owner and EU databases.

If the assumed system approach is not used, then the EPC and EU databases should clearly report the inability to maintain the required conditions (e.g. temperature settings). This approach is not recommended, since it may be difficult to explain and users may still concentrate on the apparent better performance value.

4.1.7. Calculation intervals

Paragraph 2 of Annex I requires that the energy needs are calculated using monthly, hourly or sub-hourly time calculation intervals. This is a modification from the EPBD in 2010 and 2018, which also allowed for yearly intervals in the calculation.

Smaller calculation intervals allow for a better representation of the building needs, system performance and overall energy use. This is particularly relevant when advanced control systems, renewable energy sources or energy storage are available in the building.

The Commission recommends the following intervals according to the type of building, its systems and the purpose of the calculation.

Table 2: Recommended calculation intervals for energy performance assessment

	Calculation interval			
Building type	New building requirements	Major renovation requirements	Issuing EPC	Issuing BRP

[4] The load would refer to the load of the technical system it applies to (e.g. heating, ventilation, air conditioning or domestic hot water).

Residential simple	Hourly or sub-hourly	Hourly or sub-hourly	Monthly or hourly	Hourly or sub-hourly
Residential multi	Hourly or sub-hourly	Hourly or sub-hourly	Monthly or hourly	Hourly or sub-hourly
Non-residential small	Hourly or sub-hourly	Hourly or sub-hourly	Monthly or hourly	Hourly or sub-hourly
Non-residential medium or large	Hourly or sub-hourly	Hourly or sub-hourly	Hourly or sub-hourly	Hourly or sub-hourly
All types (with advanced systems, renewable energy sources on-site or storage)	Hourly or sub-hourly	Hourly or sub-hourly	Hourly or sub-hourly	Hourly or sub-hourly

Modern products and systems have better defined performance information and allow for better adaptation to the building's needs. In part, this is a result of ecodesign and energy labelling but is also due to improved technologies.

One example is performance curves for different systems. These curves can provide better information on the performance of a system at a given speed and indoor/outdoor conditions. Hourly calculation intervals would allow a system to much better represent its performance as the calculation methodology could match the performance curve with the conditions at any given moment. This would also be of great assistance to designers and installers as it would allow them to tailor the system to the specific building conditions.

4.1.8. Use of metered energy for the calculation of energy performance

Annex I(1) of the recast EPBD indicates that the energy performance of a building can be determined on the basis of calculated or metered energy.

The recast EPBD also requires that the calculation reflects typical energy uses for the various energy uses. The consideration of typical energy uses is one of the key elements that allow for an asset rating of buildings and a comparison between different buildings of the same category (e.g. for EPCs).

In addition to the physical characteristics of the building and its technical systems, metered energy is subject to two main influences: the behaviour of occupants and the local climate. Directly using metered energy without accounting for these influences would not allow for asset rating and comparison between buildings. For this reason, the recast EPBD requires that, when using metered data, the influence of the behaviour of occupants and the local climate must not be reflected in the result of the energy performance calculation.

In order to extract the influence of behaviour and climate, a calculation method States should:

– Correct the measured performance according to the actual operating conditions compared to the typical operating conditions used in standard calculations (e.g. same temperature settings and same conditions for air quality);

– Correct the measured performance according to the actual use patterns of occupancy, compared to the typical operating use patters used in standard calculations, for example similar use hours during the day and same number of occupants;

– Correct the measured performance for the actual climate conditions compared to the standard ones.

Member States may use different means to identify these differences:

– provision of detailed metered data from building monitoring (at least indoor temperature at hourly intervals);

– provision of performance data stored in technical building systems (e.g. sensor readings or operating hours for generators);

– Measurements and evaluation by the independent expert during the assessment;

– readings from on-site weather stations or nearby official weather stations.

In order to support the use metered data for the calculation of the energy performance, Member States should make freely available climatic data measured from public owned outdoor air quality measurement stations.

The use of metered data as a basis for the calculation methodology or as a means of verifying the correctness of calculations requires that metered data is available at least on monthly readings. These readings must be actual readings (i.e. not estimates) and should be able to differentiate between EPB services and non-EPBD services per energy carrier. Where possible, especially for complex buildings, the readings should also differentiate between EPB services.

Long spans of time between intervals make it difficult to analyse and make a comparison between the readings and the typical operating conditions. In order to correct for this, the Commission recommends that metered data is available at least on hourly readings. This should be feasible given the availability of smart metering systems already available in buildings or their easy installation if retrofitted.

The use of metered energy would require that the technical systems of the building include the needed measurement instruments and a measurement plan with roles, responsibility and essential quality insurance provisions. Specific measurement systems or products tailored to the assessment of a buildings energy performance could also be used.

4.2. Indicators of energy performance and their use in requirements

Paragraph 1(4) of the EPBD requires that the energy performance is expressed by a numeric indicator of (total) primary energy use per unit of reference floor area (kWh/(m^2 y)) for the purposes of energy performance certification and compliance with minimum energy performance requirements.

For the purposes of the EPBD: total primary energy use is the sum of total non-renewable primary energy use and total renewable primary energy use.

Member States must also define additional indicators for (paragraph 3):

– total non-renewable primary energy (kWh/m^2 y);

– total renewable primary energy use (kWh/m^2 y);

– operational greenhouse gas emissions ($kgCO_{2\ eq}$ (m^2 y)).

Given that energy needs[5] is a required indicator in the EPC template (Annex V, paragraph 1(2c)), Member States must also define an indicator for energy needs. As indicated in Chapter 4.1.1, the energy need is the energy to be delivered in order to maintain the requirements for IEQ or other requirements (e.g. lighting or DHW) regardless of its source and the efficiency of the technical building system fulfilling the need. Energy needs are calculated for each EPB service and per energy carrier.

[5] For example, for heating, cooling and ventilation assessed according to EN ISO 52016-1, and for domestic hot water needs EN 12831-3.

Member States may define additional indicators.

Member States must set minimum energy performance requirements based on total primary energy use (i.e. total non-renewable + total renewable). They may set additional requirements for any other indicator.

4.3. Use of primary energy factors or weighting factors

The energy performance of a building must be expressed by a numeric indicator of primary energy use, which is the energy used to satisfy the energy needs of a building. ‘Primary energy’ is calculated from the amount of energy flows within and across the boundary of the assessment, using primary energy factors or weighting factors for the conversion between final energy and primary energy.

Primary energy factor is the term generally used in the EPBD, while weighting factor is the term used in CEN overarching standards to refer to primary energy factors when dealing with primary energy[6]. Both terms have an equivalent meaning and are subject to the same provisions. For the purposes of this guidance, any reference to primary energy factors must be understood as also referring to weighting factors, with no exception.

Energy flows include electric energy drawn from the grid, gas from networks, oil or pellets transported to the building for feeding the building’s technical systems, as well as heat or electricity produced on-site. Each energy carrier must have their respective primary energy conversion factors.

