Comparative assessment of current EPC schemes and relevant emerging building performance paradigms v2

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DELIVERABLE D1.5 Comparative assessment of current EPC schemes and relevant emerging building performance paradigms v2

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Executive Summary

EPCs are a mandatory requirement in the Member States when constructing, selling, or renting a building. This report identifies the methodologies currently used for the issuance of EPCs on a European level, explores the technological and market conditions where D^2EPC will be realized, as well as investigates the challenges of current EPC schemes. The main objective of the EPC is to be employed as a transparent information tool for building owners, occupiers, and real estate stakeholders who want a detailed energy performance of their property and recommendations for energy upgrade of building improvements. Given that, EPCs could act as a decision-making criterion on energy efficiency property improvements by providing recommendations for the cost-effective or cost-optimal upgrading of the energy performance. Building owners, occupiers, and mostly real estate stakeholders are among the most important information sources regarding energy performance in the EU's building stock. Despite substantial gaps in the existing European EPCs procedures, the D^2EPC project ambitiously aims to set the grounds for the next generation of dynamic Energy Performance Certificates (EPCs) for buildings by including novel indicators. Under the project vision, the proposed indicators will render dynamic EPCs a realistic, accurate, and comprehensive tool that can transform the European building stock into zero-energy buildings and stimulate an energy-efficient behavioural change in the building occupants.

The methodology followed in this report consists of field research committed as a set of statements with questions relevant to challenging matters of (i) EPCs issuing, quality, and control, (ii) EPCs calculation software and tools, (iii) EPCs indicators, and (iv) Qualified experts competence and skills, and desk research committed as a set of statements with questions relevant to challenging matters of EPCs. Concerning the field research, the extraction and circulation of a questionnaire to a list of stakeholders took place. The investigation concluded with the following questions aiming at stakeholders' knowledge:

1. What is the period of validity of an EPC currently issued in your region/country?
2. In case of re-assessment of an EPC based on operational data, are there incentives or penalties in relation to the owners' compliance or non-compliance with the certificate assessment/rating?
3. Is BIM documentation and literacy or digital logbooks employed by any means for the issuance of EPCs in your region/country?
4. In the case of a Building Management System (BMS) existence, to what extent is the data documented by BMS employed in the issuance or re-issuance of operational EPCs?

5. Is Geographic Information System (GIS) information exploited for issuing, validating, monitoring and verification processes of the EPC calculation?
6. Does the EPCs procedure in your region/country include any energy-related financial indicators (e.g. energy €/m²)?
7. Does the EPCs procedure in your region/country include any environmental/LCA related financial indicators (e.g. embodied energy/m²)?
8. Does the EPCs procedure in your region/country include any indoor air quality indicators (e.g. CO_2 concentration/m²)?
9. Do the EPC auditors have access to joint databases concerning the properties of building systems and building elements?
10. Is there provision for systematic and regular evaluation/assessment of energy assessor's competencies and skills?

The Stakeholder Circle® was employed for the identification and categorization of the main stakeholders, as those who affect and those who are affected by practices and policies related to EPCs - and understand their needs. The prioritization of the stakeholders, based on the same tool, aimed at the definition of the appropriate sample for the implementation of the field research and employed their power, proximity, and 'urgency'. With regard to the desk research, the methodology involved first carrying out an overview of fifty-two reports to identify the challenges, the needs, and the opportunities of current EPC schemes. This was followed by extracting twenty-five statements relevant to several constraints and limitations in the EPC procedure and a comparative assessment of EPC schemes in the twenty-seven EU Member States.

The collective analysis of data for the specific features of EPCs revealed that among the twenty-seven (27) EU Member States, fourteen (14) have adopted the methodology exclusively based on calculated energy consumption. Both the actual and calculated energy consumption in some Member States are foreseen. Penalties are rare and are mainly addressed to energy auditors. Based on the research of this report, it was revealed that the majority of EU countries do not employ by any means BIM documentation and literacy or digital logbooks for the issuance of EPCs. There is no provision, national requirement, or legal obligation of a Building Management System (BMS) existence in connection with the operational EPCs. In most of the EU Member States, information related to Geographic Information System (GIS) is not included in the EPCs. Consequently, it is not exploited for issuing, validating, monitoring, and verification processes of the EPC calculation. Additionally, analysis across the EU Member States revealed that energy-related financial indicators, as well as environmental/LCA-related financial indicators, are not found to be included in current EPCs schemes and procedures in any EU Member State. Although provisions for indoor environmental quality (including air quality, thermal

comfort – the risk of overheating and ventilation, lighting, and acoustics) are set in EPCs, there are not covered in current EPC regimes and are not included in the calculation procedure for certification of EU countries. EPCs constitute a significant database where big data concerning the actual energy performance of the European building stock are gathered. Nevertheless, there is no existence of a database describing the energy efficiency features of the building stock as a whole. Nevertheless, in some cases, there is available comprehensive information regarding the physical stage of the existing building stock gathered during the EPC issuance procedure. One-third of EU countries do not have provision for systematic and regular evaluation/assessment of energy assessor's competence and skills.

Notwithstanding the positive contribution that current EPCs have had to improve the energy performance of buildings, experience has unveiled several constraints and limitations. The underlying fundamental objectives to be addressed in this report are: i) the analysis and comparative assessment of current EPC schemes, ii) the definition of user and market requirements and needs with respect to the targeted project vision, which should be addressed or connected to the D^2EPC framework, iii) the definition of the dynamic EPC scheme proposed by the project taking into account existing solutions and operational challenges, and iv) the system specifications and detailed architecture of the D^2EPC approach, which will drive its implementation.

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List of Acronyms and Abbreviations

Term	Description
BAS	Building Automation System
BEPS	Building Energy Performance Simulation
BIM	Building Information Model
BIS	Building Information System
BMS	Building Management System
CEN	European Committee for Standardization
D.	Deliverable
dEPC	dynamic Energy Performance Certificate
EBC	Energy in Buildings and Communities
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
ESCO	Energy service company
EU	European Union
GIS	Geographic Information System
HVAC	Heating, Ventilation and Air Conditioning
IDA-ICE	IDA Indoor Climate and Energy simulation tool
IEA	International Energy Agency
IFC	Industry Foundation Classes
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
M/480	Mandate M/480, standardization requests issued as the recast of the EPBD
MS	Member State
RES	Renewable Energy Sources
SRI	Smart Readiness Indicators

T.	**Task**
WP.	**Work Package**

1 Introduction

1.1 Work package and Task description

WP1 aims to explore the technological and market conditions where D^2EPC will be realized, as well as to investigate the challenges of current EPC schemes. This work package will provide the conceptual and contextual ground for the next generation EPCs envisioned in the D^2EPC project (state-of-the-art analysis, user requirements, market trends, and detailed D^2EPC scope). Task 1.1: Comparative assessment of current EPC schemes and relevant emerging building performance paradigms has specific operational objectives. In particular, the main objective is to develop a deep understanding, at the European level, of the status and current methodologies and EPC schemes.

Due to the dynamic character of the field, the revision of D1.1 to D1.5: Comparative assessment of current EPC schemes and relevant emerging building performance paradigms v2, was performed during M18-M20. The review of data of T1.1 was conducted based on the developments of the time and on the new findings anticipated both by the project, as well as from other EPC-related initiatives, such as research and innovation projects (Section 4).

For the delivery of a state-of-the-art tool for Dynamic EPCs Issuance, it is critical first to identify the methodologies currently used for the issuance of EPCs on a European level. Accordingly, the first task that will initiate the project involves the collection of the key elements and the comparative assessment of the currently used EPC schemes, as well as of other methodologies employed in European countries for the definition of the energy performance of buildings. This mapping of the national approaches for issuing EPCs will enable the assembling and reviewing of all the available methodologies, distinguishing between the methodologies exclusively based on calculated energy consumption (asset rating) and the methodologies that use actual energy consumption data (operational rating). The goal of this task is two-fold; to highlight the key features that should be taken into consideration in the design and development of the innovative tool and to adopt effective practices from successful emerging building performance paradigms. The approach to be adopted under this task is found aligned with the core objective of the CAV EPBD on the exchange of information and experience among the Member States and other participating countries regarding the implementation of the EPBD, and in particular with the activities of Core Team 5 — Certification & Training — for the certification of buildings and the quality of certification and control systems, with special focus on monitoring, quality, and improvement of the existing schemes.

1.2 Interaction with Other Tasks and Deliverables

Task 1.1 is the initial step of the D^2EPC project and, for this reason, does not have initial input from other tasks at its initial stages. Nevertheless, this task will be the cornerstone for Task 1.3 as well as for all tasks of work package two (WP2) related to the novel set of indicators to be developed within the project.

Task 1.1 has established communication with T1.2 to avoid overlaps in the expected deliverables from those tasks (current status vs. requirements and future trends).

2 Methodology

D^2EPC aspires to deliver the next-generation of dynamic EPCs for the operational and regular assessment of buildings' energy performance through a set of cutting-edge digital design and monitoring tools and services. D^2EPC relies upon and adjusts accordingly to the smart readiness level of the buildings and the corresponding data collection infrastructure and management systems. It subsequently builds upon actual data and the 'digital twin' concept to calculate energy, environmental, financial, and human comfort indicators and, through them, the EPC classification of the building in question.

2.1 Objectives and actions

The introduction and establishment of the concept of the dynamic EPC (dEPC), an operational certificate to be calculated and issued regularly, are one of the vital objectives of this project. Although cutting-edge monitoring technologies allow the real-time integration of measured data into the calculation process of EPCs, this has still not been regulated either by existing EPC tools or methodologies. D^2EPC project aspires to define the required framework to empower the regular energy classification of buildings based on their operational performance. Based on the continuous improvement of the minimum energy requirements of EU Member States for new buildings, and in view of the nearly Zero Energy Buildings era, which will start on the 31st of December 2020, this development will lead to the enhancement of the actual energy performance of EU Member States' building stocks. In this manner, a more active role of next-generation EPCs in policy making will be enabled.

Current practices and tools of energy performance assessment and certification applied across Europe face several drawbacks and discrepancies. D^2EPC aims to analyse the quality and the drawbacks of the current EPC schemes, identify technical challenges that currently exist to overcome them (e.g. performance gap, etc.), and set the grounds for the next generation of dynamic EPCs. D^2EPC scheme will be based on the relevant EU standards and the Energy Performance of Buildings Directive in order to allow for an EU-wide deployment. One of the project's main objectives is to conclude to a specific series of recommendations for the required upgrade of existing ISO/CEN standards under Commission mandate M/480 and to enable the integration of the dynamic EPC concept.

The initial steps of this project were the identification of the challenges, the needs, and the opportunities, as well as a comparative assessment of current EPC schemes. According to that, the collection of the key elements and the comparative assessment of the currently used EPC schemes, as well as the collection of other methodologies employed in European countries for the definition of the

energy performance of buildings it was formed. The documentation of the main statements from the D^2EPC project contract was performed concerning the novelties and discrepancies aiming to be covered in next-generation EPCs.

The methodology employed for this task included the collection of primary resources, the synthesis of current status as well as the comparative assessment of current EPC schemes and relevant emerging performance paradigms. The literature overview of reports and scientific studies, the communication with competent bodies, the targeted e-Questionnaires, and finally, the interviews with stakeholders and experts were the stages followed in order for this research to be accomplished. Subsequently, the collective analysis of data for specific features of EPCs and the definition of innovative aspects that could be integrated into D^2EPC were the composing elements of the current status.

2.2 Field research

As part of the field research, it was committed a set of statements with questions relevant to challenging matters of:

- EPCs issuing, quality, and control
- EPCs calculation software and tools
- EPCs indicators
- Qualified experts' competence and skills

The methodology of this research consisted of the extraction and circulation of the questionnaire to a list of stakeholders as well as the relevant feedback and consultation from these stakeholders.

Questionnaires are a commonly-used method of gathering information from respondents. Through this questionnaire, the requirements for the aspect of next-generation EPCs were identified (i.e. identify LCA indicators employed in an EU Member State or reward/incentive schemes, etc.), and ten questions were delivered based on that. The investigation was made on the following topics, and the ten questions aiming at stakeholders' knowledge of these challenging matters were formed as follows:

<u>Topic (a): EPCs issuing, quality, and control</u>

1. What is the period of validity of an EPC currently issued in your region/country?
2. In case of re-assessment of an EPC based on operational data, are there incentives or penalties in relation to the owners' compliance or non-compliance with the certificate assessment/rating?

<u>Topic (b): EPCs calculation software and tools</u>

3. Is BIM documentation and literacy or digital log-books employed by any means for the issuance of EPCs in your region/country?

4. In case of a Building Management System (BMS) existence, to what extent is the data documented by BMS employed in the issuance or re-issuance of operational EPCs?
5. Is Geographic Information System (GIS) information exploited for issuing, validating, monitoring, and verification processes of the EPC calculation?

Topic (c): EPCs indicators

6. Does the EPCs procedure in your region/country include any energy-related financial indicators (e.g. energy €/m²)?
7. Does the EPCs procedure in your region/country include any environmental/LCA-related financial indicators (e.g. embodied energy/m²)?
8. Does the EPCs procedure in your region/country include any indoor air quality indicators (e.g. CO_2 concentration/m²)?

Topic (d): Qualified experts' competence and skills

9. Do the EPC auditors have access to joint databases concerning the properties of building systems and building elements?
10. Is there provision for systematic and regular evaluation/assessment of the energy assessor's competencies and skills?

As a result of this data investigation and according to the information collected by the e-questionnaire (Annex C, Annex D) with the assistance of stakeholders of most EU countries, a more complete picture of the current EPC schemes and procedures was formed. The feedback received by the stakeholders will be analysed in the following sections.

For the purpose of questionnaire circulation, stakeholders were identified with the use of the Stakeholder Circle® as those who affect and those who are affected by practices and policies related to EPCs. The prioritization of the stakeholders, also based on the Stakeholder Circle®, was aimed at the definition of the appropriate sample for the implementation of the field research and employed their power, proximity, and 'urgency'.

