A common European EPB Assessment and Certification scheme. U-CERT's proposal

Pablo Carnero [a], *Dick* van Dijk[b], *Niccolò* Mignani[c], *Gabriela* Ana [d].

[a] Instituto Valenciano de la Edificación, València, Spain, pcarnero@five.es

[b] Energy Performance of Buildings (EPB) Center, Rotterdam, the Netherlands, dick.vandijk@epb.center.

[c] Alma Mater Studiorum Università di Bologna, Bologna, Italy, niccolo.mignani@studio.unibo.it.

[d] Energy Performance of Buildings (EPB) Center, Rotterdam, the Netherlands, ga@epb.center.

Abstract. Buildings are responsible for great share of the global GHG emissions. Increasing buildings' energy efficiency is crucial to decarbonise the EU. For energy performance policies and requirements to have actual impact on buildings' direct and indirect emissions is crucial to develop robust, accurate, meaningful and user-friendly assessments and certification schemes. This paper presents a methodology .to calculate building energy performance fully compliant with EPB Standards. Also, it proposes a selection of holistic indicators aiming to overcome shortcomings of national energy performance certificates, while being compliant with the latest version of the Energy Performance in Buildings Directive (EPBD). The results have the ambition of laying the foundation for a common European EPB assessment and certification scheme.

Keywords. EPB standards, EPC, EPBD, user-friendliness, digitalisation, indicators, calculation.
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1. Introduction

Anthropogenic climate change stands as the greatest menace humanity must face in the XXI century. Hence, the adhesion to the International Paris Agreement [1] and the climate and environment declaration by the European Parliament [2]. Consequently, the European Green Deal [3] established the mission for Europe to be net zero emissions by 2050. The checkpoint of cutting greenhouse gas (GHG) emissions by 55% in 2030 compared to 1990 levels was defined by the Climate Target Plan [4].

Decarbonising our societies calls for multidimensional action, it is widely acknowledged that buildings shall play a key role. During their use and operation, buildings are responsible of over 40% of the energy consumption and represent approximately one third of direct and indirect GHG emissions [5]. Direct emissions caused by their low energy performance and fossil-fuel use [6]. Indirect due to the high energy demand, which strains the power and heat sector. Almost 75% of EU's building stock is inefficient, and over 85% of the buildings that exist today will still be standing in 2050. However, the weighted annual energy renovation remains sunk at 1% [7]. Thus, the 'Fit for 55' package [8] was published with a view to revising the entire climate and energy framework. As a result, the proposal for the Energy Performance in Buildings Directive (EPBD) was released at the end of 2021 [7]. The document aims at being the definitive push to national building regulation towards delivering the ambitious EU climate targets. A core instrument is the revision of Energy Performance in Building (EPB) Assessments and Certification schemes.

1.1. EPB Assessments and Certification schemes

The first version of the EPBD [9] laid down the general framework for calculating buildings' energy performance. Such energy performance shall be assessed in a transparent manner that allowed to verify compliance with minimum requirements established for buildings. Moreover, it should also feed building's energy performance certificates (EPC), posed as the key informative instrument aiming to provoke a shift in the market in favour of efficient constructions. Despite the cardinal rule EPB assessment represented, the specific methodology to obtain it was left to each member state. The definition of a comprehensive procedure capable of assessing buildings' energy performance was far from trivial. When facing such titanic effort, each country defined its own EPB assessment and certification scheme, which generated great discrepancies across the EU [10][11]. In the interest of clarity, the EPBD was recast in 2010 [5]. It further detailed the minimum requirements for energy performance calculations in buildings and mandated member states to consider the existing European standards when developing their national assessment methodologies. A revised version of the EPBD was published in 2018. The document mandated member states to *"describe their national calculation methodology following the national annexes of the overarching standards, namely ISO 52000-1, 52003-1, 52010-1, 52016-1, and 52018-1"* [12]. These standards are part of a coherent set of internationally harmonized procedures developed to assess buildings' energy performance in a systemic manner. They are often referred to as EPB standards and were developed supported by mandate M/480 from the European Commission to CEN.