4.3.1. Definition of primary energy factors (PEFs)

PEFs are a key element in the calculation of energy performance as they allow the interaction between the building and the energy grid(s) to be represented and also highlight the impact the building has on the broader system.

The calculation of primary energy must be based on PEFs per energy carrier, with a distinction between non-renewable, renewable and total primary energy. This means that Member States must define for each energy carrier their:

– renewable primary energy factor;

– non-renewable primary energy factor;

– total primary energy factor (the sum of renewable and non-renewable primary energy factor for a given carrier).

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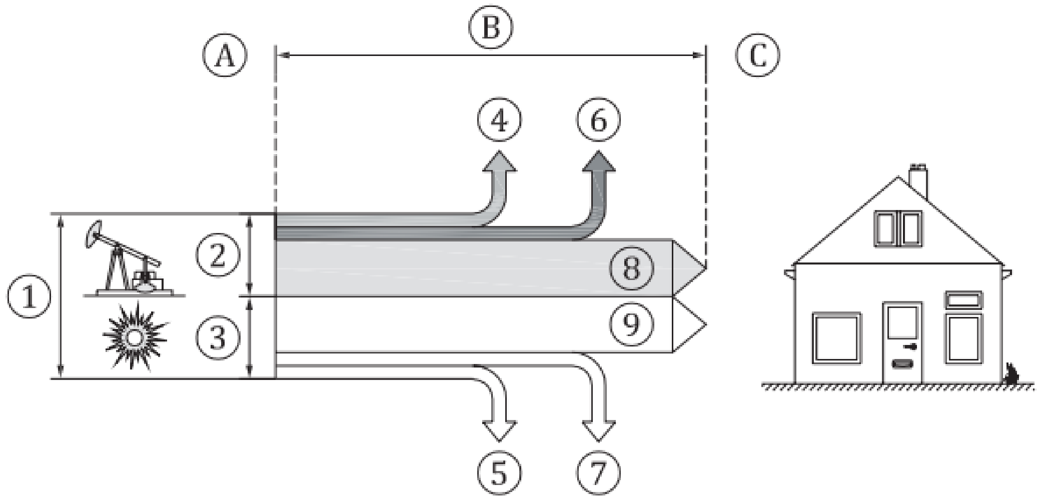
6 In CEN overarching standards, weighting factors may also be used to calculate greenhouse gas emissions, costs or additional factors. When weighting factors are applied to primary energy, they are equivalent to primary energy factors. When they are applied to greenhouse gas emissions, they are equivalent to greenhouse gas emission factors. See ISO 52000-1, Chapter 9.6.1 ‘Weighted overall energy balance’.

Figure 1: Figure taken from ISO 52001-1:2017 (page 39) representing the inefficiencies and losses in energy distribution and how they affect primary energy factors



$$f_{\text{Ptot}} = \frac{①}{⑧ + ⑨} \qquad f_{\text{Pnren}} = \frac{②}{⑧ + ⑨} \qquad f_{\text{Pren}} = \frac{③}{⑧ + ⑨}$$

Key

A	energy source	4	non-renewable infrastructure related energy
B	upstream chain of energy supply	5	renewable infrastructure related energy
C	inside the assessment boundary	6	non-renewable energy to extract, refine, convert and transport
1	total primary energy	7	renewable energy to extract, refine, convert and transport
2	non-renewable primary energy	8	delivered non-renewable energy
3	renewable primary energy	9	delivered renewable energy

Energy carriers can be broadly allocated to three groups:

– **Pure renewable carriers**: these are carriers that are completely based on renewable energy. For example: on-site solar generation or ambient heat. They will have a value for non-renewable PEF equal to 0.

– **Pure non-renewable carriers**: these are carriers that are completely based on fossil fuel energy. For example: coal or oil. They will have a value for renewable PEF equal to 0.

– **Mixed carriers**: these carriers have a mix of renewable energy and fossil fuel energy. For example: electricity from the grid or biomass. They will have a value for renewable and non-renewable PEF both different from 0.

The EPBD requires that the calculation of primary energy is based on PEFs that have to be defined and recognised by the relevant authorities (e.g. national or regional).

When defining PEFs, Member States must take into account the following aspects:

– Forward-looking: when evaluating the performance of a building (new, existing, under construction, etc.), the calculation methodology will reflect the performance of the building at a given moment. However, the building may be operating for a significant amount of time in the future. For example, the performance of electricity grids or district heating systems is continuously improving, particularly as the share of renewable energy sources increases.

– The expected energy mix on the basis of its national energy and climate plans (NECPs). NECPs contain information on the current performance of different energy carriers according to their sources. They also include information about their expected progress in the future in line with the objective of achieving decarbonisation by 2050.

The EPBD provides Member States with flexibility on how to reflect the forward-looking aspect of PEFs or the relationship with NECPs. Member States may decide how to apply these elements, which can differ depending on the use. For example:

– Member States may decide to apply a value for PEF considering their five-year forecast in line with the NECP. This value would be used to calculate energy performance in new buildings and in EPCs. This would allow for short- and medium-term changes to be considered in the value of different PEFs, which is relevant for the choice of systems in use.

– Member States may decide to apply a value for PEF considering their 20- or 25-year forecast in line with the NECP, for example an average of the PEF during this period or a weighted average to consider the higher impact in the initial years. This value would be used to calculate the cost-optimal reports. This would allow for long-term changes to be considered in the value of different PEFs, which is relevant as 'cost-optimal' takes into consideration the overall lifetime of the building.

Since two of the main uses of the calculation methodology are to produce EPCs and apply minimum energy performance requirements, the Commission recommends the use of a forward-looking PEF that includes only a short- to medium-term forecast (e.g. five years). A longer forecast would be difficult to communicate to building users, who would not see the benefits of the improvements in the grid for a long period of time.

It is important to underline that PEFs must remain neutral and reflect all technologies equally. If, for example, the PEF for a given carrier takes into account progress over the next five years (in line with the NECPs), the PEFs for other carriers must follow the same criteria. Otherwise this could result in inequalities and unfair treatment between technologies.

PEFs may be set on an annual, seasonal, monthly, daily or hourly basis or be based on more specific information made available for individual district systems. Given the increasing use of energy storage or demand flexibility, the Commission recommends that PEFs are set on an hourly basis or at least monthly. This is particularly relevant for energy carriers that are more variable, such as electricity or district heating. It would allow integration between the building and the energy grid to be better represented. In a similar way, it would also better reflect the performance of systems with efficiencies that may vary depending both on outdoor conditions and the PEF (e.g. heat pumps). In addition, local conditions can also be taken into account when defining PEFs for the purpose of calculating the energy performance of buildings.

The choices of primary factors must be reported according to EN-17423 or any superseding document. Member States must fill in Annex A of the standard, specifying the choices between methods, reference data and references to other documents.

