The EPBD recast, technical framework: part 1, definitions and ZEB

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Introduction

The Energy Buildings Performance Directive last recast has been approved by the UE Parliament in March 12th and confirmed by the Council in April 12th with the aim to decarbonize the whole EU buildings stock for achieving the EU carbon neutrality in 2050. To reach such goal the Zero Emission Building definition has been introduced, aiming to reduce the non-renewable energy use while promoting renewable energy use, being the fossil fuels the most responsible for the CO_2 production and release to the atmosphere. Thresholds must be set by Member state using an update cost-optimal procedure, which should be released by June 2025. These thresholds must be at least 10% less the "total primary energy" use established at the National Member State level for Nearly-Zero Energy Buildings on the date of EPBD recast publication. Thus, it is clear that the minimum energy performance requirements for ZEBS are set as maximum permitted total primary energy use. Art.11, Zero Emission Building, introduces additional constraints to the ZEB other than this minimum energy performance as mandatory requirements on: null on-site carbon emission from fossil fuel, climate and load adaptive building, total primary energy use covered only by renewable energy sources and/or high efficiency district heating and cooling systems and/or free carbon energy sources, and, finally, the operational greenhouse gas emission complies with a maximum threshold set at the Member State level. Furthermore, new buildings shall be designed to optimise their solar energy generation potential according to National Member State specifications. The new ZEB definition and its requirements regard new buildings from 2028 if public and from 2030 for all new building.

For the existing buildings the EPBD requires all MS's to establish a national trajectory for the progressive renovation of the residential and non-residential building stock in line with the national roadmap and the 2030, 2040 and 2050 targets contained in the Member State's building renovation plan. Thus, Member States shall set minimum energy performance requirements for existing buildings with a view to at least achieving cost-optimal levels and, where relevant, more stringent reference values such as nearly zero-energy building requirements and zero-emission buildings requirements. These performances are differently evaluated if the building is residential or non-residential: for the former, yearly primary

energy use by useful area is the performance indicator, for the latter it is defined on national basis and can be both annual primary or final energy use by useful area. These performance indicators will be then compared with thresholds (maximum permitted energy use) to verify the compliance by individual buildings and to compare the actual renovation rate with the defined roadmap. This check is foreseen to be performed through the energy performance certificates. MS's may also define additional indicators of non-renewable and renewable primary energy use, and of operational greenhouse gas emissions produced in $kgCO_{2eq}/(m^2 \cdot y)$. Exemptions are possible if the compliance of existing buildings with the defined thresholds is not technical feasible or economically not viable.

This huge effort to the path of decarbonization requires a clear technical framework to be effectively put into operation. Thus, in the following, a analysis of the Directive major points is carried out with the aim to identify unclear points and eventually propose some corrections aiming to provide a consistent and reliable technical framework for building energy and environmental performance assessment.

EPBD definitions' analysis

The starting point of any consistency analysis is to verify if the basic definitions are enough clear or can be cause of different interpretations.

One potential of misleading interpretation regards what is considered renewable energy source in EPBD, which is very important to clarify for correctly calculating the TOTAL primary energy use, which comprises both non-renewable and renewable energy use.

In Article 2 – Definitions, point 13., it is reported:

> ***'energy from renewable sources'*** *means energy from renewable non-fossil sources, namely wind, solar (solar thermal and solar photovoltaic), and geothermal energy,* ***ambient energy****, tide, wave and other ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas, and biogas.*

This definition is taken from the DIRECTIVE (EU) 2018/2001 on the promotion of the use of energy from renewable sources (recast), where it is also reported the definition of **ambient energy** as:

> *(2) '****ambient energy****' means naturally occurring thermal energy and energy accumulated in the environment with constrained boundaries, which can be stored in the ambient air, excluding in exhaust air, or in surface or sewage water.*

This definition has been sometimes misunderstood interpreting as the ambient, which is referring to, is only the indoor (constrained by boundaries) environment. Instead, analysing the sentence, it is clear that it refers to two distinct energy sources, a) and b:

> *a) '****ambient energy****' means naturally occurring thermal energy, which can be stored in the ambient air, or in surface or sewage water; (i.e. former aerothermal and hydrothermal);*
>
> *b) '****ambient energy****' means energy accumulated in the environment with constrained boundaries, which can be stored in the ambient air, excluding in exhaust air.*