Many researchers and initiatives have considered the question of EPB assessments and certification schemes in buildings. However, to date, research has given considerable more attention to cross-country comparison and identification of shortcomings [13][14][15][16][17]or auxiliary tool development [18][19], rather than proposing a common-EU methodology considering the set of EPB standards [20].

The main scope of this paper is to propose a methodology for a new energy performance in building (EPB) assessment and to define the corresponding EPC. The remainder of this paper is structured as follows: Section 2 presents the methodology used in the research. Section 3 presents results and discusses them. Finally, in Section 0, conclusions are set together and policy recommendations are given.

2. Research Methods

The research is performed in the scope of the U-CERT project. U-CERT is a Coordination and Support Action funded under the Horizon 2020 programme aiming to define the next-generation EPB assessment and certification scheme leveraging the set of EPB standards.

2.1. EPB Assessment methodology

The project deeply mapped the state of the art regarding national EPB assessments and certification schemes in 11 countries (i.e., The Netherlands, Sweden, Estonia, Hungary, Spain, Slovenia, Romania, Italy, Bulgaria, France and Denmark) [21]. The gathering of all available National Annexes, as mandated by [12], was taken as the baseline for the definition of a converged set of EPB standard choices defining the common EU assessment methodology. The procedure was to categorise the EPB Standards to facilitate the identification of the most relevant ones. Next, all Annex A choices were structured and prioritised. Lastly, expert discussions were held in dedicated task forces, using available National Annexes as benchmark, to come to a final decision on U-CERT National Datasheets.

As a result, from the 61 overviewed EPB standards, 10 were finally selected as core of the U-CERT EPB calculation methodology (i.e., EN ISO 52000-1, EN ISO 52010-1, EN 16798-1, EN ISO 52016-1, draft ISO/FDIS 520232-1, EN 15316-4-2, EN 16798-7, EN 16798-5-1, EN ISO 52003-1, and EN ISO 52018-1). Thus, a total of 237 Annex A choices were made. For a detailed description of the selected choices, refer to [22].

Although U-CERT considers measured procedures as valid methods to estimate energy performance in buildings, the lack of EPB standards comprehensively addressing whole building assessments hindered its thorough analysis.

2.2. EPC report

Once having defined the EPB assessment methodologies, U-CERT approached the task of defining the set of indicators and the visual layout of the next-generation EPC. For this purpose, the latest provisions from [7] have been considered.

Apart from the detailed analysis of the two overarching standards dealing with energy performance indicators (i.e., EN ISO 52003-1, and EN ISO 52018-1), an investigation of the latest developments in Energy Voluntary Certification schemes (EVCS) was also performed [23]. Moreover, parallelly to the technical investigation, users' perception regarding EPCs in each of the countries was analysed leveraging ethnographic research techniques [24]. Consequently, to overcome the shortcomings identified in national EPCs (e.g., lack of user-friendliness, reliability, acceptance, etc.), the following briefing for next-generation EPCs was obtained. The objective was to define a flexible EPC, which shall be sensible to the user (i.e., expert and non-expert), to object (i.e., new and existing building), and to assessment type (i.e., calculated and measured). The 'silo-thinking' regarding energy performance should be abandoned, exploiting synergies with other complementary building assessments, such as Indoor Environmental Quality (IEQ), smart readiness, and cost. Furthermore, the next-generation EPC should be designed in a modular fashion, laying the foundation for a digitalised report.

3. Results

Although, EPB assessments are often focused on standardised calculations (i.e., estimating building energy use under normal use and typical climate conditions), U-CERT allows to produce other types of assessment, as depicted in Tab. 1. They can be mainly clustered in calculated and measured.

Tab. 1 - EPB Assessment types. Adapted from [25].