4.3.2. PEFs for renewable energy produced and used on-site

Renewable energy produced and used on-site is delivered directly to technical building systems. In doing so, it displaces energy from the grid, which would otherwise be used instead. This is typically the case for PV electricity, solar thermal, ambient energy or geothermal energy.

The value of on-site production and use is that it significantly reduces the impact of the building on the energy grid, which is one of the main reasons for total primary energy use. To represent the benefits of on-site use of renewable energy sources (RES), the Commission has evaluated the following approaches:

(a) The PEF for on-site RES is given a value of 0.

(b) The PEF for on-site RES is given a value of 1. In the calculation of total primary energy, the PEF is combined with a factor (e.g. 'k_{exp}f') of value equal to 0:

    (a) k_{exp} = 0, therefore PEF*k_{exp} = 0.

Both approaches have an equivalent end result in terms of total primary energy use.

However, the use of the combination of PEF with a factor (e.g. "k_{exp}")allows for a better representation of the nature of energy generation and use, and in particular the energy flows within the assessment boundary, which is relevant in intermediate steps of the calculation methodology. This approach would be in line with EN ISO 52000-1. Because of these reasons, the Commission recommends the use of option b) (i.e. use of "k_{exp}" factor).

Recital 22 refers to the combustion of renewable fuels (e.g. biomass or biogas), which should be considered as energy produced on-site where the combustion of the renewable fuel takes place on-site. Accordingly, energy from these sources should be considered as energy produced on-site when calculating the share of RES use in a building. However, the energy flow of the combustible material will, in the vast majority of cases, cross the assessment boundary and therefore has an impact on the energy grid and commodities. For the purposes of calculating primary energy use, the combustion of renewable energies should therefore not be given a PEF of 0 nor should it have a factor equal to zero applied (e.g. 'k_{exp}=0').

4.3.3. PEFs for renewable energy generated on-site and exported to the grid

RES energy generated on-site may not be fully absorbed by the building's technical building systems.

The excess energy can be calculated by deducting the self-consumed energy from total on-site renewable energy production. The self-consumed energy can be the energy consumed within the scope of the EPBD as defined in Annex I(1) or can also include the self-consumption of other on-site uses outside the EPBD scope (see Chapter 4.3.4). The excess energy may also be stored on-site[7] for further use or exported to the grid. In some cases, the energy generated on-site may also be directly exported to the grid, without being used on-site at all. The variation in energy needs throughout the operation of the building, in combination with the variation in RES availability and local climate conditions (which vary throughout the day) are one of the reasons why detailed hourly calculation methodologies are more capable of representing actual operating conditions.

To recognise the benefits of exporting energy, the Commission recommends that the calculation methodology deducts the renewable energy produced on-site and exported to the grid (beyond the building's assessment boundary) from total primary energy use.

As with any energy flow, it is necessary to allocate a PEF to the energy carrier. Since RES generally have a base value of 1 (before infrastructure, refining, conversion and transport losses are applied), for exported energy from RES generated on-site, the PEF should not be greater than 1. The Commission recommends that, similar to RES in the grid all infrastructure, refining, conversion and transport losses are also considered. For example, if the total transmission losses for Solar PV in the grid are equal to 10%, the PEF for solar

[7] Energy storage has its own losses, which should be reflected in the calculation. See Chapter 4.5.3.

exported to the grid should also apply these losses. In this case the PEF for exported solar PV energy would have a value of about 0.9.

A similar approach could be used for other types of on-site renewables. While solar PV has generally been the most common energy export from buildings, the decentralisation of heat generation in district heating and the growth of waste heat (e.g. from industrial processes or from buildings with high internal gains) means that the export of heat from a building (across the assessment boundary) is becoming more common. To better represent the possibility of heat export, the Commission recommends that Member States also define PEFs for heat exported to the grid (e.g. to district heating systems) for thermal energy generated on-site (e.g. solar thermal, ambient heat or waste heat).

4.3.4. PEFs for renewable energy generated and used on-site for non-EPBD uses

RES energy generated on-site may not be fully absorbed by the building's technical building systems. In this case, the energy may still be used on-site, although for non-EPBD uses. For example, energy from solar PV could be used to power white goods or other electric appliances on-site. Similarly, it could also be used to charge batteries for electric vehicles.

To represent these benefits, the Commission recommends that Member States consider the energy used on-site for non-EPBD uses as if it were exported. As in the case of exported energy, energy used on-site for non-EPBD uses requires a PEF. In this case, however, there are no grid infrastructure losses. Member States can therefore choose to represent the benefit with a PEF value of 1.

4.4. EPBD and the Ecodesign for Sustainable Products Regulation

The recast EPBD (Annex I, paragraph 2(2)) indicates that where product-specific regulations for energy-related products adopted under the Ecodesign Regulation (now repealed by the Ecodesign for Sustainable Products Regulation[8]) include specific product information requirements for calculating energy performance and life cycle Global Warming Potential national calculation methods do not require additional information.

Member States should therefore not require additional information from products or set specific requirements at product level. The aim is to protect manufacturers from excessive testing, which could represent a significant burden.

This does not prevent Member States from setting requirements at system level (i.e. not at product level).

For example: a toilet space in a building that requires a given ventilation rate, which is set in building regulations. The Member State may set requirements for the specific volume and the performance of the system under these conditions. In this example, the ventilation system would need to provide at least 40 l/s of fresh air with specific system power (as opposed to specific fan power) no greater than 1.25 W/l/s. The specific system power would consider the overall installation (e.g. fan, ductwork, filters, dampers and terminal supply units).

The calculation methodology should therefore allow for the setting of input and output parameters so that the system can be represented.

4.5. Consideration of aspects in energy performance

4.5.1. User behaviour

The influence of user behaviour (behavioural measures) must not be considered in the calculation of energy performance.

[8] Regulation (EU) 2024/1781 replaces Ecodesign Directive 2009/125/EC.

User behaviour may be used as a means to provide additional and tailored information.

As indicated in Chapter 4.1.4, it is recommended that the calculation methodology allows for the modification of user behaviour for modelling and information purposes only. This could be used to provide advice and guidance on how users can adapt their behaviour, such as modifying temperature settings or limiting the opening/closing of windows when it is required. It could also be used to showcase how to adapt buildings in terms of how they operate, such as modifying operating hours.

Recommendations that are linked to data on the behaviour of the building occupant do not replace the required recommendations in EPCs or building renovation passports, which are based on an asset rating approach. They can only be provided in addition to those requirements and must clearly indicate that they apply only to the user.

4.5.2. Water use

The reduction of domestic hot water use due to behavioural measures should not be considered in the calculation methodology.