The interpretation key is "energy and energy", In fact, if the intention would be to constraint the definition to a close environment (not outdoor air), the definition should be:

> *'****ambient energy****' means naturally occurring thermal energy accumulated in the environment with constrained boundaries, which can be stored in the ambient air, excluding in exhaust air.*

The second source was probably added in the RED to credit the internal environment as a renewable source of energy for "renewable cooling" as reported in the COMMISSION DELEGATED REGULATION (EU) 2022/759 of 14 December 2021, which is technically and scientifically totally wrong.

A second potential misleading related to such definition is the example reported between round brackets just after the solar energy source: solar thermal and solar photovoltaic. Solar energy source is only one, the solar radiation on the earth surface (EN ISO/IEC 13273-2:2016, 3.3.4.1 definition: *renewable energy harnessed by exploiting radiation of the sun*), while solar thermal and solar PV are just two different ways of exploiting such source producing two different energy carriers: hot fluid and electric current, referred there as solar thermal and solar photovoltaic (energy from and not energy of). Thus, the primary energy of such carriers, according to the EPBD Primary Energy definition (*energy from renewable and non-renewable sources which has not undergone any conversion or transformation process*), is the collected site solar irradiance

times the collection surface area, and not the produced carriers themselves (see **Figure 1**).

Clarified that for EPBD also outdoor air thermal energy is a renewable energy sources as ambient energy, as well as surface or sewage water, and solar energy too, that will have a significant impact on the TOTAL primary energy indicator calculation, as we will see later.

Another unclear point is the position of the '**assessment boundary**'. Its EPBD definition is:

47. ***'assessment boundary'*** *means the boundary where the delivered and exported energy are measured or calculated;*

but the EPBD delivered energy definition (as well as exported) is:

56. ***'delivered energy'*** *means energy, expressed per energy carrier, supplied to the technical building systems through the assessment boundary, to satisfy the uses taken into account or to produce the exported energy.*

Thus, there is a circular definition that does not define in a clear and unique way where the assessment boundary is placed, causing confusion and different ways of calculating the performance indicators.

Fortunately, in definition 56 it is clearly stated that *delivered energy* means energy **supplied to the technical building systems per energy carriers**. A building technical system, which locally exploits a renewable energy source converting the source energy into an energy carrier, as converter[1], does not have in input a delivered energy carrier (or just a bit for some auxiliaries as pumping energy in solar thermal collectors' fields) but produce an energy carrier directly from the energy of the source (its input). That means that the assessment boundary must keep inside it all technical device locally exploiting the renewable energy sources, because the only present energy carrier is the output of a technical building system component to another technical building system component (storage, distribution, etc.); thus, it is not a delivered energy carrier to the technical building systems, as required by the definition. The same conclusion can be adopted if the technical building system locally exploiting a renewable energy source, as ambient heat, is a transformer[2] like a heat pump: its input is the source energy while

1 Energy converter is an equipment that converts one form of energy in another form of energy with some energy losses due to the irreversibility in the conversion process.

2 Energy transformer is an equipment that transforms the quality of the same form of energy from one level (energy in) to another level (energy out) requiring some work or thermal energy expenditure to operate.