2.2.1 Definition of stakeholders

In this step, active feedback and consultation from stakeholders were pursued. It included identifying and prioritizing stakeholders, to whom the questionnaire would be addressed, collecting missing data concerning future trends and needs, and validating the ones identified in the desk research. National ministries and public authorities responsible for developing the methodologies for issuing EPCs, Technical Committees for Building Information Modelling, as well as policymakers and energy agencies of the provinces, are only a number of the stakeholders this questionnaire was targeted on. User acceptance was key to achieving the expected impact of D^2EPC; thus, user and stakeholder-centered

design and innovation principles were adopted. This procedure recorded an accurate and detailed mapping of current status and future trends. The collected data were then evaluated in close cooperation with the involved stakeholders to identify challenges and limiting factors. The result will be the development of an evaluation report where recommendations and guidelines will be included.

Before the circulation of the questionnaire to a list of stakeholders of partners' countries, their profiles had been identified and prioritized in collaboration with partners of Task 1.2. Furthermore, as a multiplier of all national member countries, the e-questionnaire was circulated to relevant technical European Standardization Committees CEN / TC.

2.2.2 Identification of stakeholders

An EPC is an information tool that enables owners, occupiers, and all property stakeholders to understand the energy efficiency of individual property and compare it with other properties. The ultimate goal of EPCs is to create a demand-driven market for increased energy efficiency in buildings. As such, it is of vital importance to define the European entities and stakeholders involved in this market. A project stakeholder is an individual, group, or organization that may affect, be affected by, or perceive itself to be affected by a project's decision, activity, or outcome [1]. Project Management Institute (PMI) is an organization according to which the defined methodology of stakeholders' identification was adopted. The Stakeholder Circle® was employed to identify the stakeholders and understand their needs. A category approach of three categories was applied to identify the main stakeholders. These categories are the following:

i. Stakeholders who affect the EPC assessment
ii. Stakeholders who are affected by the EPC assessment
iii. Stakeholders who may be interested in the EPC processes

The first category includes the stakeholders who are involved in the delivery of EPCs and those who determine the context of the EPCs. Organizations or companies implementing and developing EPC software and assessments and entities that set the legal framework and specific rules of the market are represented in this category.

The second category involves the stakeholders who are directly or indirectly affected by the EPC assessment, depending on the context. Users, community groups and associations, and the general public are some of the stakeholders encompassed in this category.

The third category represents stakeholders who may be interested in the outcomes and methodology for EPCs for research purposes, media, campaigns, or future projects within this frame of reference.

2.2.3 Hierarchy of stakeholders

The hierarchy of stakeholders was made according to the recommended communication effort. This effort is based on the stakeholder's priority and the comparison of their current and optimum levels of support and receptiveness in collaboration with partners of Task 1.2. Stakeholders' prioritization aimed at the definition of the appropriate sample for the implementation of the field research. A category approach of four was applied to prioritize the main stakeholders. In these categories are included:

(a) Stakeholders of higher priority that assumed to need a more proactive communication effort,

(b) Stakeholders that are below optimum on both the receptiveness and support dimensions,

(c) Stakeholders below optimum on one dimension rate, followed by optimal stakeholders

(d) Stakeholders rated better than optimal are assessed as needing 'business as usual' communication.

Prioritization of the stakeholders was also based on the Stakeholder Circle® and employed their power, proximity, and 'urgency'. The results of this hierarchy procedure are represented in Table 1, Annex A. For the purposes of Task 1.1 project research, the e-questionnaire was addressed to the first twelve (12) stakeholders in order to collect missing data concerning future trends and needs, as well as to validate the ones identified in the desk research.

2.3 Desk research - Challenging matters of EPCs

This action included the definition of the main statements and challenges related to next-generation EPCs within the project. Furthermore, it consisted of the implementation of desk research – documentation of statements within the collected reports, which accordingly provide evidence on current practices in the EU Member States. As the last phase of the desk research was the analysis of the statements and the extraction of conclusions concerning good practices and performance paradigms.

Following the collection of reports on EU EPCs' current conditions, the content of the stakeholders' questionnaire was about committing a set of statements with questions relevant to challenging matters of EPCs. A total of twenty-five statements were collected, with the most typical to be as below:

Topic (a): EPCs issuing, quality, and control

- There is limited information on the actual energy performance of buildings.
- The performance gap, i.e. the difference between estimated and actual energy performance, maybe hinder EPCs' reliability.

- According to existing practices, energy performance certificates are issued at the early stages of the building construction; thus, they fail to present the actual energy behaviour of the building over time.
- There is a stringent need to strengthen the monitoring of EPC scheme compliance (both at MS and European level), especially in regard to independent control systems and enforcement of the penalties for non-compliance.
- Lack of enforcement of the penalty system may considerably dilute the quality, credibility, and usefulness of the EPC schemes.

Topic (b): EPCs calculation software and tools

- Most of the software used in EU MSs are based on simplified architecture.
- EPCs calculation is not combined with the building energy performance simulation for the design of the HVAC equipment and buildings' thermal comfort.
- At this stage, there is no integration of BMSs and digital twins into the certification process.
- The quality control of input parameters is performed in the central EPC register in 19 Member States.
- Errors in the input data are among the most typical factors that influence the quality of the EPCs. With the use of digital solutions and tools, this is possible to optimize the process of issuing, validating, and verifying the EPC.
- Not all MSs require the physical presence of the certifier on-site to gather the technical information to issue the EPC (for existing buildings). This would provide better reliability of the EPC issued and allows for more effective tailor-made recommendations.
- Thermal and human comfort aspects related to occupant well-being in inhabited spaces are currently not considered by the existing EPC schemes.

Topic (c): EPCs indicators

- The recommendations for energy upgrades are automatically generated by a standard list (e.g. increasing insulation, replacing windows, etc.) and do not offer a user-friendly document that would motivate renovation.
- Thermal and human comfort aspects related to occupant well-being in inhabited spaces are currently not considered by the existing EPC schemes.
- Even though thermal and acoustic comfort, indoor air quality, and daylight are among the primary drivers for buildings renovation, they are not considered in current EPCs.

Topic (d): Qualified experts' competence and skills

- 15% of EPCs lodged are incorrectly rated.

- Among the 28 EU Member States, 14 have adopted the methodology exclusively based on calculated energy consumption.
- Almost all Member States set up a system to collect EPC data voluntarily, and in most cases, the responsibility to manage the databases lies with the central or regional government bodies.
- The energy assessor's competence needs to be considered in the accreditation procedure.
- The independent control of qualified experts is performed in 8 Member States.
- The EPC delivery process can be subjective, and, as a result, data quality can be easily influenced by the energy assessors because of the standard assumptions made in the process of producing the certificate.
- In 20 out of 28 Member States, a compulsory exam to check the certifiers' skills is recognized as a best practice. Mandatory training is required in only 14 out of 28 Member States and, in some countries, only when there is a lack of education and professional experience.
- In 12 countries, public access to the EPC information is provided either via direct access to the database and/or aggregated results; however, 9 countries do not allow public access.
- In 11 Member States, the first quality control of input data is performed in the calculation software (i.e. plausibility check).
- Errors in the input data are among the most typical factors that influence the quality of the EPCs. With the use of digital solutions and tools, this is possible to optimize the process of issuing, validating, and verifying the EPC.

The diagrams of the four different topics relevant to the main challenges of current EPC schemes are presented in Figures 1 to 5, respectively in Annex B.

2.3.1 Collection of reports on EU EPCs current conditions

This action included the desk research, i.e. reading and analysis, of reports examining EPCs in Europe, as well as the preparation of a list of available reports (Table 1) regarding the current conditions concerning the EPCs in the EU Member States. This accumulation included fifty-two (52) reports from various reliable sources, such as national energy-related reports of EU countries. All the reports, in total thirty-four, presenting the EPBD implementation per country or region in some cases, for 2018, were by the funded project of Concerted Action EPBD [2] - [31]. Additionally, for the same year, information was collected on technical elements, existing buildings and systems, as well as certification, control system, and quality by the same project [32][33][34]. Project's issued books were employed featuring country reports for the previous years of 2010 [35], 2012 [36], and 2016 [37]. Two reports of Buildings Performance Institute Europe (BPIE) regarding the energy performance certificates

across Europe and the inner value of a building in 2010 [38] and 2018 [39], respectively were implemented. The Climate Policy Initiative of Berlin has presented a report about the effectiveness of EPCs in Germany in 2011 [40], and the European Commission has dealt with EPCs' impact on transaction prices and rents in 2013 [41]. Furthermore, under the Concerted Action EPBD project in 2015, two more reports were presented relevant to the reliability of quality control schemes and the best use of EPCs [42][43]. The project Request2action in 2015 [44] introduced a report about the existing monitoring initiatives and database systems, and the project by the name QUALICHeCK in 2017 [45] conducted a summary of all collected data on EPCs compliance and quality issues. The four most recent reports by which beneficial information was gathered were of 2020. Two of them were based on the local EPC situation and best EPC practices within the project QualDeEPC [46][47]. Information was accumulated regarding the EPCs' status and potential assessment by the X-tendo project [48] and the technical support to the development of a smart readiness indicator for buildings by the European Commission [49]. In a brief picture, according to the reports regarding the current conditions concerning the EPCs in the EU Member States for the last decade, information was collected by 70% by European funded projects and 30% by European institutes, organizations, and the European Commission. This action aimed to summarize existing knowledge on current EPC schemes based on legislation and regulation in the EU countries and emerging future market requirements.

Notwithstanding the positive contribution that current EPCs have had on improving the energy performance of buildings, experience has unveiled several constraints and limitations. According to that, the identification of the challenges, needs, and opportunities and a comparative assessment of current EPC schemes are presented below.

2.3.2 Overview of reports

This action included the presentation of a list of available overview reports on EPCs in the European Union Member States in an attempt of extracting answers relevant to the formed questions gathered as the first material to be analysed further on.

In relevance to the topics of the questionnaire, this overview report included a collection of reports from various reliable sources, such as national energy-related reports of EU countries, aimed to summarize existing knowledge on current EPC schemes based on legislation and regulation in the EU countries as well as emerging future requirements of the market. As a consequence, energy, environmental, financial, and human comfort indicators were identified for the next generation EPCs.

Although remarkable progress has been achieved in the past few years concerning energy efficiency indicators for buildings (e.g. IEA Annex 53), these have still not been integrated into the EPC on a

European level. D^2EPC project seeks to the enhancement of EPCs through a novel set of indicators that cover environmental, financial, human comfort, and technical aspects of new and existing buildings, aiming to simplify the understanding of buildings' energy performance and to present a more comprehensive overview of the actual energy performance of buildings across Europe. These indicators, which were human-centric and oriented towards the whole life cycle of the building, enabled the evaluation of buildings in a holistic, cost-effective, and user-friendly manner across several complementary dimensions that will consider both the envelope and the system performances of buildings.

3 Comparative assessment

EPCs are a mandatory requirement in the Member States (MSs) when constructing, selling, or renting a building; EPCs play an important role in this process as they serve as a transparent information instrument for building owners. Real estate stakeholders are among the most important information sources regarding energy performance in the EU's building stock. Notwithstanding the positive contribution that current EPCs have had on improving the energy performance of buildings, experience has unveiled several constraints and limitations. According to these discrepancies, in this section will be conducted a comparative assessment of the current status of EPC schemes and procedures of the twenty-seven (27) EU Member States.

3.1 EPCs issuing, quality, and control

3.1.1 Validity period of Energy Performance Certificates and rating methods

The validity period of EPCs throughout the EU Member States has an extent of several years. According to the Directive 2010/31/EU, this time shall not exceed a period of ten years. The way the Directive 2010/31/EU was relocated for new buildings is that an EPC has to be issued as a prerequisite for getting a building permit, which in some cases is not granted in case of non-compliance [38][41]. Following the field and desk research conducted on this issue, it was revealed that for new and existing buildings, the period of validity of an EPC currently issued to receive a building permit is up to ten (10) years in most EU countries [38][46]. A re-issuance of the certificate is mandatory after this period. This may differ in some countries, where the EPC of new buildings is valid for up to six (6) years from the date of commissioning of the building, and the EPC of existing buildings has to be renewed within a three-year period [6]. It is recommended, and in some countries required, to be updated following a major reconstruction-renovation of the building envelope or the technical systems, even if the works take place before the expiry date [12]. Notwithstanding, for both residential and non-residential buildings (private and public), an EPC has to be issued before and after the implementation of energy efficiency measures in order for savings to be verified [2][6][23]. If the input parameters alter the energy class of the building, then the EPC has to be reissued [8].

Furthermore, guidance is provided by the EPBD (Art.3, Annex I) for the Member States regarding the EPC calculation methodology, following the EU standards. The energy performance of buildings can be evaluated based on the asset rating or the operational rating associated with a typical use [50]. While the methodology based on asset rating considers the primary energy needs to be based upon various

building characteristics, the operational rating is based on the energy delivered to the buildings, without taking into account all the losses derived from the production of energy. It, therefore, includes users' behaviors with minor adjustments [51]. Among the twenty-seven (27) EU Member States, fourteen (14) have adopted the methodology exclusively based on calculated energy consumption. Both the actual and calculated energy consumption in some Member States are foreseen. Existing buildings tend to undergo performance degradations, changes in use, and unexpected faults or malfunctions over time [52][53]. These events often result in significant deterioration of the overall system performance, inefficient operation, and unacceptable human comfort conditions. These facts underline the necessity of the employment of operational rating, as well as the deficiencies of asset rating. Given that, the D^EPC project's envision is the engaging of operational rating, updated regularly.

3.1.2 Incentivisation and restriction practices into the EPC rationale

Current EPC schemes are based on a cradle-to-site rationale, completing their mission after delivering the certificate to the building user, overlooking the user's behavior and the actual energy performance of the building that might change dynamically within time. The dynamic EPCs will allow for the monitoring of the actual performance of building users on a regular basis and the introduction of intelligent financial schemes associated with output-based assessment. These schemes will either be based on financial awards (e.g. tax reliefs) for those building owners who exceed EPC expectations or on penalties for the "unconscious" users, not meet the EPC expected class, based on the "polluter pays" principle. Incentives that encourage consumers/owners to achieve energy savings for their buildings by providing targeted guidelines and requirements of a particular level of energy performance could be adopted by the Member States. D^2EPC aims at the introduction of next-generation dynamic EPCs' where their issuance will be according to real-time energy consumption values. In practice, there is no enforcement compliance in EPC implementation [38].