There are products currently available on the market (e.g. flow restrictors) that can be installed in buildings and offer a permanent reduction in water flow. If these products can be identified by an independent expert and their improved performance can be determined (e.g. through the use of labelling or certification), Member States may allow for reduced volumes in domestic hot water to be considered.

This is particularly relevant for Member States where there are constraints on water availability. Because of this, the presence of these devices could also be indicated in the EPC as it would provide the building user with valuable information.

4.5.3. Energy storage

Energy storage – electric or thermal – is becoming more typical as technology develops. This is for example the case for PV combined with batteries.

Energy storage is not defined in the EPBD. Nevertheless, it should be differentiated from typical applications that also use some form of storage (e.g. domestic hot water tanks). For the purposes of differentiating, Member States could consider multiple aspects, where energy storage is used:

– to store excess energy generated on-site;
– to improve the performance of the system;
– over the course of multiple hours or longer;
– to provide flexibility to the building or the grid.

The calculation methodology should consider at least the following four aspects when assessing how storage systems influence the performance of buildings:

– the efficiency of transferring energy to/from the storage depending on the product (e.g. manufacturer’s information) – Member States may set minimum requirements;
– energy losses during storage;
– the primary energy factor associated to its energy carrier (especially when using energy from the grid);
– the control of the storage and its delivery;

– the capacity of the energy storage in relation to the renewable energy generation or energy need.

The efficiency of energy transfer and storage will depend on the individual product and the energy source (e.g. manufacturer's information). Member States may set specific minimum requirements at this level. For example: the energy losses of a thermal storage may not exceed a certain amount of kWh / day as a function of the storage volume.

The primary energy factor will depend on the energy carrier used.. For example, if the energy storage uses energy from the grid at off-peak times, then it should use the relevant grid-PEF..

Batteries in electric cars should only be considered electric storage for buildings if the battery allows for bi-directional flow and the stored energy can be used within the building

4.6. Reporting to the Commission using EPB standards

The recast EPBD requires Member States to describe their calculation methodology on the basis of Annex A for the following standards:

(a) EN ISO 52000-1: Overarching EPB assessment – Part 1: General framework and procedures.

(b) EN ISO 52003-1: Indicators, requirements, ratings and certificates – Part 1: General aspects and application to the overall energy performance.

(c) EN ISO 52010-1: External climatic conditions – Part 1: Conversion of climatic data for energy calculations.

(d) EN ISO 52016-1: Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads.

(e) EN ISO 52018-1: Indicators for partial EPB requirements related to thermal energy balance and fabric features.

(f) EN ISO 52120-1: Contribution of building automation and controls and building management.

(g) EN 16798-1: Ventilation of buildings – Part 1: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics.

(h) EN 17423: Determination and reporting of Primary Energy Factors (PEF) and CO2 emission coefficient.

Member States must submit the filled in Annexes for all these standards as part of their transposition obligations. The reporting based on the standards from A to E were already part of the obligations in the EPBD Amending Directive in 2018[9]. Member States must resubmit these Annexes as part of the transposition, including updating any of the information if the calculation methodology has been modified since then.

Since 2018, the EPB Center[10] has published information and guidance on how to fill in the Annexes from A to E. At the time of writing this guidance, the information was still available on their website. The Commission recommends that Member States use this resource.

9 Directive (EU) 2018/844 of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency.

10 EPB Center | EPB Standards.

4.7. Changes to the framework for the calculation of energy performance

The recast EPBD requires that the calculation methodology reflects the typical energy use of buildings and that this energy use is representative of actual operating conditions and user behaviour.

The way buildings have operated over the years has significantly changed. Higher comfort standards and climate change now require increased cooling. This can be due to technological or societal changes. For example, buildings nowadays contain more electronic equipment than 50 years ago (which has an effect on internal gains). Buildings are also increasingly used for charging electric vehicles. The typical occupancy of buildings also reflects the changes in family composition. The COVID-19 pandemic brought about a very substantial increase in work from home, which significantly changes occupancy patterns in buildings (both residential and non-residential). Last but not least, buildings are also subject to climate change and increasing temperatures.

To represent these changes, it is to be expected that the calculation methodology and its underlying elements (e.g. building use patterns) also evolve over time.

As indicated in Chapter 4.1.3, the Commission encourages Member States to evaluate their calculation methodology at regular intervals (e.g. every 5 or 10 years), particularly in terms of climate, user behaviour types of systems, new technologies and innovation. Modifying the calculation methodology is a complex process with multiple consequences. While the Commission recommends that Member States evaluate the calculation methodology at regular intervals, it also recommends they only revise or modify the methodology when significant differences are identified. For example, Member States may decide to modify the calculation methodology only when the difference between the typical conditions in the methodology and the typical operating conditions results in differences greater than 15% in multiple cases. This threshold is similar to the one used in the cost-optimal methodology to identify significant differences.

Member States may also decide to apply changes in smaller scales. For example, they may decide to only apply changes to a specific building category.

Primary energy factors are also relevant, particularly as their evolution is monitored by the NECPs.

When modifying the calculation methodology, Member States should carefully consider the effects on the following aspects:

– **Effects on cost-optimal methodology**: if the calculation methodology has been modified since the last cost-optimal report was submitted, the next cost-optimal report should include a section indicating the changes to the methodology and their effects. In particular, it should include an estimate of the value of the previous cost-optimal results according to the new methodology.

– **Effects on minimum energy performance requirements**: changes to these requirements should be communicated like any other transposition measure subsequently modified. Member States may also use regular reporting through the national building renovation plans by including a section on the changes.

– **Effects on zero-emission building (ZEB) and nearly-zero energy building (NZEB) levels**: these changes are particularly important given the fact that ZEB levels are linked to NZEB levels (ZEBs must be at least 10% better than NZEBs). Both NZEBs and ZEBs are linked to cost-optimal reporting. Following an update to the calculation methodology, Member States should communicate to the

Commission the effects on ZEB levels and provide an estimate of the value of NZEBs when applying the new methodology. This reporting should be carried out at the earliest opportunity or through the regular reporting of the national building renovation plans.

– **Effects on EPCs**: EPCs have a validity of 10 years. A change in the calculation methodology will affect the value of all EPCs that were issued before the change and which are still legally valid. The increased use of databases for EPCs could help address this issue by providing an updated and corrected value of the EPC. Alternatively, Member States could also create conversion tools and send an update to building owners. In any case, this type of update would not extend the validity of the EPC.

Changes in the calculation methodology will affect the work of independent experts and many professionals working in the building industry (e.g. designers or facility managers) and product manufacturers (from technical building systems to software developers). The Commission therefore strongly recommends that Member States carefully consider communicating these changes to all relevant professionals, preferably with a tailored approach according to the needs. This can include interservice consultations (during the process itself), guides, training (e.g. online courses), workshops, presentations, interactive tools, FAQs or a combination of all of them.