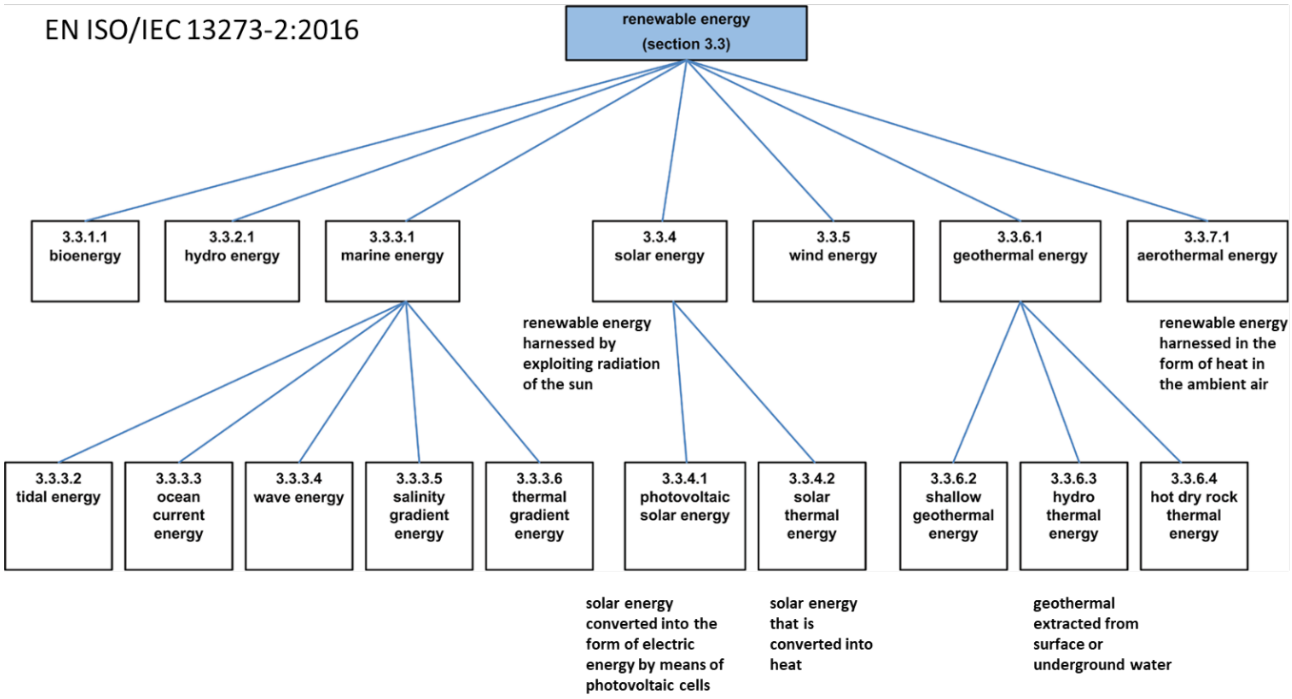

Figure 1. EN ISO/IEC 13273-2:2016 Energy efficiency and renewable energy sources — Common international terminology - Part 2: Renewable energy sources, definitions.

its output is an energy carrier directly to the indoor ambient or to anther system component.

Thus, the assessment boundary is the boundary through which energy carriers are going through regardless of the direction (inward = delivered, outward = exported) and their nature (produced by non-renewable or renewable energy sources, **but only nearby or distant**) to satisfy the EPBD energy use. Building technical system/components locally exploiting on-site renewable energy sources are placed inside the assessment boundary and their effects are accounted in the reduction of delivered energy carriers and, eventually, in the presence of exported energy carriers (see **Figure 2**).

Finally, the energy use is defined as (def. 52) "*energy input to a technical building system providing a EPB-service intended to satisfy an energy need*;". Thus, combining the assessment boundary definition with the energy use definition, the latter shall be calculated or metered as the difference between delivered and exported energy carriers crossing the assessment boundary:

$$E_u = \sum E_{del;j} - \sum E_{exp;j}$$

If a final energy indicator will be chosen, then this will be:

$$E_F = E_u / A_{useful}$$

If a primary energy indicator has to be used, first the primary energy use must be calculated using the primary energy factors for any involved energy carrier as:

$$E_P = \sum F_{P,del;j} E_{del;j} - \sum F_{P,exp;j} E_{exp;j}$$

Then, the indicator as:

$$EP_P = E_P / A_{useful}$$

The unclear point is what kind of primary energy shall be used: total, non-renewable or renewable?