Following the field and desk research, it is depicted that none of the EU Member States apply incentives or penalties concerning the owners' compliance or non-compliance with the certificated assessment, in case of re-assessment of an EPC, based on operational data. In the majority of the countries, assessment is based on relevant energy calculations or estimations. The assessment and re-assessment of EU EPCs are based on relevant estimations and energy calculations on the properties of the building and the installation; namely, they are asset rating focused. In the case of an invalid or incorrect certificate, fines are applied to the owners. Otherwise, penalties are rare and are mainly addressed to energy auditors. No statistical data indicate the frequency and the level of penalties [2]. Legal actions may be taken merely if complaints are received [19][20]. Until minimum requirements

are met, graded sanctions are imposed concerning the error's intensity, type, and repetitiveness [10][17]. Other penal consequences may be imposed in a case of fraud [13][18]. Furthermore, penalties are anticipated for not meeting ventilation requirements or not ensuring regular inspection of the central heating systems of buildings [3][8][28]. The inspectors' and EPC audits' infringements are punished with suspension or removal from the registries [18]. An EPC incentive-based approach would benefit and motivate end-users to change their behaviour towards optimized energy use and provide confidence in choosing the right way and focusing on energy savings and eco-friendly processes. In several countries, incentives are provided only in terms of tax deductions, either as a reduction of construction tax burdens for new private buildings, renovations, or as taxation of real estate [17][18]. Another incentive focused more on new and large buildings is the establishment of the 5% extra building space allowance for buildings that reach A class, with at least 25% of their primary energy consumption coming from RES [8].

3.1.3 Key facts

- In most countries, the period of validity of an EPC currently issued to receive a building permit is up to 10 years. After this period, a re-issuance of the certificate is mandatory.
- In some countries, the EPC of new buildings is valid for up to 6 years from the date of commissioning of the building, and the EPC of existing buildings has to be renewed within 3 years.
- Following a major reconstruction-renovation of the building envelope or the technical systems, an update of the certificate is mandatory.
- Among the 27 EU Member States, 14 have adopted the methodology exclusively based on calculated energy consumption.
- None of the EU Member States apply incentives or penalties concerning the owners' compliance or non-compliance with the certificated assessment, in case of re-assessment of an EPC, based on operational data.
- In the case of an invalid or incorrect certificate, fines are applied to the owners.
- Penalties are rare and are mainly addressed to energy auditors.
- The inspectors' and EPC audits' infringements are punished with suspension or removal from the registries.
- In several countries, incentives are provided only in terms of tax deductions, either as reduction of construction tax burdens for new private buildings, renovations or as taxation of real estate.

3.2 EPCs calculation software and tools

3.2.1 Building digitalization and enhanced Building Information Models

The European Parliament (EUR 28977 EN) approved the utilization of electronic tools, such as BIM, by the EU Member States in European public procurement projects [54]. This decision will be advantageous to the taxpayers in terms of cost savings, the construction sector as an economic boost, and sustainable design [55]. In order to improve the method of information exchange in the construction industry, recent efforts have concentrated on integrating Building Information Modelling (BIM) with Building Energy Performance Simulation (BEPS) tools [56]. Despite the readiness of the integration of BIM with BEPS tools, at present, the calculation of the EPC of a building is an activity on its own. Integration levels differ among countries, and more work from policymakers, construction-related associations, and research institutions is needed to harmonize BIM practices among European Member States [57]. All input data must be collected and entered into the software tool. This effort can only rely on either simplified calculation procedures (e.g. single-zone calculation, default values for systems performance, thermal bridges simplification) or software with embedded databases [58]. With the expected market uptake of BIM, cost-effective and reliable assessment methods for the assessment of Smart Readiness Indicators (SRI), proposed in the amendment of the EPBD of 2018, should also become possible.

The International Organization for Standardization (committee ISO/TC 59/SC), and the European Committee for Standardization (committee CEN/TC 442) are the top standardization bodies concerning the organization and the digitization of information about buildings and civil engineering works, including building information modelling (BIM) [59][60]. In line with the objectives, the work of the technical committee 442 (CEN/TC 442) – the European approach of International Standards – strives to elaborate a structured set of standards, specifications, and reports which specify methodologies to define, describe, exchange, monitor, record and securely handle asset data, semantics, and processes with links to geospatial and other external data [61].

D^2EPC project aims to retrieve all required information concerning the building envelope, design, materials, and building systems through BIM documentation in a calculation tool. At the same time, the collection of operational data, data analysis, and simulation/emulation (inverse modelling) will also be realized with the use of digital twins integrated with the BIM (design-based) approach. The information processed by the BIM documents to the D^2EPC BEPS will also deliver the set of indicators envisioned by the project, which will enhance the user-friendliness of the novel EPCs.

Following the field as well as desk research conducted on this topic, it was revealed that the majority of EU countries do not employ by any means BIM documentation and literacy or digital logbooks for the issuance of EPCs. Even though there is the provision of BIM documentation and digital logbooks in some countries, these are used as a source of information for the EPC assessment procedure or energy simulations for building permits. Some BIM-based tools are employed in the EPCs issuance, such as the IDA-ICE dynamic simulation tool and also the IFC geometry model, that are commonly used for the energy simulation of an EPC in Finland, but as it is shown by the field and desk research that there is no obligation for Member States to use BIM software. The introduction and implementation of Building Information System (BIS), an electronic site that accompanies information relevant to the construction process and the parties involved, aiming to digitalize the documentation of the entire construction process, is one more way of employing building data [19]. Within the next year, Belgium will establish BIM source documentation for the declaration of the energy performance of newly built buildings, and the Netherlands will provide the option to the three suppliers of the validated calculation tool of using BIM for the EPC calculation.

As a way to involve owners of buildings and stakeholders in the value increase and accessibility of EPC data, digital or printed logbooks have been certified and highly elaborated in several EU countries [48]. The EU Member States are planning to include digital logbooks for building monitoring and maintenance data as part of their EPC systems. This could be accomplished by setting up a template for statistics generation on heating or cooling system logbook, as well as for energy efficiency reports [18]. Additionally, plans of fully developing building logbooks as part of a “building renovation passport” and of allowing digital documentation of inspection results and storage of data appear to be implemented in several EU countries [4][48]. The introduction and implementation of Building Information System (BIS), an electronic site that accompanies information relevant to the construction process and the parties involved, aiming to digitalize the documentation of the entire construction process, is one more way of employing building data [19].

3.2.2 The use of Building Management Systems in the issuance of Energy Performance Certificates

Although significant progress has been achieved in the past decade in the field of buildings digital design with the use of advanced tools, most of the software used in the EU Member States is based on simplified architecture. The calculation methods on which EPCs software relies follow methods described in CEN standards, where the description of the building is simplified and based on aggregated values (in terms of building elements' areas, thermal zones, etc.) and look-up tables (in terms of material thermal properties, infiltration rates, etc.), while correlation factors or predefined schedules are also used for the dynamic effects modelling. Also, in most cases, EPCs calculation is not combined with the building energy performance simulation for the design of the HVAC equipment and the building's thermal comfort. However, it is performed individually, using different calculation paths. These practices make it more difficult to ensure the quality of the EPC calculation procedure and introduce additional design steps of questionable quality. An update on the revised Energy Performance of Buildings Directive (EPBD) by the Committee on Industry, Research, and Energy (ITRE) has concluded that regulations have tightened and energy efficiency, green buildings, and money-saving drive the building automation and building management, power management, energy efficiency, and smart buildings markets and initiatives [62].

Building automation is defined as the automatic centralized control of a building's heating, ventilation, and air conditioning (HVAC), lighting, and other systems through a building management system (BMS) [63]. A BMS, otherwise a building automation system (BAS), is a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment [64]. A BMS consists of software and hardware; the software program, usually configured in a hierarchical manner, can be proprietary, using protocols as well as Internet protocols and open standards [65]. Typical applications of sensors in buildings are meant to modulate the performance of the HVAC system for thermal comfort or adjust lighting levels. Recently, however, more constituents are being monitored for fault diagnostics, humidity control, and improved air quality, while various pieces of building equipment contain sensors that monitor their performance [66]. BMS Technology alone will not achieve building energy conservation goals, and humans and their energy-related behaviour within buildings should be included in energy performance efforts. Despite many studies revolving around human behaviour and building energy performance, the understanding of occupant behaviour and its role in building energy performance remains vague, confusing, and inconsistent [67].

According to the feedback on the questionnaire and the desk research carried out on this topic, there is no provision, national requirement, or legal obligation for a Building Management System (BMS)

existence in connection with the operational EPCs. BMS data documentation is not employed as a source of relevant data, or there are no provisions or legal obligations to be used in the issuance or re-issuance of operational EPCs. Given that very little to no information has been retrieved concerning the extent of the data documented by BMS employed in the issuance or re-issuance of operational EPCs. BMS is encountered as part of the documentation, as a tool for more accurate and easier analysis of energy performance of buildings, or is employed as a source of relevant data for newly issued EPCs. Additionally, EPCs are based on calculated data for an indoor reference condition and are not directly connected to real energy uses indicated by BMS. Studies are conducted so as to establish to what extent the data in a BMS can be (re-)used to issue the EPC for non-residential EPCs.

3.2.3 Information schemes regarding Geographic Information Systems

Nowadays, the use of Geographic Information Systems (GIS) is considered useful and effective in a large number of scientific domains and not only in mapping. In the field of energy performance certification and buildings energy efficiency, the spatial attribute tables of mapping building blocks, neighbourhoods, and cities combined with databases is an innovative procedure, and such GIS applications are currently part of Smart Cities [68]. Until today, the most widespread use of GIS technology in this field is the two-dimensional spatial rendering of spatial information (attribute fields as alphanumeric information) and the 'energy' information of each building.

The development of new tools based on spatial databases is a current and future need. The wealth of data available in the proposed dEPCs can be used to create a fully representative picture of the energy profiling of the building stock and act as an invaluable instrument for informing policy and decision making. Visualizing the energy performance in a GIS environment and being able to perform a variety of queries can help authorities not only map and monitor building stock but also quantify energy demand, examine the energy sources used in a building, and launch investment strategies to enhance the share of renewables.

Following the field and desk research, it was revealed that in most of the EU Member States, information related to Geographic Information System (GIS) is not included in the EPCs. Consequently, it is not exploited for issuing, validating, monitoring, and verification processes of the EPC calculation. Several countries employ GIS software for EPCs calculation for climatic and thermal regions. GIS software is used for mapping buildings in the land registry, and there is no legal obligation of using it as a tool for EPC assessment. Nevertheless, in many countries, EPC databases are connected to either the construction and housing register, the official cadastral register (EPC database), or the joint

municipal property register [44]. Additionally, EPC databases are linked to other data sources, such as to national census and GIS online database enabling the visualization of building energy efficiency (2017 beta version), which provides a more comprehensive understanding of the building stock [25][28].

3.2.4 Key facts

- The majority of EU countries do not employ by any means BIM documentation and literacy or digital logbooks for the issuance of EPCs.
- BIM documentation and digital logbooks are used as a source of information for the EPC assessment procedure or energy simulations for building permits.
- There is no obligation for Member States to use BIM software.
- Within the next year, Belgium will establish BIM source documentation for the declaration of the energy performance of newly built buildings, and the Netherlands will provide the option to the three suppliers of the validated calculation tool of using BIM for the EPC calculation.
- There is no provision, national requirement, or legal obligation of a BMS existence in connection with the operational EPCs.
- BMS data documentation is not employed as a source of relevant data, or there are no provisions or legal obligations to be used in the issuance or re-issuance of operational EPCs.
- Studies are conducted so as to establish to what extent the data in a BMS can be (re-)used to issue the EPC for non-residential EPCs.
- In most of the EU Member States, information related to GIS is not included in the EPCs; not exploited for issuing, validating, monitoring, and verification processes of the EPC calculation.
- In many countries, EPC databases are connected to either the construction and housing register, the official cadastral register (EPC database), or the joint municipal property register.

3.3 EPC indicators

3.3.1 Energy-related financial indicators on EPCs

EPCs are, by definition, indicator-oriented documents that aim to inform building users about the energy performance of their space. Energy performance indicators are indispensable tools for prioritizing interventions to monitor and control energy consumption in the building sector. Service standards and principles of the European Commission include the costing of any action taken for the EPCs' issuance and procedures, guided by the benefit of the European citizen. According to this, the development of indicators of an economic nature, such as energy €/m² of building systems, whether

it is of electricity, oil, or gas utilization, will enable the interpretation of the individual elements of buildings' energy performance into normalized monetary values, based on the well-established concept of whole life cycle costing. The delivery of such indicators will also enable the employment of EPCs for the financial assessment of buildings' energy upgrade measures. It will allow the exploitation of the information produced by EPCs by energy audit processes, bridging the gap between the energy-related directives of EPBD and the energy efficiency. This will be accomplished, in compliance with the IEA EBC Annex 56, with the inclusion of the documentation of the economic indicator, which may be employed in EPCs based on the inputs, the outputs, the scope, and the normalization factors.

Following the field and desk research carried out on this topic, energy-related financial indicators are not found to be included in current EPCs schemes and procedures in any EU Member State. It appears that, in several countries, the energy cost and the carbon dioxide emissions per m^2 are included in the EPC procedures. Apart from that, financial indicators for the proposed investments in the building retrofit and the payback time of proposed measures, economic values of energy improvements, and evaluation recommendations for cost-effective measures are reported but not directly issued in the EPC procedure.

The dynamic character of the calculation procedure will impose in the future the regular update of the reference values of the building stock and thus the continuous update of the minimum energy performance requirements of buildings on a national level. Based on the continuous improvement of the minimum energy requirements of EU Member States for new buildings, and in accordance to the Directive 2010/31/EU and the nearly Zero Energy Buildings era, which will start on the 31st of December 2020, this development will lead to the enhancement of the actual energy performance of EU Member States' building stocks.

Indicators are also effective in quantifying the potential impact and benefits of interventions. While defining and constructing energy indicators is rather flexible, their accuracy strongly depends on the quality and detail of available energy end-use data. D^2EPC project's vision is to extend this rationale by introducing a set of additional novel economic indicators in relation to the energy performance of a building, which will turn the energy certificate into a more user-friendly and informative document, covering different aspects of the energy and comfort performance of buildings. Furthermore, based on the EU emissions trading system (EU ETS), the cornerstone of the EU's policy on climate change and cost-effective reduction of greenhouse gas emissions, the conversion of the carbon dioxide emitted by a building into an equivalent cost could be accomplished.