5. GUIDANCE ON TRANSPARENT BUILDING ELEMENTS

The energy performance of transparent building elements – primarily windows and glazing systems – greatly influences both heating and cooling demands and indoor environmental quality in buildings in Europe. According to the energy studies of the European Council for an Energy Efficient Economy, windows alone account for approximately 23% of heating energy consumption in residential buildings[11] as such transparent building elements are a cause of heat loss. However, the effect on cooling energy needs is difficult to evaluate due to the combined influence of climate, orientation, shading, architectural aspects, ventilation, the use of the building and internal heat gains, among other elements. In summer, excess solar gains from windows may be a deciding factor in the requirement to install active cooling, which would also have a substantial impact on energy consumption. Transparent building elements are the main source of access to daylight in buildings, which plays a key role in adequate indoor environmental quality.

The EPBD requires Member States to take the necessary steps to set minimum energy performance requirements for building elements that have a significant impact on the energy performance of the building. Following on from the paragraph above, transparent building elements should fall under this category and Member States should set requirements accordingly by adopting a cost-optimal methodology for setting minimum energy performance requirements for building elements, including transparent components. In line with the cost-optimal methodology, the requirements should allow for differentiated requirements tailored to local climate zones and building categories. This will ensure that energy efficiency measures are both ambitious and economic over the lifetime of the product.

[11] European Council for an Energy Efficient Economy.

Most Member States have set up requirements on transparent building elements, but there is still room for improvement.

EU Member States currently employ different metrics and indicators primarily based on the U-value (thermal transmittance) and, to a lesser extent, the g-value (solar factor) to assess and regulate the effect of transparent elements on the energy performance of buildings. The U-value measures a window's insulation efficiency by quantifying the rate of heat transfer, whereas the g-value accounts for solar heat gain. While heat gains are particularly relevant in warmer climates as they impact cooling demands, their impact during winter is also quite significant and should not be ignored.

For instance, France has set a U-value requirement of 1.9 W/m²K to limit heat loss. Other examples include Germany and Italy, with U-values around 1.3 W/m²K and 1.1-3 W/m²K, respectively. Countries with more stringent U-values like Hungary and Slovakia (both 1 W/m²K or lower) place a stronger emphasis on reducing thermal losses in colder climates. In contrast, Cyprus requires a U-value of 2.25 W/m²K, which reflects the milder climate.

While U-values are widely adopted across Member States, only a few include the g-value as part of their performance metrics, potentially overlooking the role of solar heat gain in energy consumption for cooling and heating. However, countries like Denmark, Estonia and Germany emphasise an 'energy balance' approach. This accounts for both heat retention and solar gain, acknowledging the dual impact of windows on both heating and cooling needs.

There are also differences in how Member States measure the effects of orientation, shading or architectural features.

Furthermore, Member States also apply differences in the treatment of transparent building elements across building categories or depending on the purpose of calculations. In general, residential buildings use simpler methods with limited data, while larger and more complex buildings require more detailed calculations. Similarly, calculations for the issuance of an EPC in an existing building may be different from the calculations required for a new building.

5.1. Summary of obligations under the EPBD

The following Articles refer to obligations that EU Member States have in relation to the energy performance of the transparent building elements. These obligations mainly deal with windows and doors and their contribution to energy efficiency improvements. They also cover facades with a high proportion of transparent elements (e.g. high-rise buildings).

Article 4

Article 4 of the EPBD mandates that Member States develop and implement a methodology for calculating the energy performance of buildings. This methodology must be aligned with the calculation framework outlined in Annex I.

Article 5

Article 5 requires that minimum energy performance requirements are set for buildings and or building units. Furthermore, it requires Member States to ensure that specific minimum energy performance requirements are set for building elements that have a significant impact on the energy performance of the building envelope when these are replaced or retrofitted. Given the weight of transparent building elements in the overall building performance, virtually all Member States have set specific requirements for windows for new construction, major renovation or replacement.

Under Article 5, these minimum energy performance requirements must be set at cost-optimal levels, balancing the initial investment with long-term energy savings.

Article 7

Article 7 of the EPBD mandates that all new buildings meet energy performance requirements laid down in accordance with Article 5 until the application of the requirements that all new buildings are zero-emission as from 1 January 2028 for new buildings owned by public bodies and as from 1 January 2030 for all new buildings. This requirement extends to transparent building elements – such as windows and doors – which must comply with high insulation and thermal standards, incorporating factors to reduce heat loss and optimise energy efficiency.

Article 8

Article 8 of the EPBD mandates that EU Member States take necessary measures to upgrade the energy performance of existing buildings when they undergo major renovations. This includes ensuring that the energy performance of renovated parts meets minimum performance requirements, as established under Article 5, provided that these upgrades are technically, functionally and economically feasible. This obligation extends to individual building elements such as windows and doors that form part of the building envelope and significantly impact its energy performance. If such elements are retrofitted or replaced, they must also meet minimum energy performance standards, aligned with the Directive's goals.

At the same time, Member States are encouraged to consider high-efficiency alternative systems for buildings undergoing major renovations. These measures aim to improve energy performance while also improving indoor environmental quality, adapting buildings to climate change, and addressing safety and accessibility concerns in alignment with national building regulations.

Article 11

Article 7 of the EPBD stipulates the requirements for zero-emission buildings (ZEB), notably asking for a ZEB maximum energy demand threshold to be setup "with a view to achieving at least the cost-optimal levels" and "at least 10 % lower than the threshold for total primary energy use" in place in the MS for nearly-zero energy buildings. Member States must also set operational greenhouse gas emission thresholds for ZEBs.

Annex I

Annex I(4(a)), requires that Member States' methodologies for calculating the energy performance of buildings take into account multiple factors that are related to transparent building elements:

– thermal capacity;
– insulation;
– thermal bridges;

– natural ventilation;

– orientation and climate;

– passive solar systems and solar protection.

Member States are also required to take into consideration the positive influence of local exposure conditions, active solar systems and natural lighting.

Through this approach, Annex I encourages a more holistic approach that integrates both thermal and solar performance. At the same time, the calculation framework provides flexibility to adapt to their various needs and conditions, including climate, building categories and the purpose of the calculations.

Energy calculations can be complex given the multiple data inputs and the need to consider the performance of the building at overall levels and at specific moments/periods. However, the advent of computer-aided tools in the latter part of the 20th century, the widespread use of 3D models, including Building Information Modelling, has made the task of all professionals in the field much easier. It is now easier than ever to gather the necessary input data and apply it to any number of available calculation engines. These will in turn produce valuable information for evaluating the performance of the building. This information is of high value when making decisions about the design of new or renovated buildings or the replacement of existing building elements.

5.2. Implementation of obligations under the EPBD

The obligations to apply a methodology for calculating the energy performance of buildings has been in place since the EPBD was first adopted in 2002 and was modified in 2010 and 2018. Member States must implement the laws, regulations and administrative provisions necessary to comply with the new or modified elements of the recast EPBD by the transposition deadline of 29 May 2026.