Type	Building situation	Use	Climate
Calculated	Design for new construction	Standard	Standard
		Project	Project
	As built existing building	Standard	Standard
		Actual	Actual
	Design for renovation	Standard	Standard
		Project	Project
		Actual	Actual
Measured	As built existing building	Actual	Actual
		Standard	Standard

The calculated assessment can be applicable to all building situations. In the design for a new construction, the calculations can be arranged to represent standard use and climate, or other project conditions. The first option is usually preferred when dealing with official EPB assessments, whereas the second option is always available for any other tailored analysis. Similarly, when having an existing building, standard or actual conditions can be applied to calculations representing the as built status. In the case of design for renovation, the calculated EPB assessments can reflect standard conditions, usually applicable for checking requirements or fulfilling regulatory obligations; or project conditions, which can be related to actual building use. The latter of special relevance when envisioning tailored-to-actual use renovation roadmaps. In contrast, the measured assessment is only applicable to as built existing buildings since they require having access to metered data. However, such measurements can be normalised to reflect standard conditions or left as measured to represent actual building use and climate influence and as such to be compared with a tailored calculation. Note that measured EPB assessment can't include an estimation of the building renovation potential.

With respect to the selection of indicators, to be included in the EPC report, there are four categories: energy performance (EP), IEQ, smart readiness and cost. These categories of indicators are sensible to whether they are embedded in calculated or measured EPB assessments, as shown in Tab. 2 and Tab. 3.

Tab. 2 – Calculated EPB Assessment indicators.

Category	Indicators	U-CERT Included	U-CERT Left as voluntary
General information		X	-
EP	Overall	X	-
	Partial	X	-
Smart Readiness	SRI	X	-
IEQ	ALDREN Thermal score	X	-
Cost	Cost	-	-

Tab. 3 – Measured EPB Assessment indicators.

Category	Indicators	U-CERT Included	U-CERT Left as voluntary
General information		X	-
EP	Overall	X	-
	Partial	-	X
Smart Readiness	SRI	-	X
IEQ	ALDREN Thermal score	-	X
Cost	Cost	X	-

Note that the indicators included in U-CERT's selection vary depending on the type of assessment. However, all assessments contain general information (e.g., contextual data, identification of the building and the assessor, link to databases, etc.). In the next subsections greater detail is given on the specific indicators within each category.

3.1. Energy Performance

The selection of energy performance indicators can be found in Data access statement

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

Appendix A. The main EP indicator defines the EP rating, according to a single reference point scale ranging from A to G, with the A+ subclass.

3.2. Smart Readiness

Smart Readiness refers to the capability of buildings or building units to adapt their operation to the needs of the occupant, also optimizing energy efficiency and overall performance, and to adapt their operation in reaction to signals from the grid. Smart Readiness consideration in the scope of U-CERT's EPB assessment is done by means of the Smart Readiness Indicator, as defined in [26]. This assessment produces an SRI rating.

The fully-fledged SRI assessment could be regarded as a parallel analysis to be included as an annex in EPB Assessments and Certification schemes.

ALDREN's EVC goes in this direction [18]. U-CERT is aware that the complete inclusion of SRI as independent from EPB Assessments could represent too much extra work for EPB assessors further hindering the uptake of next generation EPCs. However, if smoothly integrated in the EPB assessment process, added value could be given to EPCs, while not overburdening assessors. For a detailed identification of the overlapping elements between SRI and U-CERT's EPB Assessment, refer to [27].

3.3. IEQ

U-CERT decision with respect to including IEQ indicators in EPB assessments and certification schemes is to use the discomfort indicators defined as overall EP indicators (i.e., summer, winter and DHW thermal discomfort), along with the thermal score defined by the ALDREN project in [20].

3.4. Cost

In EN ISO 52000-1's Annex B a weighting factor is foreseen for the energy cost. However, U-CERT considers that for an asset EPB assessment, introducing a cost indicator may be counterproductive. This is because the asset EPB assessment represents the calculated EPB performance under standard conditions and standard weather data. Thus, any cost indicator that builds on such theoretical energy calculations won't provide meaningful information to both final users and EPB experts, who would tend to compare the cost indicator with the information present in the energy invoices.