3.3.2 Environmental/LCA related financial indicators on EPCs

Life Cycle Assessment (LCA), as an internationally standardized methodology (ISO 14040, [69]), enables the assessment of the environmental impact of any system throughout its lifecycle. According to the European Commission and its Communication on Integrated Product Policy (COM (2003)302, [70]), it was depicted that more consistent data and consensus LCA methodologies are needed. Actions towards a comprehensive assessment of all the nine categories of the potential environmental impacts of products, such as eutrophication and acidification potential of the building materials of the entire building, should be followed, based on the EU data collection efforts and existing harmonization initiatives. The definition and assessment of the type and functional units of the LCA indicators for EPCs, such as "energy savings", expressed in "embodied energy/m^2" and "carbon reductions", expressed in "carbon dioxide equivalent/m^2" should provide the option to the building design engineers to improve and optimize the environmental performance of the building, based on changes to be integrated at the initial design stages of the building.

Concerning the field and desk research, it was recognized that environmental/LCA-related financial indicators are not considered for the EPC issuance. It was revealed that in many EU countries, the necessity of the carbon footprint assessment based on a complete life cycle analysis has arisen [13]. Environmental indicators present in energy certificates today are usually linked to carbon dioxide emissions, such as calculated during exploitation derived from primary energy. Carbon dioxide emissions vary from country to country depending on each country's energy system, and in particular by the factor of the primary to final energy conversion. Nowadays, energy carriers' primary and final energy demands, such as oil or gas, are estimated as equal. The rationale behind the Primary Energy Conversion Factor is the conversion of final energy consumption to primary energy consumption for the production of an electric unit or thermal energy [71]. Additionally, the comfort factor is combined in assessment systems, but it is not calculated in the analysis. Nevertheless, it is not yet been included any comfort assessment or the employment of sustainable materials with low environmental impact from a life-cycle perspective as a part of a country's EPC calculation method [30]. Either by increasing the share of RES or by improving the building envelope, countries gradually involved citizens in decreasing the non-renewable primary energy of their buildings [9].

The rationale behind including LCA indicators concerns the transition of the EPC to a holistic tool, which considers the entire life cycle of the building as a construction. It will promote best practices in resource efficiency, which is a key policy issue for the European Union. An additional reduction of greenhouse gases is further expected due to the inclusion of LCA indicators within the D^2EPC scheme that will result in the integration of both midpoint and endpoint environmental impact assessment

categories as well as in the utilization of cleaner sources of energy with deficient LCA emission factors. It is highlighted the importance of employing LCA methodologies for the efficient energy design of buildings and enabling the parameterization of its embodied energy and primary energy demand [72] to be included in dynamic EPCs. This task could be implemented in accordance with the content of the IEA EBC Annex 72 concerning the Assessment of Life Cycle Related Environmental Impacts Caused by Buildings. The anticipated benefits of EPC systems can only be achieved through an appropriately endorsed management and control system. Sustainability assessment methods and systems, such as Building Research Establishment Environmental Assessment Method (BREEAM) and Leadership in Energy and Environmental Design (LEED), contribute to a concise framework for building owners and stakeholders by applying third-party verification and certification of the assessment of the sustainability performance of a building. This procedure improves the performance across all the most environmentally essential factors and metrics.

3.3.3 Indoor Environmental Quality indicators on EPCs

Although the EPC calculation process is based on a comprehensive set of standards, it still overlooks some important determinant attributes, such as indoor environmental quality, which can negatively influence occupants' experience in buildings [73]. Also, there is space for the enhancement of the information provided by the EPC to the building user in terms of simply interpreted indicators. Even though thermal and acoustic comfort, indoor air quality, and daylight are among the primary drivers for buildings renovation, they are not considered in current EPCs. At the same time, the recommendations for energy upgrades are automatically generated by a standard list (e.g. increasing insulation, replacing windows, etc.) and do not offer a user-friendly document that would motivate renovation.

The EN 16798 series Standards on the ventilation for buildings include the determination of indoor environmental input parameters for design and assessment addressing indoor air quality, thermal environment, lighting, and acoustics. According to Directive 2018/844/EU and the 2009 World Health Organisation guidelines, a methodology based on the European standards should be followed for the calculation of the energy performance per season and year. The higher the comfort levels are, and therefore the indoor air quality, the healthier and greater the performance of the buildings will be for the owners/users and the energy balance.

Although provisions for indoor environmental quality (including air quality, thermal comfort – the risk of overheating and ventilation, lighting, and acoustics) are set in EPCs, there are not covered in current EPC regimes and are not included in the calculation procedure for certification of EU countries, as it

was revealed by the field and desk research [4][16][19]. Very often, the majority of requirements refer to energy performance and insulation for renovation, but EPCs rarely cover them. In several countries, indoor temperature and values for fresh air needs provided information only consists of a tick-box based on the subjective evaluation of the EPC expert [48]. Nevertheless, a lot of registers are presented data regarding the value of CO_2 emissions associated with primary energy used in the building [24][29].

The currently available tools are generally restricted to determining energy and carbon footprints without integrating specific comfort criteria and analysing the implications of the life cycle of the materials used with associated costs. These additional factors are scarcely considered. They are measured individually rather than integrated on a common consolidated platform, more in a post-processing workflow, even when they are. Thermal comfort models of Fanger [74], Jones [75], Wissler [76], Clo-Man [77], Tranmod [78], and Gagge [79] are used to analyse the users' adaptive behaviour. Moreover, the simulation models of Reinhart [80], Bourgeois et al. [81], Rijal et al. [82], including DOE-2 (Department of Energy-2), BLAST (Building Loads Analysis and System Thermodynamics), eQUEST (QUick Energy Simulation Tool), ESP-r (Environmental Systems Performance, Research version), EnergyPlus, TRNSYS (Transient System simulation program), BESA (Building Energy System Analysis) are used to assess the energy performance [83]. This set of standards and methodologies provides a comprehensive framework for the energy assessment of buildings. However, it is a fact that in EPC calculations, important aspects of these calculation tools are neglected. Despite much-dedicated efforts, a precise and proficient assessment model of user satisfaction with adaptive behaviours is far from being achieved [84]. D^2EPC aspires to integrate significant elements of these tools into the real-time EPC calculation procedure and take into account environmental and human-centric factors that have an impact on a building's energy performance. These actions will be achieved by utilizing real-time energy data and ambient information in order to infer the impact of resident actions and comfort preferences on the building equipment and, as a result, to understand the boundary conditions under which humans will act in order to restore comfortable ambient conditions – including but not limited to thermal comfort, visual comfort, occupants activity profiling, indoor air quality.

3.3.4 Key facts

- Energy-related financial indicators are not found to be included in current EPCs schemes and procedures in any EU Member State.
- In several countries, the energy cost and the carbon dioxide emissions per m^2 are included in the EPC procedures.
- Environmental/LCA-related financial indicators are not taken into consideration for the EPC issuance.

- Environmental indicators, which are present in energy certificates today, are usually linked to carbon dioxide emissions.
- The comfort factor is combined in assessment systems, but it is not calculated in the analysis.
- It is not yet been included any comfort assessment or the employment of sustainable materials with low environmental impact from a life-cycle perspective as a part of a country's EPC calculation method.
- Indoor environmental quality indicators are not covered in current EPC regimes and are not included in the calculation procedure for certification of EU countries.

3.4 Qualified experts' competence and skills

3.4.1 Joint databases of building systems and building elements

EPCs constitute a significant database where big data concerning the actual energy performance of the European building stock are gathered. The appropriate management of this data can drive the developments in the field of policymaking in the EU. Should the appropriate buildings' energy monitoring infrastructure be developed, EPC registries have the potential to become the EU monitoring database of the actual energy consumption of the European building stock.

According to the Directive 2018/844/EU, information concerning EPCs should be collected in national databases available for monitoring and verification practicality, aiming at developing data of the highest class relevant to the building stock of all Member States. This action, given that it is in accord with Union law and legislation, should not comprise as an inhibitory factor for other challenging and goal-oriented energy performance requirements for buildings and for building elements of the Member States. The EPC delivery process can be subjective due to a lack of assessors' competency, and, as a result, data quality can be easily influenced by the energy assessors because of the standard assumptions made in the process of producing the certificate. Thus, the need for high-quality data regarding the building stock is accurate, and it could be satisfied by the developed EU EPC databases of Member States.

As per the field and desk research carried out on this issue, it appeared that most EU Member States had developed central databases for collection, registration, and inspection of EPCs and technical building systems of existing and new buildings, which are used as well for exporting statistics [4][23]. No doubt, there is no existence of a database describing the energy efficiency features of the building stock as a whole [14][21]. Nevertheless, in some cases, there is available comprehensive information regarding the physical stage of the existing building stock gathered during the EPC issuance procedure [10]. The employment of inventories, in relation to properties of building materials and building

systems, is not a practice that is usually followed, but it has been developed an online public database providing characteristics of construction products, such as walls and floors. This kind of database could be enhanced and included in the next-generation EPCs. In some countries, only parts of the building stock are examined visually or estimated in relevance to the calculations, as in the case of windows quality and infiltration estimation of buildings [16][46]. EPC auditors do not have access to joint databases concerning the properties of building systems and building elements, but there is the existence of websites including indicative default values for heat transmission values for building elements accessible from appointed standards [46]. Depending on the country, information regarding building elements and systems is available with gradual allowance/permission to the auditors, or access is permitted for calculations. In several EU countries, a lot of such data is provided in national guidelines and regulations but not included in a separate database. Till now, all around the EU have set the minimum performance preconditions and regulations for technical building systems and building envelope elements, as well as have put in place measures and inspections concerning the buildings or technical elements [12][21][32]. In the coming years, these requirements and attempts will be extended in relation to building systems and elements databases.

Digitalization of the process of EPC issuing and updating through the integration of intelligent infrastructure in the certification process would support harmonization of EPC data collection, enable automatic upload to a central registry and make the statistical analysis of data simple from a technical point of view [85]. Moreover, the use of advanced design models and tools could turn EPC into a tool, which would enable holistic technical, economic, and environmental approaches for the design and operation of sustainable buildings. Linking the design process with the calculation process can significantly speed up the EPC issuing and updating process, reduce potential mistakes and better represent the functional and physical characteristics of a building. At the same time, the wealth of data in EPC databases can be used for profiling the energy status. The gap between joint databases of building systems and building elements could be covered based on the provisions of the standard ISO 10456:2007 [86] about the thermophysical properties of building materials as well as the EN 15459-1:2017 [87] about the economic evaluation procedure for energy systems in buildings. This means that information regarding the cost and life cycle of several building materials could be extracted and enhance the quality of the data already used to issue the EPCs.

3.4.2 Energy assessors' competence and skills

As of current, most EPC calculations rely on a range of standard inputs or default inputs, the competency of the assessors is an important reason for the formation of several constraints and limitations in the current EPCs [88]. To ensure the high quality of EPCs, the energy assessor's

competence is needed to be considered in the accreditation procedure (Art. 17, 2010/31). The training, successful qualification, and accreditation of assessors of all Member States are of high importance for the energy efficiency and performance of buildings, and this was initially addressed by the inspection schemes of Directives 2010/31/EU and 2018/844/EU.

Following the field and desk research carried out for this topic, it is depicted that one-third of EU countries do not have provision for systematic and regular evaluation/assessment of energy assessor's competence and skills. There is a legislative gap in both the certification and the regular evaluation. Intending to improve the quality of the EPCs further, experts have to update their skills and knowledge continuously through regular training and lack of malpractice, with France having the most long-term control in their regulatory requirements [13][38]. It emerged that energy assessors in each country have to follow different practices to retain their certification and relevant to EPCs knowledge. More specifically, there is a qualification system according to which assessors need to renew their occupational qualification certificates annually, every five (5) years, or every seven (7) years, depending on the country. This is based on reference works and/or participation in in-service training courses. Furthermore, evaluation and periodic training and workshops prescribed by legislation have to be followed in order for EPC assessors to have a valid certificate. In the majority of the EU countries, periodic training and verification are not required [6][28]. In some of these countries, EPC assessors are certified once, and their license is valid for the rest of their lives [46]. In several countries, there is a point system, i.e. collection of credits that training sessions workshops, and courses can earn or can be loosened in case of not enough evident education or repeated mistakes in their EPCs. The latter may lead to re-examination. If accredited inspectors fail the examination, then access to the register, the open database, and the EPCs' issuing authorization can be temporarily or permanently withdrawn [13][30][31]. In some other EU countries, at least once a year or more, depending on the country, a training program for a specific number of hours is mandatory for energy assessors responsible for energy certifications of buildings and inspections of heating systems [46]. A fee for renewal of registration may be paid annually as well as additional educational or administrative requirements for assessors paid by them [38][41]. In countries that no mandatory training is required for energy assessors, there is a voluntary attendance of seminars and training organized by vocational centers and academic institutions [15][46].

3.4.3 Key facts

- Most EU Member States have developed central databases for collection, registration, and inspection of EPCs and technical building systems of existing and new buildings, which are used as well for exporting statistics.

- There is no existence of a database describing the energy efficiency features of the building stock as a whole.
- In some countries, only parts of the building stock are examined visually or estimated in relevance to the calculations.
- 1/3 of the EU countries do not have provision for systematic and regular evaluation/assessment of energy assessor's competence and skills.
- Experts have to continuously update their skills and knowledge through regular training and lack of malpractice.
- In the majority of the EU countries, periodic training and verification are not required.
- In some countries, EPC assessors are certified once, and their license is valid for the rest of their lives.