Transparent building elements such as windows, glazed exterior walls, skylights and rooflights play a dual role in building energy performance, influencing both heat losses and gains. Their energy performance is quantified primarily based on heat transfer due to temperature difference (conduction and convection) and through radiation (e.g. solar gains). The most commonly used indicators to express heat transfer are the U-value (thermal transmittance) and g-value (solar gains).

However, using these parameters in isolation does not provide a complete picture, as factors such as geographical location or architectural design among other aspects[12] also play a key role. Annex I of the EPBD highlights the importance of an energy balance approach, combining all elements to calculate the overall energy performance of the building. This approach is critical for optimising building envelopes throughout the whole year.

As this guidance focuses on transparent building elements, thermal transmittance can be assessed at different levels. The Ug-value refers specifically to the glazing’s insulation performance, while the U-value accounts for the entire window unit, including the frame and spacer effects.

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12 Other aspects include solar shading, orientation, etc.

5.3. Background

5.3.1. Energy balance

The energy performance of transparent building elements depends on a combination of heat conduction (U-value multiplied by temperature difference) and heat radiance (g-value multiplied by solar irradiance (B)), which must be assessed across different seasons. Both heat conduction and heat radiance depend on the physical characteristics of the transparent building element. However, there are also other elements that may affect them, such as the presence of shading, the design of the building, orientation and local climate. Transparent elements' orientation plays a key role in the solar irradiance (B) rather than simply taking into account the location of the building. When oriented south, the B-value will be three to four times higher than for those oriented towards the north. This will in turn be affected by the presence of shading elements, which help control solar irradiance.

The design of the transparent building element must take into account these different elements. This is usually done through an energy balance approach.

Other elements, such as ventilation and infiltration losses, as well as internal gains, play significant roles in the overall energy balance of buildings. Ventilation heat transfer (H) accounts for air exchanges through windows or mechanical ventilation systems and should be explicitly included in energy assessments. Internal heat gains from occupants, lighting and appliances also contribute to the energy balance, reducing heating demand in winter, but increasing cooling loads in summer.

The energy balance method provides a holistic assessment of a transparent element's energy contribution. For instance, windows with low U-values may perform well in colder climates. However, if g-values, shading or the overall architectural design are not optimised, they may cause excessive cooling demands in warmer days. Similarly, the optimisation of the window and building design also allows for the use of solar gains in winter, offsetting the need for active heating. For modern buildings, which have high levels of insulation, solar gains may even need to be controlled in winter. Although solar radiance in northern climates is not as intense as in southern regions, the very low angle of incidence enables a high proportion of solar gains to reach the interior of the building, which has a significant effect. It is therefore recommended to consider the overall window and building design even in colder climatic conditions.

As a result, transparent elements must perform to a level where they adapt to the seasonal and external conditions: a low U-value and high g-value in winter to optimise insulation and maximise free solar gain, and a low U-value and low g-value in summer to optimise insulation and limit solar gain for thermal comfort. This reduces the need for active cooling.

5.3.2. U-value, g-value and key concepts

The U-value (W/m^2K) represents the thermal transmittance of a transparent element, indicating its ability to conduct heat to/from the building (i.e. retain or release heat). Given the weight of the building envelope in energy performance, the improvement in windows in particular has become an overriding factor in many situations. This is particularly the case in colder climates, where low U-values are a key to minimising heat losses.

Conversely, the g-value quantifies the amount of solar radiation that passes through the window, contributing to heat gains. The management of g-values allows us to influence heat gains through transparent elements during the heating season and minimise solar gains in hotter regions.

Other key concepts:

– **Heating degree** (A): a numerical value that reflects the accumulated need for heating, typically expressed in kKd (Kilo Kelvin days), due to the difference between the indoor and outdoor temperature across the heating season. This value is heavily dependent on the local climatic conditions of the building analysed and the building itself. It is commonly calculated using heating degree days, degree hours or with the aid of thermal models.

– **Cooling degree** (X): a value that quantifies the accumulated need for cooling to maintain indoor thermal comfort over a given period. It is commonly calculated using degree days, degree hours or with the aid of thermal models.

– **Solar irradiance** (B): solar energy that enters a building through transparent elements. Solar irradiance may also consider the influence of orientation or shading.

– **Solar irradiance leading to overheating** (Y): refers to the portion of solar energy that enters a building through transparent elements and contributes to indoor temperatures that exceed comfortable thresholds. It depends on different aspects: climatic condition, orientation, insulation level of the building envelope, etc.

– **Transmittance cause by air infiltration** (H): heat transfer that occurs due to uncontrolled air leakage through gaps, joints or seals in a building's transparent elements.

5.3.3. Heating vs cooling seasons

In the heating season, U-values play a major role in mitigating heat losses, while g-values (or shading) control solar gains. During the cooling season, g-values (or shading) dominate as they significantly affect the internal heat load, especially in south-facing orientations. Energy balance calculations must therefore distinguish between these seasonal dynamics to tailor requirements effectively.

Quantitatively, the heating energy demand is therefore expressed as:

$$A \cdot (U + H) - B \cdot g = Heating\ energy\ needs$$

whereas the cooling energy demand is expressed as follows:

$$-X \cdot (U + H) + Y \cdot g = Cooling\ energy\ needs$$

It is important to highlight that air infiltration (H) must also be considered, as shown in the previous equations, and depends on the transparent elements' air permeability class and local wind levels.

5.3.4. Calculation intervals

Heating degrees or cooling degrees were, until very recently, calculated mostly on the basis of monthly or daily climate data. In some cases, annual data is still used. This allowed for a calculation of the influence of the heat losses and heat gains that was sufficiently representative, where heat losses were the main driver.

Modern calculation tools allow for much more detailed calculations, with calculation intervals that go to the level of hourly or even sub-hourly. Detailed calculations are particularly useful for transparent building elements given their importance for peak conditions. This is even more so the case in modern buildings, where the heat gains and heat losses are much closer to one another.

Given the improvement of the building envelope, proper consideration of the balance between heat gains and heat losses has become particularly important throughout all operational hours.

It is recommended that the calculation interval is also considered when setting the minimum energy performance requirements or when calculating the energy performance of buildings and building elements.

The Commission recommends at least an hourly calculation interval for both the setting of minimum energy performance requirements and the calculation of the energy performance of buildings.

Means of controlling solar gains

In addition to the U-value and g-value, there are other elements to also consider when taking into account both heat loss and solar gains: orientation, building design and solar shading.

ISO 52022-1 (solar & daylight characteristics – simple) and ISO 52022-3 (solar & daylight characteristics – detailed) provide multiple options for the calculation and consideration of the different elements.

The example below, based on the Spanish building code, provides a summary table with the different elements, including examples of values provided for simplified calculations.