A calculated cost indicator could be meaningful if it were performed under tailored conditions, rather than standardized. If the EPB assessment were configurated to reflect the actual use conditions (e.g., thermostatic setpoints, control strategies, occupant behaviour, etc.) and under actual weather influence, - tailored-to-actual conditions- then the cost indicator could be closer to reflect the actual energy expenditure. Moreover, it could be valuable to use it as baseline model for the ideation of tailored renovation roadmaps.

3.5. EPC report

The U-CERT project performed the selection of indicators with a view to easing the integration into building logbooks and EPC databases. Moreover, the EPC report, although produced in a static fashion, it has been structured and designed envisioning evolution to a digital environment. The most relevant feature is the concept of extended and reduced report. The former contains all the indicators and detailed information relevant to an expert user, while the latter just contains the basic insights addressed to a non-expert user. A summary can be found in Tab. 4 and Tab. 5.

Tab. 4 – Calculated EPC report. Content overview.

Calculated EPB Assessment	Reduced	Extended
Existing building or new building		
General information	X	X
Main EP rating in scale	X	X
Thermal comfort rating in scale	X	X
Smart Readiness in scale	X	X
Overall EP indicators	-	X
Partial EP indicators	-	X
SRI report	-	X
ALDREN Thermal score report	-	X
Voluntary indicators as annexes	-	X
Renovation potential *per each renovation action*		
Description of renovation action	X	X
Main EP rating in scale	X	X
Thermal comfort rating in scale	X	X
Smart Readiness in scale	X	X
Cost of renovation action	X	X
Overall EP indicators	-	X
Partial EP indicators	-	X
SRI report	-	X
ALDREN Thermal score report	-	X
Voluntary indicators as annexes	-	X
for the complete renovation scenario		
Description of renovation scenario	X	X
Main EP rating in scale	X	X
Thermal comfort rating in scale	X	X
Smart Readiness in scale	X	X
Cost of renovation scenario	X	X
Overall EP indicators	-	X
Partial EP indicators	-	X
SRI report	-	X
ALDREN Thermal score report	-	X
Voluntary indicators as annexes	-	X

Tab. 5 – Measured EPC report. Content overview.

Measured EPB Assessment	Reduced	Extended
Existing building or new building		
General information	X	X
Main EP rating in scale	X	X
Thermal comfort rating in scale (if performed)	X	X
Smart Readiness in scale (if performed)	X	X
Overall EP indicators	-	X
Partial EP indicators (if	-	X

performed)		
SRI report (if performed)	-	X
ALDREN Thermal score report (if performed)	-	X
Voluntary indicators as annexes	-	X

The EPC report template design has not been reproduced here due to space restrictions. It can be found in [27].

4. Conclusions

U-CERT sets the foundation of next-generation EPB assessments and certification schemes by producing a calculation methodology fully compliant with EPB Standards. Moreover, proposes a selection of holistic indicators, covering energy and complementary-to-energy dimensions, and a design of an EPC report which aims to overcome the shortcomings of national procedures. These results have been produced considering the latest provisions from [7]. Thus, they have the ambition of laying the foundation of a common European EPB assessment and certification scheme. Member states may find in U-CERT's value propositions a valuable stepping stone when aiming to renew their national procedures when having to transpose the EPBD to their national regulation.

Although progressing on existing research, this investigation is not exempt from limitations. In the scope of the project it was possible to retrieve users' perception on existing national EPCs from 11 countries. Nevertheless, replicating the methodology with the new EPC report was not possible during project duration. Furthermore, the calculation methodology has not been transferred to a functional simulation software. The EPC report could not be digitalised. These last two endeavours are left to future research.

5. Acknowledgement

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6. Data access statement

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

7. Appendix A

The indicators considered for U-CERT's EPB assessments can be classified into overall and partial indicators. The overall indicators include the following:

- Overall non-renewable primary energy use [kWh/m^2] [kWh]. Calculated according to H5 in Annex H in ISO 52000-1 [2]; thus, considering compensation between different energy carriers and the effect of exported energy.

This indicator assesses the final global impact the energy performance of the building has. An excess consumption during certain moments during the year may be balanced by surplus of energy in others. It constitutes the main EP indicator. This is in line with ALDREN project [18].