While for new buildings it is clear that total primary energy must be used (), for the existing buildings there is no direct indication on what kind of primary energy must be used. Only reading clause 3 of article 9, "*In addition to primary energy use referred to in paragraphs 1 and 2, Member States may define additional indicators of non-renewable and renewable primary energy use*,…", it is possible to understand that if primary energy use

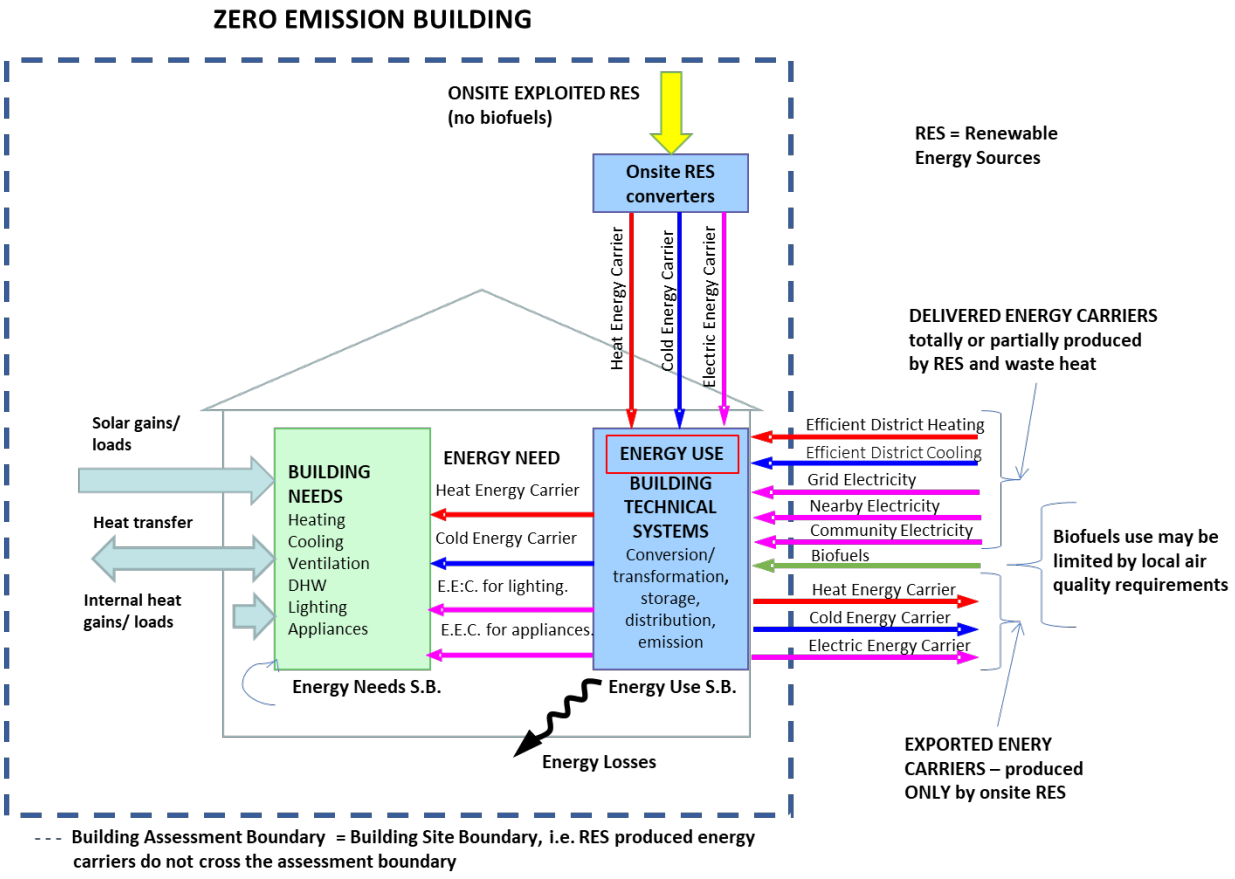

Figure 2. Building assessment boundary consistent with the EPBD recast definitions.

is referred in the Directive, that means total primary energy.

Another unclear point is what are the EPBD services that contribute to form the energy use and then the TOTAL primary energy use and related indicators, which are not anymore explicitly defined because "other uses" have been added by the Council in definition point (50), even if they are not depending on the building fabric and services systems but just on the users' habits (as personal lighting, white and brown goods electricity use, etc.).

Finally, there are some other unclarified terms like "weighting factor" that can be used instead of "primary energy factor" in Annex I (the resulting energy performance will be in that case not anymore in terms of primary energy), as well as contradictory implicit definitions as the "renewable energy share", which is required in Annex I and Annex V, where in the last is defined as "*renewable energy produced on site in % of energy use*", that is a local energy ratio and not a primary energy ratio considering any kind of renewable energy (exploited on side, nearby or distant).