Table 3: Elements that account for solar contributions

Element identified	Description	Quantified?	Value?	Where?
Different types of glazing	- Simple - Double …	Yes	g_{wi}[13] for: Single glazing: 0.77 Double glazing: 0.68 Double glazing with low emissivity: 0.60 Triple glazing with low emissivity: 0.45 Double window: 0.68 Figure 2 illustrates other g-values depending on the glass type	Table 11
Blinds (exterior mobile shade)	Solar transmission with movable shading devices (both automated or manual), affects solar energy transmission in openings. It depends on the type of glass and its g-value.	Yes	Summary of the values (see details in Tables 12 and 14): - 0 (for blinds) - 0.2 (for awnings) - 0.4 (for curtains)	Tables 12 and 14 (mobile blinds)

[13] g_{wi} is the total solar energy transmittance value of the glazing (without an active shading device).

Curtains (interior mobile shade)	Used as internal shading, affects the total solar transmission through openings.	Yes	Summary of the values (see details in Table 12): - 0.4	Table 12
Trees/vegetation	Shadow factor can be adjusted based on vegetation density and type (perennial or deciduous).	No (the shadow factor corresponding to vegetation may be included at the discretion of the designer)	-	Sec. 2.2.4
Sunshades (e.g. awnings, shades with slats)	Various shading elements that adjust the solar factor and reduce solar transmission.	Yes	Summary of the values (see details in Tables 12 and 18): - 0.2	Tables 12 and 18
Overhangs	Fixed external shading devices with shadow factors based on orientation and size.	Yes	Details in Table 16	Table 16
Skylights		Yes	Details in Table 19	Table 19
Architectural setbacks	Setbacks can influence the amount of direct sunlight that enters a building.	Yes	Details in Table 17	Table 17
Orientation of openings	U-value limits set by orientation (north, south, east, west) and climate zone, affecting solar gains.	Yes	-	Depends on the location
Frame material	Frame types (wood, aluminium, aluminium with thermal break) and air permeability considerations.	Yes	-	Depends on the supplier

Night ventilation		No	-	-
Use of daylight	The energy use for artificial lighting should be considered.	No	-	-

Figure 2: Range of g-values with associated glass types (source: Glass for Europe)

g-value range	Type of glass
0.05-0	Occultation (theoretical)
0.20-0.05	Dynamic solar control in colored state
0.20-0.35	Solar control for commercial sector (WWR* > 30%)
0.35-0.50	Solar control for residential sector (Warm Climate and/or WWR < 30%)
0.50-0.60	Low emissivity
0.60-0.80	Low-emissivity extra clear
0.80-1	Full transmittance

**WWR= Window-to-wall ratio. The size of the glazed surface will affect the calculation of the energy performance and the type of glazing to be installed.*

5.4. Impact of solar contributions on various building types

Solar contributions, including the g-value and the various values in Table 1, play a major role in determining the energy performance of transparent building elements. The impact of these contributions varies depending on the building type, usage patterns and climatic conditions. For instance, residential buildings often prioritise maximising daylight while mitigating overheating risks, whereas non-residential buildings might focus on managing solar gains for comfort and reducing cooling loads in large glazed areas. Differentiating these effects is critical in order to optimise transparent elements for new constructions, deep renovations and replacements.

Nevertheless, it is recommended to adopt an overall approach that prioritises optimising the building performance as a whole, and the building envelope in particular. This includes integrating shading elements, overhangs and other architectural features to manage solar heat gains and improve the overall energy efficiency of the building. By prioritising a comprehensive strategy for the entire envelope, including insulation and airtightness, the energy performance of the building can be significantly improved. While the optimisation of glazing remains important, it should be viewed as part of a broader design strategy rather than a standalone priority.

Furthermore, in Member States where mechanical air cooling is necessary, effective passive heat protection should be prioritised to minimise the energy required for cooling as far as possible.

Furthermore, the Commission recommends that Member States base the methodology for planning summer thermal insulation on climate projections that account for expected conditions in the short to medium term (e.g. over the next 20 years). This approach ensures that the design considers at least half of the service life of building components and aligns with anticipated climate trends. Reliable and comprehensive future climate data across Europe should be used to make building designs more resilient.

5.4.1. Non-residential buildings: new or existing undergoing major renovation

Non-residential buildings, such as offices or commercial spaces, typically feature larger glazed areas, which increases the relevance of solar contributions. These buildings often have higher internal heat loads due to equipment (e.g. computers, printers, different lighting systems, machinery, etc.) and occupants, making it critical to balance all requirements effectively.

According to the provisions in the recast EPBD (Article 9(2)), new buildings from 2020 and buildings undergoing major renovations must comply with zero-emission building requirements, which will be at least 10% stricter than current nearly-zero energy building levels. While this approach ensures that these buildings are energy efficient, it also means that the balance between heat losses and heat gains will become more relevant. If not adequately managed, this may result in overheating, which would then require a cooling system to compensate. This would in turn increase the energy consumption of the building. Given the improved thermal insulation and airtightness, the energy demand for cooling could rise, particularly in buildings with large glazed areas. It is therefore essential to integrate effective strategies for controlling solar heat gains, such as the use of architectural design, solar shading and/or low-g-value glazing to maintain a comfortable and energy-efficient indoor environment.

For different building categories, Member States should ensure that a comprehensive calculation methodology, as outlined in this guidance document and in compliance with Article 4 of the EPBD, is rigorously applied. This methodology must account for all factors affecting solar contributions, as detailed in Table 1. The energy balance should reflect these contributions, considering variables such as glazing properties, orientation, shading and climate conditions to ensure accurate energy performance assessments. Member States should determine a requirement level according to specific local conditions and features. The same calculation methodology should be used when producing an EPC assessment. This will ensure an accurate evaluation of a building's energy performance, taking into account both solar gains and heat losses.

Member States are encouraged to set minimum requirements in terms of the U-value or g-value. However, given the need to balance different elements, the Commission recommends that Member States allow for exceptions to the minimum requirements (for individual building elements) if designers and developers can use an energy balance approach to demonstrate that the building would have a better energy performance. For example, if there are minimum requirements on the g-value, but the developer demonstrates that through the use of architectural design or fixed shading the g-value is no longer needed, then the Member State could allow for the installation of elements that do not comply with the g-value requirements.

In order to allow for this flexibility, it is important that the calculation methodologies in Member States are precise enough and account for as many elements as possible that influence the performance of transparent building elements.