- Overall total primary energy use [kWh/m^2] [kWh]. Calculated according to H4 in Annex H in ISO 52000-1 [2]; thus, not considering compensation between different energy carriers nor the effect of exported energy.

This indicator assesses the total primary energy the building requires to operate according to the energy needs, technical building system efficiency and renewable contribution to the onsite energy use. It seeks to prevent buildings to balance a poor envelope and inefficient systems with oversized renewable generation.

- Summer thermal comfort [K·h].

This indicator serves to account for overheating during the cooling period. It refers to the amount of (weighted) occupation hours the temperature is above a certain reference temperature.

- Winter thermal comfort. [K·h].

This indicator serves to account for underheating during the heating period. It refers to the amount of (weighted) occupation hours the temperature is below a certain reference temperature.

- Domestic Hot Water thermal comfort [K·h].

This indicator serves to check that sanitary hot water is provided, when there is demand, at a certain minimum reference temperature.

Additionally, the following overall indicators are considered of informative nature.

- Overall non-renewable primary energy use [kWh/m^2] [kWh]. Calculated according to H4 in Annex H in ISO 52000-1 [2]; thus, not considering compensation between different energy carriers nor the effect of exported energy. This indicator is also compliant with Level(s).

- Overall renewable primary energy production [kWh/m^2] [kWh]. Considering the whole renewable primary energy production, regardless of whether consumed onsite or exported to the grid.

- Overall renewable primary energy use [kWh/m^2] [kWh]. The portion of the previous indicator compensating the energy demanded by the uses considered in the assessment.

- Overall equivalent CO_2 emissions [kg/m^2]. Calculated following H5 in Annex H in ISO 52000-1 [2]; thus, considering compensation between different energy carriers and the effect of exported energy.

- Renewable electricity generation by onsite PV, wind turbines or CHP [kWh/m^2] [kWh].

- Renewable electricity from onsite PV, wind turbines or CHP self-used [kWh/m^2] [kWh].

- Renewable electricity exported to non-EPB uses by onsite PV, wind turbines or CHP [kWh/m^2] [kWh].

- Renewable electricity exported to the grid by onsite PV, wind turbines or CHP [kWh/m^2] [kWh].

- Energy needs per service – heating, cooling, domestic hot water, humidification and dehumidification, and mechanical ventilation - [kWh/m^2].

For the case of the lighting, the metric proposed would be the Daylight Autonomy (DA). Thus, the indicator of the lighting energy needs would be the percentage of the occupied hours of the year when artificial lighting is needed, because daylight alone can't meet the minimum illuminance threshold [19].

- Energy use per system service – heating, cooling, domestic hot water, humidification and dehumidification, mechanical ventilation, and lighting - and energy vector [kWh/m^2] [kWh].

The partial indicators cover physical and technological elements, which could have strong connection with building and system inspections. They can be subdivided into envelope, technical building systems and renewable electricity production performance indicators.

The envelope performance indicators selected to be included in U-CERT are the following:

- Per opaque envelope construction.
  - Thermal transmittance [W/(m^2·K)];
  - Colour outside layer;

Additionally, a description of the layered materials should be included. It should cover (from outer to inner element), at least name, thickness, and conductivity of the material. Other features, such as density or specific heat may also be included.

- Per window/skylight:
  - Thermal transmittance [W/(m^2·K)];
  - Opening control (e.g., manual or fixed windows, open/closed detection to act on HVAC, based on sensor data, etc.)
  - Solar shading of glazings:
    - Presence;
    - Technology (e.g., awning, blinds, shutters, etc.);
    - Control (e.g., manual, motorized, automation based on sensor data, combined control with HVAC, predictive control, etc.)
    - Solar shading potential [%], according to ISO 18292 [20];
  - Glass thermal transmittance [W/(m^2·K)];
  - Glass solar factor [-];
  - Frame thermal transmittance [W/(m^2·K)];
  - Frame colour or absorptance.
  - Air permeability class, according to EN 12207.

Additionally, a description of each representative window/skylight should be included.