4 Overall progress overview

4.1 Sister projects synergy

A big community, including among others researchers, market actors, and policy makers, is working towards a more sustainable energy approach while exchanging synergies with similar projects under the Horizon 2020 initiative. The synergy of these projects under the topic "Next-generation of Energy Performance Assessment and Certification" includes proposals that should consist of measures that encourage EU-wide convergence of EPC schemes and enhance the linkage between EPCs and deep renovation. This ensures a consistent level of high-quality, independent control and certification. In Europe, improving the energy efficiency of buildings is a priority, and Energy Performance Certificates (EPCs) are the main instrument towards decarbonized building stock. Some projects focus on specific issues concerning the EPCs. For example, the "Integrating Building Renovation Passports into Energy Performance Certification schemes for a decarbonized building stock - **iBRoad2EPC**" project [105] investigates energy performance assessment schemes and certification methods for the promotion and showcasing of the integration of Building Renovation Passport features into EPC schemes. Also, the "High-quality Energy Performance Assessment and Certification in Europe Accelerating Deep Energy Renovation – **QualDeEPC**" project [97] intends to improve the quality and cross-EU convergence of EPC programs, as well as the link between EPCs and thorough rehabilitation by providing refurbishment recommendations. Inaccuracy, a disconnect between theoretical and actual usage, a lack of adequate protocols for incorporating smart and novel technology, a lack of convergence across EU schemes, and a lack of user knowledge of energy efficiency are among the various issues of EPCs. For that reason, homogeneity across Europe is one of the goals of the "European

Building Sustainability performance and energy certification Hub - **EUB SuperHub**" project [103], which helps create a standardized certification procedure in the EU by providing a scalable system for viewing, assessing, and monitoring buildings throughout their life cycle, as well as the "Cross Assessment of Energy Certificates in Europe – **crossCert**" project [106] which aims to increase the EPCs' accuracy and usability by developing a product testing methodology for new EPC approaches. Monitoring energy performance is critical to the creation of a more sustainable, environmentally friendly, and secure future. With this in mind, on one hand, the "Towards innovative methods for energy performance assessment and certification of buildings – **TIMEPAC**" project [104] aims to improve the effectiveness and reliability of certification of EPCs by moving away from a single, static certification and toward a more holistic and dynamic system. On the other hand, the "Smart European Energy Performance AssessmeNt And CErtificAtion – **ePANACEA**" project [100] intends to provide a holistic methodology by employing cutting-edge approaches in dynamic and automated simulation modeling, big data analysis, machine learning, and inverse modeling. In addition, the increase in energy efficiency, as well as the improvement of the overall building performance, are two of the ultimate goals of the next-generation EPCs. Thus, the recommendation of more effective energy-saving actions integrated by the "Energy flexible DYnamic building CErtification - **E-DYCE**" project [101] is presented. Moreover, the new set of energy-performance criteria so as to make new certification schemes more practical and reliable using a comprehensive and user-centered approach implemented by the "Towards a new generation of "user-centered Energy Performance Assessment and Certification"; facilitated and empowered by the EPB Center - **U-CERT"** project [99] is presented as well. Furthermore, the focus remains on the way that could better serve the next-generation EPC performance. On the one hand, by developing an online hub presenting all of the available revolutionary features, including smart solutions, trusted examples, and computations, as well as guidance and recommendations in the "eXTENDing the energy performance assessment and certification schemes via a mOdular approach - **X-tendo**" project [98]. On the other hand, by creating a well-structured toolkit to enable the development, performance, and validation of new EPCs, focusing on existing residential buildings with significant retrofit needs in the "Energy Performance Certificate Recast - **EPC RECAST**" project [102]. An overview of the aforementioned projects is presented in Table 2.

4.2 Energy Performance of Buildings Directive Recast

In December of 2021, the European Commission suggested the recast of the Energy Performance of Buildings Directive [95] within the "Fit for 55 %" Package of policies that aims to put Europe on pace to reduce carbon emissions by 55% by 2030. The proposed revised version of the Energy Performance of Buildings Directive brings new standards for energy efficiency to reduce carbon emissions in the

built environment, with adjustments to concepts of energy performance standards, modifications to national building renovation plans, and a new procedure for life-cycle emission measurements for new builds. The proposal adds various additional definitions that raise the bar for restoration efforts [96], such as the zero-emission building, the nearly-zero energy building, and the deep renovation until 2030 or after 2030 (Articles 2 and 6). National Building Renovation Plans, known initially as "Long-Term Renovation Strategies," will need to be modified by 2030, 2040, and 2050 to contain a timeframe and national goals (Article 3). Additionally, Member States must ensure that all public and non-residential buildings are at least class F or E by 2027, with all residential structures achieving class F or E by 2033 (Article 6). 15% of the current building stock, estimated to be over 40 million structures across the EU, would need to be refurbished to achieve these objectives. All new buildings must be zero-emission by 2030, and public buildings must be zero-emission until 2027 (Article 7). This will account for the structures' whole life-cycle carbon emissions, encompassing the processes of production and construction, use, and end-of-life. Furthermore, by 2025, the modified EPBD attempts to discourage all financial support for fossil fuel boilers, providing the Member States with a legal basis to do so (Article 11). New requirements aim at improving the Smart Readiness Indicator and Energy Performance Certificates, as well as giving data to owners and buyers and maintaining uniformity across the EU are among the ultimate goals of this recast (Articles 13-19).

5 Conclusions

Despite substantial gaps in the existing European EPCs procedures, D^2EPC ambitiously aims to set the grounds for the next generation of dynamic Energy Performance Certificates (EPCs) for buildings. Therefore, the proposed scheme will contribute to the redefinition of EPC-related policies and the update of current standards, guidance for their implementation, and introduce incentivization and restriction practices into the EPC rationale. The collective analysis of data for the specific features of EPCs revealed that among the twenty-seven (27) EU Member States, fourteen (14) had adopted the methodology based on calculated energy consumption. Both the actual and calculated energy consumption in some Member States are foreseen. In addition, for new and existing buildings, the period of validity of an EPC currently issued to receive a building permit is up to ten (10) years in most EU countries. It is recommended, and in some countries required, to be updated following a major reconstruction-renovation of the building envelope or the technical systems, even if the works take place before the expiry date. Furthermore, none of the EU Member States apply incentives or penalties concerning the owners' compliance or non-compliance with the certificated assessment based on operational data in case of re-assessment of an EPC. Penalties are rare and are mainly addressed to energy auditors.

Based on the research of this report, it was revealed that the majority of EU countries do not employ by any means BIM documentation and literacy or digital logbooks for the issuance of EPCs. Even though there is the provision of BIM documentation and digital logbooks in some countries, these are used as a source of information for the EPC assessment procedure or energy simulations for building permits. There is no provision, national requirement, or legal obligation of a Building Management System (BMS) existence in connection with the operational EPCs. BMS data documentation is not employed as a source of relevant data, or there are no provisions or legal obligations to be used in the issuance or re-issuance of operational EPCs. Additionally, it was shown that in most of the EU Member States, information related to Geographic Information System is not included in the EPCs. Consequently, it is not exploited for issuing, validating, monitoring, and verification processes of the EPC calculation.

Analysis across the EU Member States, energy-related financial indicators are not found to be included in current EPCs schemes and procedures in any EU Member State. It appears that in several countries, the energy cost and the carbon dioxide emissions per m^2 are included in the EPC procedures. Apart from that, financial indicators for the proposed investments in the building retrofit and the payback time of proposed measures, economic values of energy improvements, and evaluation recommendations for cost-effective measures are reported but not directly issued in the EPC procedure. It was recognized that environmental/LCA-related financial indicators are not taken into consideration for the EPC issuance. Environmental indicators, which are present in energy certificates today, are usually linked to carbon dioxide emissions, which consequently vary from country to country depending on each country's energy system, and in particular by the factor of the primary to final energy conversion. The rationale behind the Primary Energy Conversion Factor is the conversion of final energy consumption to primary energy consumption for the production of an electric unit or thermal energy. Although provisions for indoor environmental quality (including air quality, thermal comfort – the risk of overheating and ventilation, lighting, and acoustics) are set in EPCs, there are not covered in current EPC regimes and are not included in the calculation procedure for certification of EU countries.

EPCs constitute a significant database where big data concerning the actual energy performance of the European building stock are gathered. Most EU Member States have developed central databases for the collection, registration, and inspection of EPCs and technical building systems of existing and new buildings. Without any doubt, there is no existence of a database describing the energy efficiency features of the building stock as a whole. Nevertheless, in some cases, there is available comprehensive information regarding the physical stage of the existing building stock gathered during the EPC issuance procedure. The employment of inventories, in relation to properties of building materials and

building systems, is not a practice that is usually followed, but as time goes by, this kind of information and databases could be enhanced and included in the next-generation EPCs. One-third of EU countries do not have provision for systematic and regular evaluation/assessment of energy assessor's competence and skills. Intending to improve the quality of the EPCs further, experts have to update their skills and knowledge continuously through regular training. More specifically, there is a qualification system according to which assessors need to renew their occupational qualification certificates in a period of time, depending on their country.

The field and desk research conducted for the purposes of this report have depicted the substantial gaps in the existing European EPCs procedures, where the D^2EPC project aims to contribute in the following ways:

a. The introduction and establishment of the concept of the dynamic EPC (dEPC), an operational certificate to be calculated and issued on a regular basis by:
   - the establishment of the concept of dynamic EPCs issued regularly.
   - enabling the regular update of EU Member States' reference values of their building blocks.
   - the regular information of building owners on the actual class of their buildings, in comparison to regional average values.
   - the development of "polluter pays" and reward policies for building users with below or exceeded expectations EPCs.
b. The definition of the drawbacks and discrepancies of the current EPC scheme, as well as the update of EU standards on the classification requirements of buildings;
c. The enhancement of EPCs through a novel set of indicators that cover environmental, financial, human comfort, and technical aspects of new and existing buildings aiming to simplify the understanding of buildings' energy performance and to present a more comprehensive overview of the actual energy performance of buildings with the introduction of LCA and human comfort-related indicators as well as monetary indicators for the energy assessment and certification of new and existing dwellings and non-dwellings;
d. The integration of actual operational data from buildings into the EPCs using advanced data collection infrastructure and BEPS tools integrated into BIM;
e. The integration of smart readiness rationale into the building's energy performance assessment and certification with the introduction of SRI related indicators for the energy assessment and certification of new and existing dwellings and non-dwellings;

f. Intelligent operational digital platform for dynamic EPCs issuance and actual building performance monitoring and improvement, validated and demonstrated under realistic conditions with the introduction of geolocation representation of actual energy performance of buildings.

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[98]. eXTENDing the energy performance assessment and certification schemes via a mOdular approach – X-tendo Link: https://cordis.europa.eu/project/id/845958
[99]. Towards a new generation of user-centered Energy Performance Assessment and Certification; facilitated and empowered by the EPB Center – U-CERT Link: https://cordis.europa.eu/project/id/839937
[100]. Smart European Energy Performance AssessmeNt And CErtificAtion – ePANACEA Link: https://cordis.europa.eu/project/id/892421
[101]. Energy flexible DYnamic building Certification – E-DYCE Link: https://cordis.europa.eu/project/id/893945
[102]. Energy Performance Certificate Recast – EPC RECAST Link: https://cordis.europa.eu/project/id/893118
[103]. European Building Sustainability performance and energy certification Hub - EUB SuperHub Link: https://cordis.europa.eu/project/id/101033916
[104]. Towards innovative methods for energy performance assessment and certification of buildings – TIMEPAC Link: https://cordis.europa.eu/project/id/101033819
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Annex A-Tables

Table 1: Prioritization of Stakeholders [assessment and engagement]

A/A	Name	Role	Power	Prox.	Urg.	Priority	Level of Communication
1.	EPC Registries	Deployment of the service	4	4	5	**1**	High Priority
2.	Engineers	Service provider - Implementation	4	4	4	**2**	High Priority
3.	Suppliers	Direct or indirect affected parties	4	4	4	**3**	High Priority
4.	R&D sector	Deployment of the service	4	4	4	**4**	**Heroic**
5.	Contractors, sub-contractors	Service provider - Implementation	4	3	4	**5**	High Priority
6.	State/Governmental Departments - Public bodies	Decision maker on National level - Service, operation & Monitoring	4	3	4	**6**	High Priority
7.	Users/Owners	Directly affected parties	4	2	4	**7**	High Priority
8.	Building Designers	Service provider - Implementation	4	3	3	**8**	High Priority
9.	Energy Agencies	Policy advisor & Monitoring	4	3	3	**9**	High Priority
10.	Energy service companies (ESCOs)	Service provider - Implementation	4	2	3	**10**	High Priority
11.	Standardization Bodies	Key decision maker - Defining the context	3	3	3	**11**	Focused
12.	Researchers/Academia	Deployment of the service	3	3	3	**12**	Business As Usual

13.	Tool developers	Deployment of the service	3	2	3	**13**	Focused
14.	Building Material Industries	Direct on inderct affected parties	3	2	3	**14**	Focused
15.	EU Commission - legislative instruments	Key decision maker - Defining the context	1	1	3	**15**	Business As Usual
16.	Real Estate agencies	Directly affected parties	1	1	3	**16**	Focused
17.	Consumer associations	Directly affected parties	1	1	3	**17**	Business As Usual
18.	Facility Managers	Direct on indirect affected parties	1	1	2	**18**	Business As Usual
19.	Local community groups and associations	Parties that may be interested	1	1	2	**19**	Focused
20.	Environmental/social campaigning organizations	Parties that may be interested	1	1	2	**20**	Focused
21.	Building Services Industry	Direct on indirect affected parties	1	2	1	**21**	Focused
22.	Financial Institutions/Banks	Deployment of the service	1	2	1	**22**	Business As Usual
23.	Media	Parties that may be interested	1	1	1	**23**	Business As Usual

Table 2: Overview of sister project

Project Acronym	Objective	Link
1. QualDeEPC	▪ quality and cross-EU convergence deep renovation ▪ practical implementation of the assessment, issuance, design and use ▪ renovation recommendations	https://cordis.europa.eu/project/id/847100
2. X-tendo	▪ online hub ▪ innovative features from smart solutions and trusted examples ▪ calculations to guidelines and recommendations	https://cordis.europa.eu/project/id/845958
3. U-CERT	▪ practical and reliable certification schemes via a holistic and user-centred approach ▪ new set of energy-performance standards easily accessible to a wide range of users by leveraging the diverse services ▪ decarbonised EU building stock	https://cordis.europa.eu/project/id/839937
4. ePANACEA	▪ holistic methodology for energy performance assessment and certification of buildings ▪ advanced techniques in dynamic and automated simulation modelling, big data analysis, machine learning and inverse modelling ▪ energy transition through the building sector	https://cordis.europa.eu/project/id/892421
5. EPC RECAST	▪ development, performance, validation ▪ existing residential buildings with high retrofit needs	https://cordis.europa.eu/project/id/893118
6. E-DYCE	▪ methodology for dynamic EPC intended to replace or be used in conjunction with the current static or steady-state methodology ▪ suggest more effective energy-efficient behaviours to consumers.	https://cordis.europa.eu/project/id/893945
7. EUB SuperHub	▪ developing a scalable methodology to view, assess and monitor the operational use of buildings throughout their life cycle	https://cordis.europa.eu/project/id/101033916
8. TIMEPAC	▪ monitoring of energy performance ▪ transition from a single, static certification to a more holistic and dynamic ▪ combine EPC databases with other data sources to make certification more effective and reliable ▪ develop training resources about certification processes	https://cordis.europa.eu/project/id/101033819