Zero Emission Building Feasibility

Zero Emission Building is defined in EPBD article 2, clause 2, as

> *"a building with a very high energy performance, as determined in accordance with Annex I, requiring zero or a very low amount of energy, producing zero on-site carbon emissions from fossil fuels and producing zero or a very low amount of operational greenhouse gas emissions, in accordance with the requirements set out in Article 11;"*

Complemented by the requirement set up by article 7, cause 2:

> *".. the life-cycle Global Warming Potential (GWP) is calculated in accordance with Annex III and disclosed through the energy performance certificate of the building .."*

and 11:

1. cannot cause any on-site carbon emissions from fossil fuels.
2. energy threshold at least 10% lower than the total primary energy of NZEB.
3. operational greenhouse gas emissions shall comply with a maximum threshold established at the Member State level.
4. the total annual primary energy use has to be covered on annual bases, **where technically and economically feasible**, by:
   - energy from renewable sources generated onsite or nearby.
   - energy from renewable sources provided from a renewable energy community.
   - energy from efficient district heating and cooling.
   - energy from carbon free sources.
5. shall offer the capacity to react to external signals and adapt its energy use, generation or storage, where economically and technically feasible (adaptive building).

Turning around such requirements, we can say that a ZEB building can only use as heating system:

- a boiler, burning only biofuels or hydrogen (no on-site carbon emissions from fossil fuels).
- a substation of an efficient district heating system[3], if any available, according to EED recast (13/09/2023).
- a heat pump driven by electricity produced on-site, nearby or from renewable energy communities, or by grid electricity if fully produced from carbon free sources (i.e. renewable energy sources or nuclear power plant).
- direct electrical heating under the same conditions of electrical driven heat pumps.
- a heat pump driven by thermal energy produced on-site, nearby or from renewable energy communities, or by efficient district heating systems.

In the same way, it can only use as cooling systems:

- a chiller or an air cooler driven by electricity produced on-site, nearby or from renewable energy communities, or by grid electricity if fully produced from carbon free sources (i.e.

3 efficient district heating and cooling system is a system using at least 50 % renewable energy, 50 % waste heat, 75 % cogenerated heat or 50 % of a combination of such energy and heat until 31 December 2017 and increasing time by time such fraction till using in 2050 only renewable energy, only waste heat, or only a combination of renewable energy and waste heat.

renewable energy sources or nuclear power plant).
- an absorption/adsorption chiller driven by heat produced by solar collectors on site or nearby or from a renewable energy community.
- natural free cooling.
- mechanical free cooling or evaporative cooling with the same limitation of the electric chiller.
- a substation of an efficient district cooling system.

In all cases for lighting and internal transportation and for any auxiliary of the heating and cooling systems, the used electricity shall be produced only by carbon free sources.

Are we ready to supply carbon free electricity to all new buildings from 2028? Or biofuels and hydrogen, or efficient district heating and cooling systems in all Europe?

Personally, I do not believe that we are ready. That means that the clause of "*where technically and economically feasible*" will be extensively used and the way this will be done will strongly differ Country by Country.

This clause has been specified as follows:

> *"Where it is technically and economically not feasible to fulfil the requirements under this paragraph, the total annual primary energy use may also be covered by other energy from the grid complying with criteria established at national level".*

Thus, thus the result will be to mostly use for NZEB electrical driven heat pumps/chillers fed by grid electricity and some local produced PV electricity, even if the threshold on total primary energy and on operational GWP will be set not too low, because the operational GWP will consider the far production of CO_{2eq} in the grid power stations.

Partial conclusions

The aim of the Directive to have an EU common path to buildings decarbonization is only partially addressed, because the objective is a bit too strong of what is probably feasible possible. Thus, an escape possibility has been provided to each Member State from these strong constraints, giving to them the possibility to set up less stringent thresholds and requirements in the light of a technical and economic feasibility. That will mean that is strongly possible that each Member State will follow its personal route to building decarbonization increasing the differences among them instead of reducing.

What will be the consequences of having chosen the total primary energy use as the building performance indicator, at least for new buildings from 2028, will be analysed in a second paper. ■