5.4.2. Residential buildings: new or existing undergoing major renovation

New and renovated residential buildings share several requirements on the integration of transparent building elements that optimise energy performance with their non-residential counterparts. However, there are key distinctions in the design, occupancy patterns and energy usage of residential buildings that call for tailored considerations for both new constructions and renovations. The following section presents different considerations for residential buildings:

- These buildings typically feature smaller glazed areas compared to non-residential buildings. This reduces overall solar contributions but makes it more important to carefully optimise each transparent element to balance heat retention and solar gain.
- They prioritise natural daylight and indoor comfort. Transparent components must be selected to maximise visible light transmittance while minimising glare and energy losses.
- They often experience lower internal heat loads than non-residential buildings, making the management of heating and cooling needs heavily reliant on external factors like solar irradiance, natural shading (trees, neighbourhood buildings, etc.) and insulation quality.

The methodology used for assessing the energy performance of transparent elements in non-residential buildings can also be effectively applied to residential buildings. This ensures consistency across building types, while keeping in mind the differences in certain aspects such as heat loads.

As in the case of new and renovated non-residential buildings, the same best practices can be drawn upon for new and renovated residential buildings.

5.4.3. Existing residential or small non-residential buildings

The recast EPBD requires that Member States ensure that minimum performance requirements are in place for building elements when they are replaced or retrofitted.

As indicated in this document, upgrading transparent building elements plays a crucial role in reducing energy needs. Retrofitting measures should address factors such as replacing outdated glazing with high-performance alternatives that optimise the performance of the element (e.g. U-values and g-values), incorporating external shading devices and improving the building's overall airtightness to mitigate heat losses.

For new buildings and major renovations, a design team is generally in charge of the process due to the inherent complexity of such projects. Because the building is addressed as a whole, the design team has the tools and capacity to ensure that the windows are integrated with the rest of the elements. However, this is not always the case when the renovation works affect only the transparent building elements. This is typically the case when replacing windows. This does not cover isolated glass replacements due to breakage or damage but rather the systematic upgrade of windows as part of an energy performance improvement strategy.

Given the constraints of existing buildings and the capacity constraints that small businesses experience, there is a need to support the replacement of transparent window elements.

To facilitate this process, the Commission recommends that Member States provide support mechanisms, particularly for small businesses, to ensure effective decision-making and compliance with energy performance requirements.

The preferred option would be for installers to make calculations to determine the most fitting window replacement for the existing conditions. Member States should consider developing practical tools to allow installers to assess the impact of replacing windows on a building's energy balance using predefined factors.

If detailed calculations cannot be made, the Commission recommends that Member States prepare detailed guidance. This should include the following:

- required and recommended U-value and g-value for different orientations;

– guidance on how to account for the presence of solar shading elements (e.g. for windows with solar shading, the g-value requirement is waived).

When preparing the requirements and recommendations, Member States should rely on a methodology based on the energy balance. The cost-optimal report, which Member States must carry out every five years, is a good framework to include this assessment at national level.

Retrofit strategies, such as installing external shading, should also be prioritised to reduce cooling demands while maintaining comfort and energy efficiency.

5.4.4. Summary of recommendations

The following is a summary of the recommended requirements for different types of buildings and works.

Table 4: Summary of recommendations for the treatment of transparent building elements

Type of works	Type of building	Energy Balance calculation	U-value requirements	G-value requirements
New	Single residential	Yes	Yes	Based on EB results
	Multi-residential	Yes	Yes	Based on EB results
	Small non-residential	Yes	Yes	Based on EB results
	Non-residential (rest of buildings)	Yes	Yes	Based on EB results
Major renovation	Single residential	Yes	Yes	Based on EB results or Member State simplified guidance
	Multi-residential	Yes	Yes	Based on EB results
	Small non-residential	Yes	Yes	Based on EB results or Member State simplified guidance
	Non-residential (rest of buildings)	Yes	Yes	Based on EB results
Replacement	Single residential	Optional	Yes	Based on EB results or Member State simplified guidance
	Multi-residential	Yes	Yes	Based on EB results
	Small non-residential	Optional	Yes	Based on EB results or Member State simplified guidance
	Non-residential (rest of buildings)	Yes	Yes	Based on EB results

Uw-value requirements: Member States should introduce specific requirements based on U-values to limit heat losses through transparent building elements.

gw-value requirements: Member States should consider introducing simplified g-value requirements for residential buildings and small non-residential buildings. They should account for different uses and, in particular, orientation and climate in their requirements. Glazing with g-values ranging from 0.25 to 0.8 are already available in Europe, including low-emissivity glazing (designed to minimise heat transfer while allowing solar gain) and solar control glazing (which limits excessive solar heat gain to prevent overheating). If the building has adequate fixed solar shading, the requirements could be waived. For new buildings or larger non-residential buildings, it is recommended that the g-value is selected on the basis of the energy balance.

Energy balance: Member States should introduce both simplified and detailed methodologies for calculating the energy balance. Simplified and detailed calculations could be used by designers in new buildings or renovations. For simple replacement, where in many cases the selection is done directly by installers, it is recommended that Member States provide guidance for the application of a simplified energy balance.

5.5. Best practices from different Member States:

Denmark:

Denmark's approach to energy efficiency for transparent building elements is governed by its national building regulations, known as BR18. These regulations enforce stringent energy balance requirements for windows and other glazing elements, applicable to both new constructions, deep renovations and single window replacements.

Windows must achieve 'energy-neutral' status, meaning they must allow as much solar gain during the heating season as they lose through thermal transmittance. This is calculated using the following formula[14]:

$$E_{ref} = I \cdot g_w - G \cdot U_w = 196.4 \cdot g_w - 90.36 \cdot U_w$$

Where I is the solar incidence corrected for the g-value's dependence on the angle of incidence; g_w is the total solar transmittance for the window; G is the heating degree based on an indoor temperature of 20°C and U_w is the heat transmission coefficient of the window.

BR18 addresses the overall energy consumption and climate impact of buildings in Chapter 11. Specific requirements for the energy performance of windows are outlined in §258, with detailed explanations and implementation guidance provided in Section 1.6. These regulations ensure that transparent building elements contribute effectively to reducing energy demand while supporting Denmark's sustainability goals.

Germany:

The technical standard DIN/TS 18599-2 is used in Germany for calculating the energy performance of buildings as part of the DIN/TS 18599[15] series. The series provides detailed methodologies for assessing the efficiency of energy systems and building components, including heating, cooling, ventilation, lighting and building envelopes.

DIN/TS 18599-2 focuses on building envelopes, including transparent components like windows and glazing, and provides calculation methodologies for their energy performance by introducing a new characteristic, BK_{tr}. This parameter represents the energy balance of transparent components and integrates factors like the U-value, g-value and S_f known as the radiation gain coefficient dependent on the orientation. It ensures an accurate energy assessment of transparent elements within the overall building envelope.

The DIN/TS 18599 series is used to ensure compliance with the German Building Energy Act[16].

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[14] Based on the calculation of a European standard size window (1.23 x 1.48 m, – cf. EN 14351-1).

[15] DIN V 18599: DENA guidelines on achieving energy efficiency | BUILD UP.

[16] BMWSB – Building Energy Act.