9. iBRoad2EPC	▪ In this context, the EU-funded iBRoad2EPC project will explore ▪ energy performance assessment schemes ▪ certification practices of promoting and showcasing the integration of Building Renovation Passport elements into EPC schemes. ▪ support policy proposals and improve the implementation process of EPCs	https://cordis.europa.eu/project/id/101033781
10. crossCert	▪ product testing methodology for new EPC building renovation goals ▪ improve the accuracy and usability of the EPCs ▪ boost homogeneity across Europe	https://cordis.europa.eu/project/id/101033778

Annex B- Figures

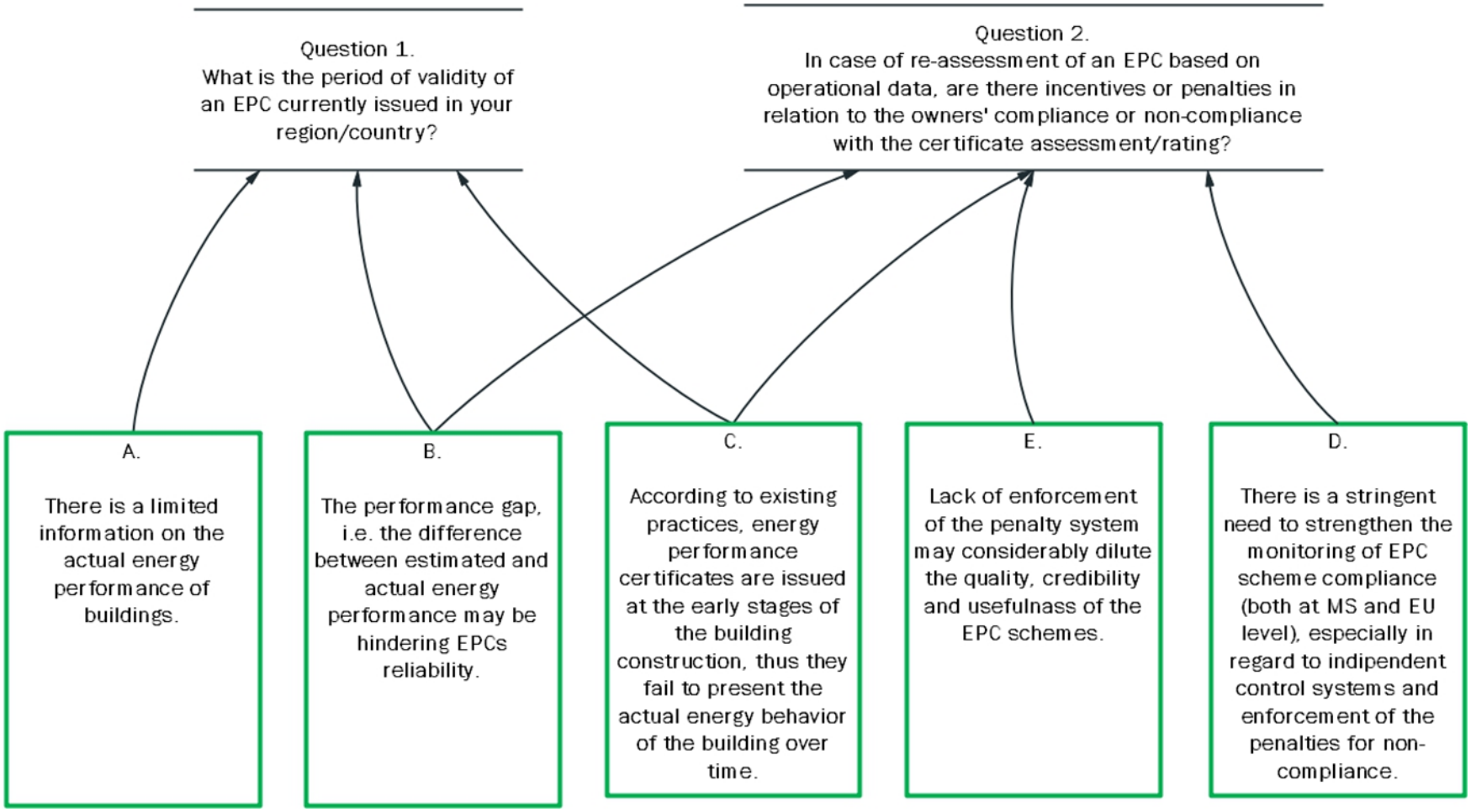


Figure 1: EPCs issuing, quality and control

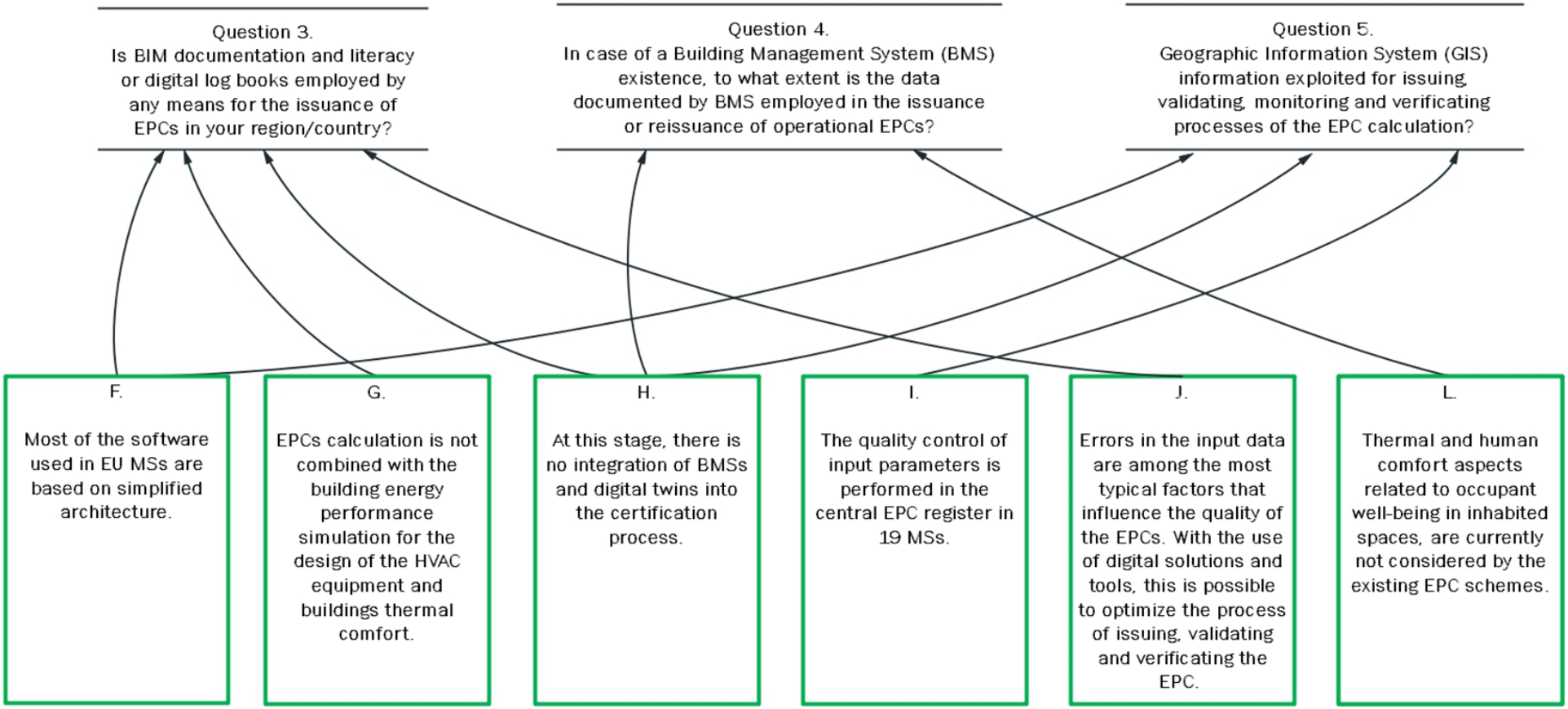


Figure 2: EPCs calculation software and tools

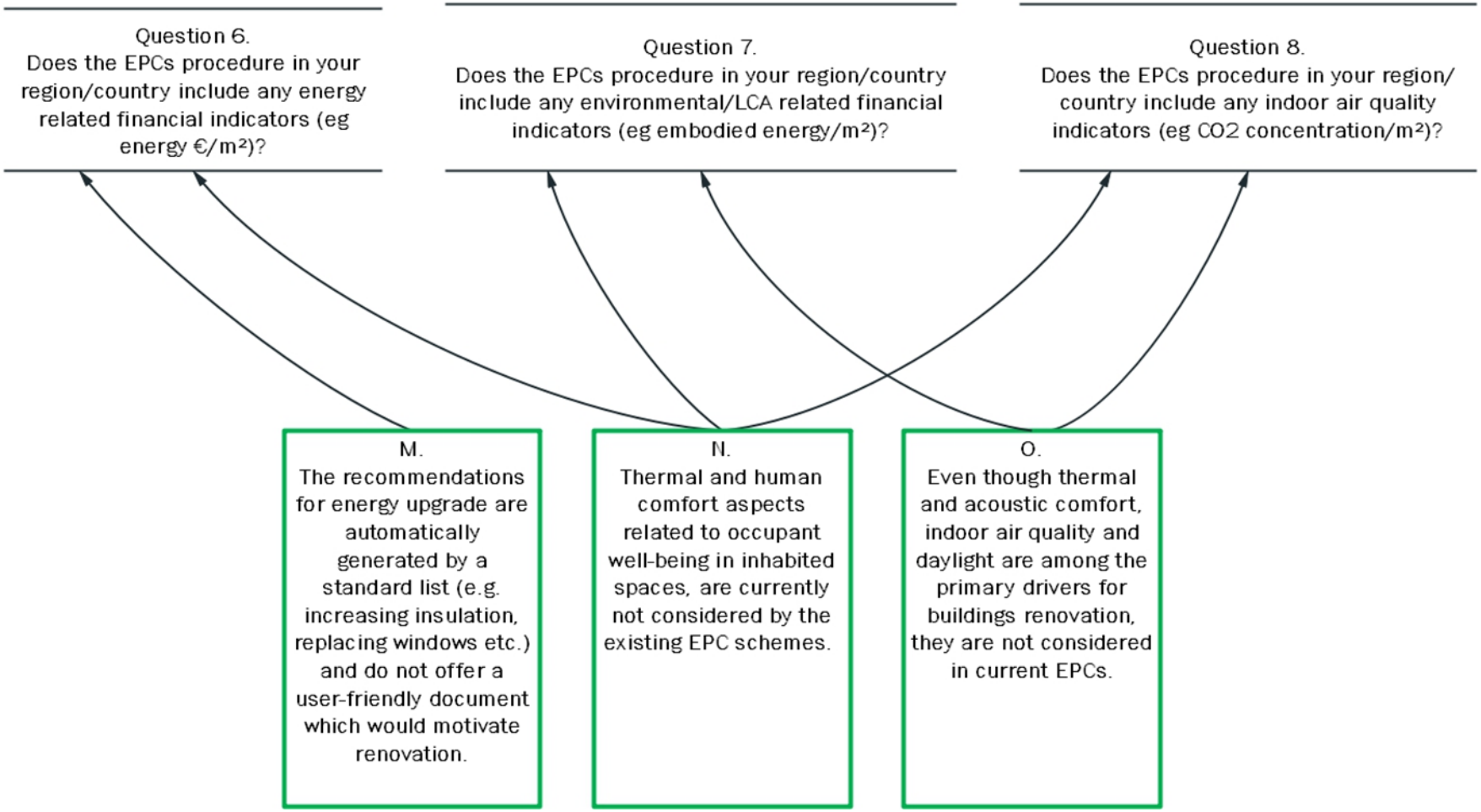


Figure 3: EPCs indicators

Question 9.
Do the EPC auditors have access to joint databases concerning the properties of building systems and building elements?

P.	Q.	R.	U.	W.	X.	Y.
15% of EPCs lodged are incorrectly rated.	Among the 28 EU MSs, 14 have adopted the methodology exclusively based on calculated energy consumption.	Almost all MSs set up a system to collect EPC data voluntarily and in most cases, the responsibility to manage the databases lies with the central or regional government bodies.	The EPC delivery process can be subjective, and, as a result, data quality can be easily influenced by the energy assessors because of the standard assumptions made in the process of producing the certificate.	In 12 countries, public access to the EPC information is provided either via direct access to the database and / or aggregated results, however 9 countries do not allow public access.	In 11 MSs, the first quality control of input data is performed in the calculation software (i.e. plausibility check).	Errors in the input data are among the most typical factors that influence the quality of the EPCs. With the use of digital solutions and tools, this is possible to optimize the process of issuing, validating and verificating the EPC.