- Thermal bridges, per type of junction (e.g., corner, slab-façade, pillar, etc.):
  - Linear thermal transmittance Ψ [W/(m·K)].
  - Length [m].

- Air leakage:
  - Air change rate at 50Pa [1/h].

This indicator should be measured by means of a Blower Door test according to EN 13829 [21] whenever possible, and its value should be included in the calculations.

Continuing with the infrastructure present in the building, the technical building systems per service also provide valuable information about the energy performance of the building, as a whole.

- Technical Building Systems per service or combination of services.

Additionally, to the categories presented below, a general description of the installation should be included.

  - Service or services linked to the system.
  - Overall installation efficiency.
  - Generation:
    - Technology (e.g., conventional boiler, condensing boiler, air-to-air heat pump, electric heater, etc.);
    - Energy carrier;
    - Nominal power [kW];
    - Effective rated output [kW];
    - Nominal efficiency [%];
    - Renewable contribution (if applicable);
    - Metering;
    - Control (e.g., on-off control; control according to fixed priority list; control according to dynamic priority list; control according to dynamic priority list and predicted information; control according to dynamic priority list, predicted information and external

signals).
- Storage:
  - Capacity [m^3].
  - Control (e.g., continuous storage operation, scheduled storage operation, load prediction-based storage operation, flexible control according to external signals, etc.).
- Distribution:
  - Typology of circuit (e.g., two-pipe, four-pipe, recirculation, etc.);
  - Insulation of pipes;
    Further detail may be included.
  - Circulation device (e.g., pumps, fans, etc.).
    Further detail may be included.
  - Control (e.g., on-off control, multi-stage control, variable speed circulation device control based on internal signals or on external signals).
- Emission:
  - Technology (e.g., radiators, heated floor, fancoils, etc.);
  - Control (e.g., central automatic control, individual room control, individual room control with communication between controllers and to BACS, individual room control with communication and occupancy detection).
- Reporting of performance (e.g., central reporting of KPIs, historical data, forecasting and/or benchmarking, predictive management, and fault detection, etc.).

The aim is to characterize the main elements of the Heating, Cooling, DHW, Humidification & Dehumidification, and Mechanical Ventilation technical systems.

With respect to Lighting, the following may apply:
- Technology (e.g., LED, dichroic, fluorescent, etc.).
- Nominal power;
- Control (e.g., manual, sweeping extinction signal, automatic detection, etc.).

If there is a certain service which lacks technical building system, it should be explicitly mentioned.

U-CERT proposes including the following indicators about renewable electricity production.

- Photovoltaics:
  - Technology (e.g., monocrystalline, etc.).
  - Installed peak power [kWp].
  - Nominal efficiency [%].
  - Orientation [°].
  - Inclination [°].
  - Possibility to export electricity to the grid.
  - Inverter type (e.g., central inverter, power optimizer + inverter, or microinverters).
  - Reporting of performance (e.g., current generation data, actual values and historical data, performance evaluation including forecast and/or benchmarking, predictive management, and fault detection, etc.).

- Wind turbine:
  - Technology.
  - Installed peak power [kWp].
  - Nominal efficiency [%].
  - Possibility to export electricity to the grid.
  - Reporting of performance (e.g., current generation data, actual values and historical data, performance evaluation including forecast and/or benchmarking, predictive management, and fault detection, etc.).

- CHP:
  - Installed peak power [kWp].
  - Technology.
  - Nominal efficiency for thermal and power generation.

- Storage:
  - Technology (e.g., dedicated battery storage, dedicated thermal energy storage, etc.).
  - Installed peak capacity [kWh].
  - Control (e.g., direct storage of on-site production, controlled based on grid signals, optimising the use of locally generated electricity, possibility to feed back into the grid, etc.).
  - Reporting of performance (e.g., current state of charge, actual values and historical data, performance evaluation including forecast and/or benchmarking, predictive management, and fault detection, etc.).

In the case the building or building unit is connected to an energy community or district heating/cooling network it should also be made explicit.

8. Data Access Statement

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

9. References

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