Figure 4: Qualified experts competence and skills

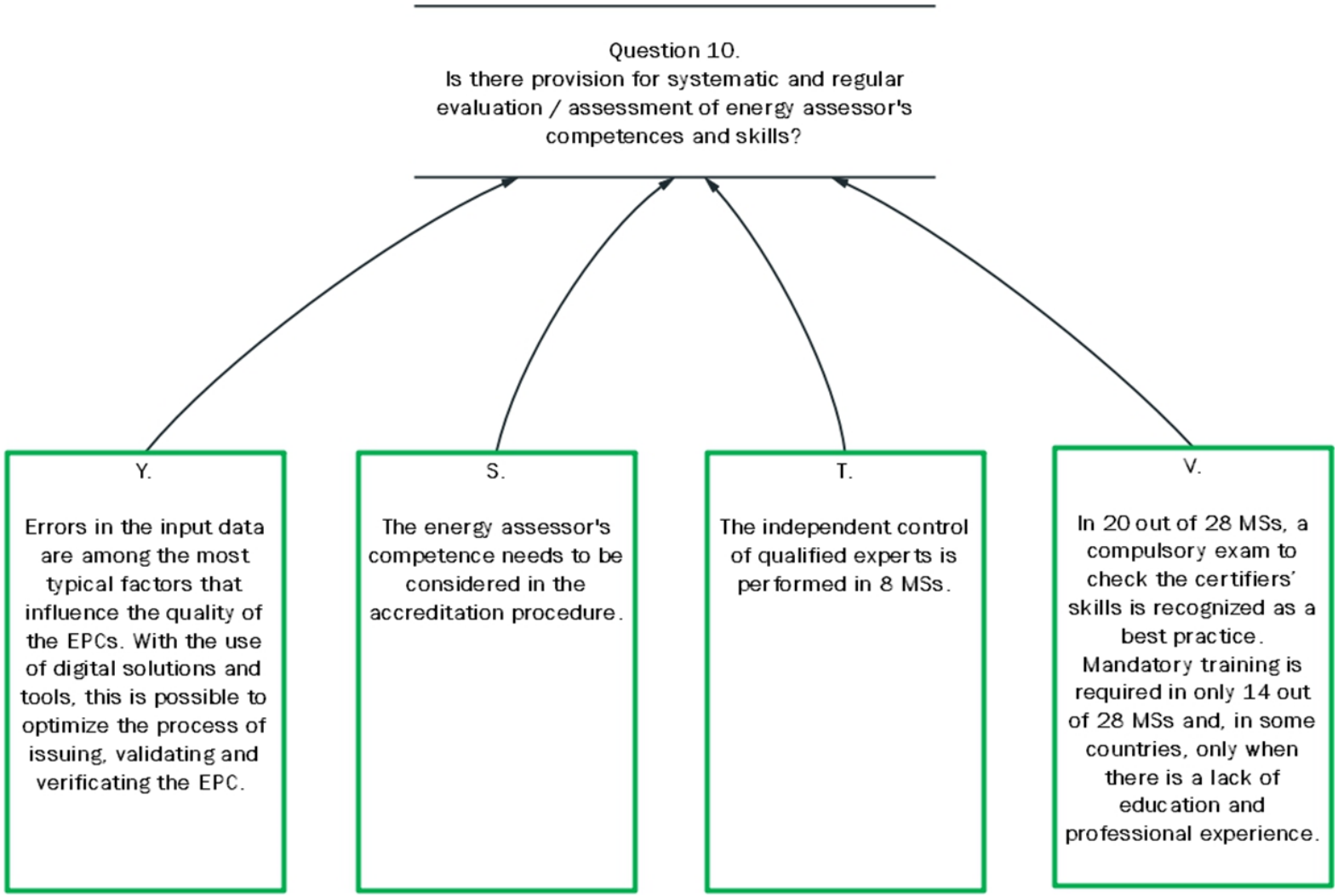
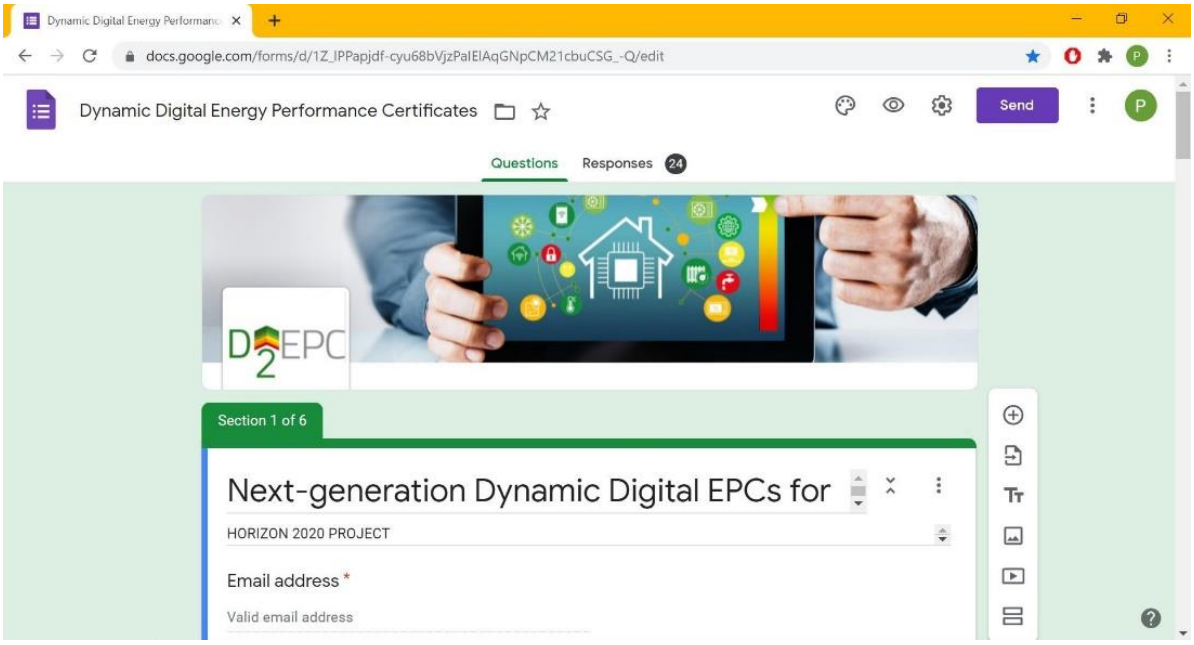
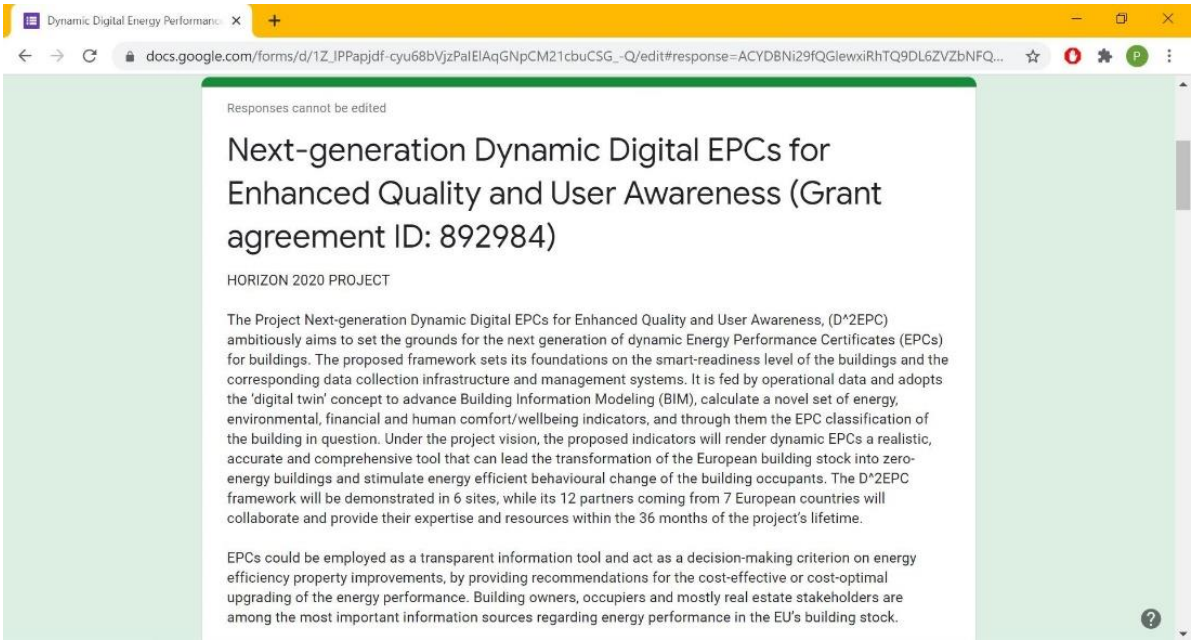
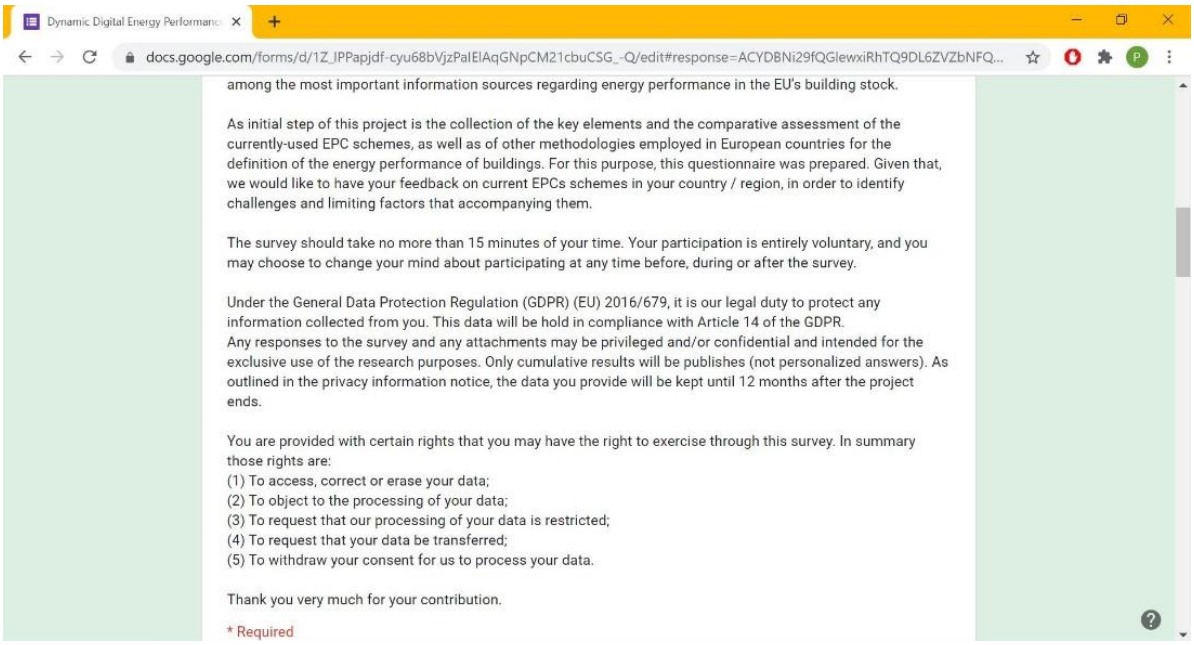


Figure 5: Qualified experts competence and skills (cont'd)

ANNEX C: Stakeholders questionnaire – e-Questionnaire



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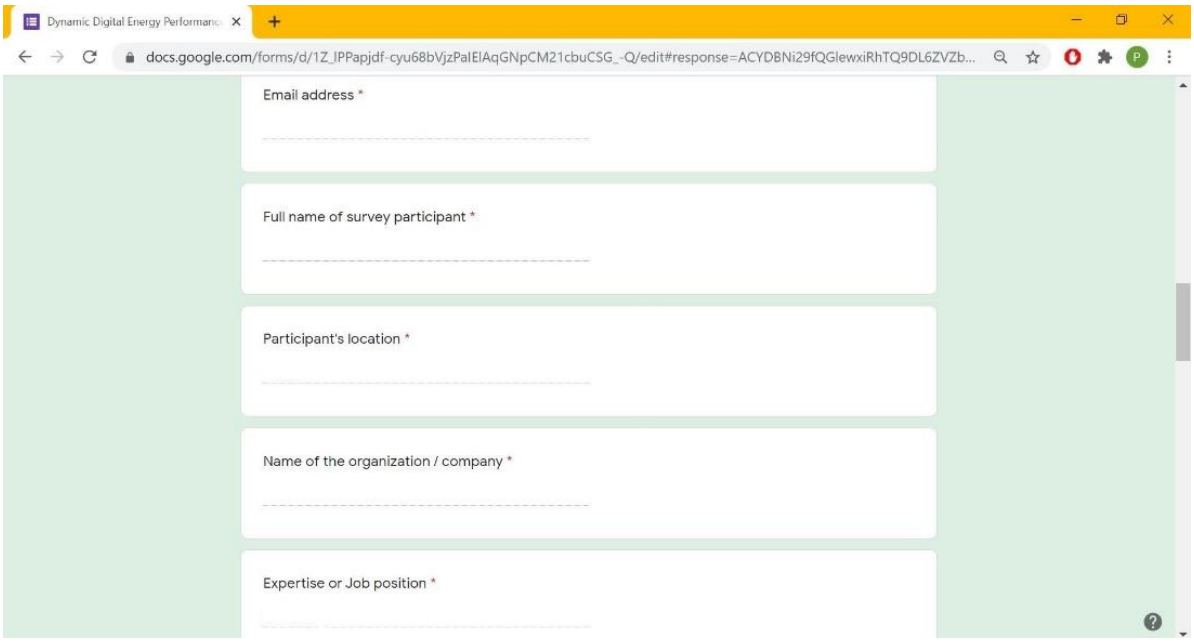
among the most important information sources regarding energy performance in the EU's building stock.
As initial step of this project is the collection of the key elements and the comparative assessment of the currently-used EPC schemes, as well as of other methodologies employed in European countries for the definition of the energy performance of buildings. For this purpose, this questionnaire was prepared. Given that, we would like to have your feedback on current EPCs schemes in your country / region, in order to identify challenges and limiting factors that accompanying them.
The survey should take no more than 15 minutes of your time. Your participation is entirely voluntary, and you may choose to change your mind about participating at any time before, during or after the survey.
Under the General Data Protection Regulation (GDPR) (EU) 2016/679, it is our legal duty to protect any information collected from you. This data will be hold in compliance with Article 14 of the GDPR.
Any responses to the survey and any attachments may be privileged and/or confidential and intended for the exclusive use of the research purposes. Only cumulative results will be publishes (not personalized answers). As outlined in the privacy information notice, the data you provide will be kept until 12 months after the project ends.
You are provided with certain rights that you may have the right to exercise through this survey. In summary those rights are:
(1) To access, correct or erase your data;
(2) To object to the processing of your data;
(3) To request that our processing of your data is restricted;
(4) To request that your data be transferred;
(5) To withdraw your consent for us to process your data.
Thank you very much for your contribution.
* Required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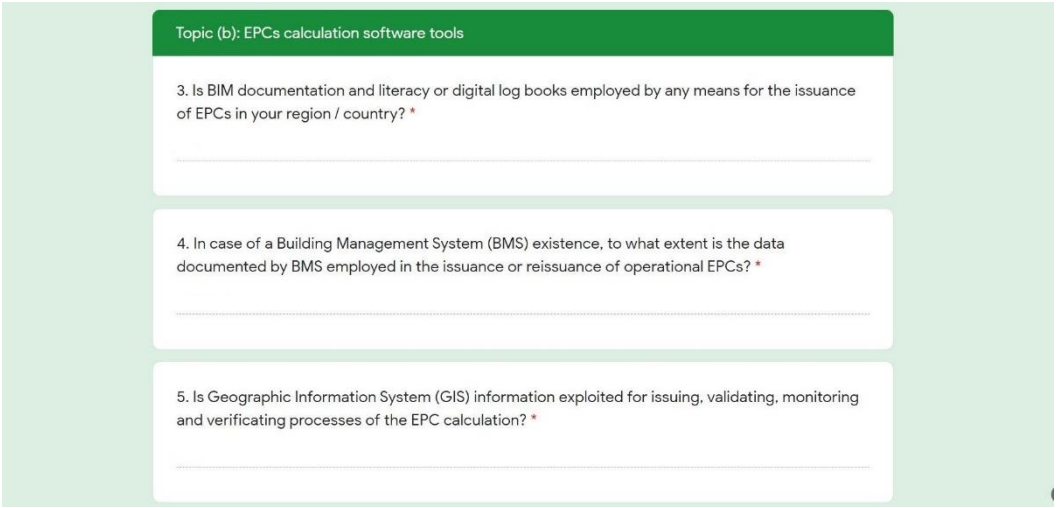
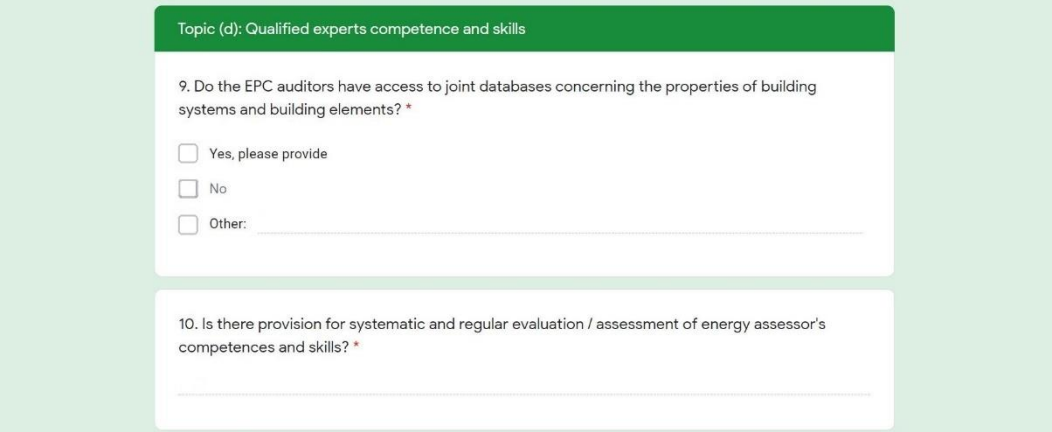
Email address *
Full name of survey participant *
Participant's location *
Name of the organization / company *
Expertise or Job position *


Topic (a): EPCs issuing, quality and control
1. What is the period of validity of an EPC currently issued in your region/country? *
2. In case of re-assessment of an EPC based on operational data, are there incentives or penalties in relation to the owners' compliance or non-compliance with the certificate assessment / rating? *


Topic (b): EPCs calculation software tools
3. Is BIM documentation and literacy or digital log books employed by any means for the issuance of EPCs in your region / country? *
4. In case of a Building Management System (BMS) existence, to what extent is the data documented by BMS employed in the issuance or reissuance of operational EPCs? *
5. Is Geographic Information System (GIS) information exploited for issuing, validating, monitoring and verificating processes of the EPC calculation? *


Topic (c): EPCs indicators
6. Does the EPCs procedure in your region / country include any energy related financial indicators (e.g. energy € / m²)? *
7. Does the EPCs procedure in your region / country include any environmental / LCA related financial indicators (e.g. embodied energy / m²)? *
8. Does the EPCs procedure in your region / country include any indoor air quality indicators (e.g. CO2 concentration / m²)? *


Topic (d): Qualified experts competence and skills
9. Do the EPC auditors have access to joint databases concerning the properties of building systems and building elements? *
Yes, please provide
No
Other:
10. Is there provision for systematic and regular evaluation / assessment of energy assessor's competences and skills? *

ANNEX D: Field research

i. EPCs issuing, quality and control

A/A	Country	Type of Stakeholder	Q1. What is the period of validity of an EPC currently issued in your region/country?	Q.2 In case of re-assessment of an EPC based on operational data, are there incentives or penalties in relation to the owners' compliance or non-compliance with the certificate assessment/rating?
1.	Austria	Energy Agency	10 years	No
2.	Austria	Energy Agency	10 years	Penalties if there is no EPC
3.	Austria	Contractors, sub-contractors	10 years	There are only requirements for new buildings and renovation regarding the EPC.
4.	Belgium	Energy Agency	10 years	No (in Flanders, there is nog re-assessment of an EPC based on operational data. At least, if you mean that operational data = measured energy consumptions, measured U-values, etc.)
5.	Bulgaria	ESCO	up to 6 years	Yes
6.	Bulgaria	State/Governmental Departments	3 years	Yes
7.	Croatia	Energy Agency	10 years	There is no re-assessment based on operational data predicted
8.	Cyprus	State/Governmental Departments	10 years	Operational data are not taken into account for the calculation of energy performance rating. The assessment is based on relevant estimations.
9.	Czech Republic	ESCO	10 years	Not aware of any
10.	Denmark	Researcher/Academia	10 years	Don't know

11.	Estonia	Researcher/Academia	10 years	No
12.	Finland	Researcher/Academia	10 years	No penalties. Finnish EPC is always based on energy calculation, not operational.
13.	France	Engineer	10 years	No
14.	Germany	ESCO	10 years	No
15.	Greece	Engineer	10 years	Operational data are not taken into account for the calculation of energy performance rating. It is optional for an EPC Assessor to provide with them.
16.	Greece	ESCO	10 years	No
17.	Greece	Engineer	10 years	No. The EPC is not based on operational data but the Asset method
18.	Greece	ESCO	10 years	No
19.	Greece	Engineer	10 years	No
20.	Hungary	R&D sector	10 years, or shorter, if there is a major repair	No information
21.	Ireland	ESCO	10 years	Asset rating only in Ireland
22.	Italy	Researcher/Academia	10 years	No penalties, no incentives
23.	Italy	Engineer	10 years	Yes
24.	Latvia	Researcher/Academia	2 year for new and 10 years for existing	Not to owners. Some penalties can be applied to the energy auditor
25.	Lithuania	Researcher/Academia	no longer than 10 years	Re-assessment can be performed under owners' will or under the requirement of the control institution, but it does not depend on operational data; penalty for an incorrect certificate can be a warning, a

				suspension of the accreditation for 6 months, or cancel the accreditation of the expert
26.	Poland	Researcher/Academia	10 years	No
27.	Romania	ESCO	10 years	No
28.	Romania	Engineer	10 years	None
29.	Slovakia	ESCO	10 years	No incentives apply, penalties are rare
30.	Slovenia	Engineer	10 years	No
31.	Spain	Engineer	10 years	No
32.	Spain	Contractors, sub-contractors	10 years	No
33.	The Netherlands	Energy Agency	10 years	As in many European countries, our EPC is not based on operational data. It is based on the properties of the building and the installation (asset rating). In principle, the independent qualified EPC-expert under the certified system is responsible for the correct assessment of the EPC. EPC-experts risk losing their permit by non-compliance according to the assessment directive BRL9500. Non-compliant EPC's are withdrawn. The building owner is responsible for having a valid EPC when required. (and can be fined if he doesn't meet this requirement)

ii. EPCs calculation software and tools

A/A	Country	Type of Stakeholder	Q3. Is BIM documentation and literacy or digital logbooks employed by any means for the issuance of EPCs in your region/country?	Q4. In case of a Building Management System (BMS) existence, to what extent is the data documented by BMS employed in the issuance or re-issuance of operational EPCs?	Q5. Is Geographic Information System (GIS) information exploited for issuing, validating, monitoring and verification processes of the EPC calculation?
1.	Austria	Energy Agency	No	It is part of the documentation.	No
2.	Austria	Energy Agency	N/A	N/A	GIS is necessary for EPC in my region
3.	Austria	Contractors, sub-contractors	No	Not at all.	No
4.	Belgium	Energy Agency	Not for issuing EPC's. For the declaration of the energy performance of newly built buildings, a BIM source documentation will be made possible within the next year.	For residential EPC's: not yet the case and no plans to do so. For non-residential EPC's: it is under research now to what extent the data in a BMS can be (re-)used to issue the EPC.	No
5.	Bulgaria	ESCO	No	N/A	Yes
6.	Bulgaria	State/Governmental Departments	Yes	Not applicable	Yes
7.	Croatia	Energy Agency	No	There is no legal obligation of using BMS as a tool for EPC assessment. If there is BMS installed it is just a tool for more	No

				accurate and easier analysis of energy performance	
8.	Cyprus	State/Governmental Departments	No	BMS is not mentioned in the legislation in connection with EPC. BMS can be a source of relevant data (heating efficiency recording) for newly issued EPCs.	There is no legal obligation of using GIS as a tool for EPC assessment. GIS is used for mapping buildings in the land registry.
9.	Czech Republic	ESCO	No	No	No
10.	Denmark	Researcher/Academia	Not that I know of	Not employed	Not that I know of
11.	Estonia	Researcher/Academia	BIM models can be used for energy simulations when calculation based EPC is issued for building permit.	BIM models can be used for energy simulations when calculation based EPC is issued for building permit.	No
12.	Finland	Researcher/Academia	IFC geometry model is commonly used for energy simulation of EPC. IDA-ICE dynamic simulation tool is the most common tool to issue EPC.	BMS is common, but not used, because of calculated EPC also for existing buildings.	No. Energy simulation with one national TRY does not need this information.
13.	France	Engineer	No (BIM documentation is not globally used in building right now)	No idea	No
14.	Germany	ESCO	No	There is no mandatory connection.	Not detailed – but for thermal regions within Germany
15.	Greece	Engineer	No	In Greece, there is no provision / national requirement for Operational EPCs. Operational Data are not taken into for the	No

				calculation of energy performance in Standard EPCs	
16.	Greece	ESCO	Not always	Don’t know	No
17.	Greece	Engineer	No	Not applicable. Asset method rating in Greece.	No
18.	Greece	ESCO	Yes	Limited extent	Yes
19.	Greece	Engineer	In a few cases	I don't know	Yes
20.	Hungary	R&D sector	No BIM documentation is known	No info	No info
21.	Ireland	ESCO	No	Not at all	No
22.	Italy	Researcher/ Academia	Yes, there is a digital logbook in every region with a standard xml. The BIM documentation is not homogeneous nationally	The BMS is used just for large projects	Not yet used
23.	Italy	Engineer	Yes for a digital log in my region but not for all regions yet. Not for BIM documentation.	Not possible. Our EPC is based on standard use building for comparing them in an energy labelling	Yes
24.	Latvia	Researcher/ Academia	No	Not used	No
25.	Lithuania	Researcher/ Academia	BIM-based projects or digital logbooks can be a source of information for the EPC assessment procedure, but it is not obligatory and it doesn't work in a digitalized way	It is not employed at all	No

26.	Poland	Researcher/ Academia	No. EPCs are made on the basis of calculations in accordance with Standards for the reference data.	There are practically no operational EPCs based on measurement data in Poland	No
27.	Romania	ESCO	No	Not at all.	No
28.	Romania	Engineer	Printed logbooks, yes.	EPC is based on calculated data for a reference indoor condition, so, not directly connected to real energy uses indicated by BMS.	Only climatic regions, which are in a number of 5.
29.	Slovakia	ESCO	No	BMS is not mentioned in the legislation in connection with EPC. BMS can be the source of relevant data for EPC. A different approach can be applied case by case by each certifier and building owner.	No
30.	Slovenia	Engineer	No	To a very small extent	No
31.	Spain	Engineer	No		No
32.	Spain	Contractors, sub-contractors	No	Partly	In some regional Registries
33.	The Netherlands	Energy Agency	The three suppliers of the validated calculation tool can or will be using BIM for the EPC-calculation. This is an option and no obligation. (Please note that my answers are for the new	Data of BMS is not used in the calculation of the EPC's.	GIS is not used in the calculation of the EPC's.

			system enter into force on the 1st of January 2021)		

iii. EPCs indicators

A/A	Country	Type of Stakeholder	Q6. Does the EPCs procedure in your region/country include any energy-related financial indicators (e.g. energy € / m²)?	Q7. Does the EPCs procedure in your region/country include any environmental / LCA related financial indicators (e.g. embodied energy / m²)?	Q8. Does the EPCs procedure in your region/country include any indoor air quality indicators (e.g. CO2 concentration / m²)?
1.	Austria	Energy Agency	No	No	No
2.	Austria	Energy Agency	No	Yes, but not mandatory	No, but including the minimum ventilation rate
3.	Austria	Contractors, sub-contractors	Not to my knowledge	Not to my knowledge	Yes
4.	Belgium	Energy Agency	no (the calculations within EPC need to be standardized, meaning that assumptions need to be made that are often not according to the real use of the building. hence, it is our opinion it is not a good idea to translate the calculation output into 'real-life' parameters like euro. We only use the calculation to determine the theoretical energy performance, which we translate into a more abstract energy label.)	No (same reason as above)	no (same reason as above)
5.	Bulgaria	ESCO	Yes	Yes	No
6.	Bulgaria	State/Governmental Departments	Yes	Yes	Yes
7.	Croatia	Energy Agency	Yes, EPC is issued after an energy audit is performed - within energy audit financial analysis is performed.	No	No

8.	Cyprus	State/Governmental Departments	Evaluation recommendations for cost-effective measures	CO_2 indicators derived from primary energy	CO_2 emissions by estimated produced energy
9.	Czech Republic	ESCO	No	No	No
10.	Denmark	Researcher/Academia	Yes	No	No
11.	Estonia	Researcher/Academia	No	No	No
12.	Finland	Researcher/Academia	No. EPC is limited to delivered and primary energy.	No	Not exactly. Another regulation applies for indoor climate (ventilation rates, IAQ, thermal comfort, noise) for new (similar part of the building code as energy performance requirements) and another regulation for existing buildings.
13.	France	Engineer	Yes	Yes	No
14.	Germany	ESCO	No	Please specify “embodied energy”	No
15.	Greece	Engineer	Yes	No	No
16.	Greece	ESCO	Yes	Yes	Yes
17.	Greece	Engineer	Yes. Energy Cost and CO2 emissions per m2	No	No. Only a general evaluation of the Energy Auditor but is based only on observation
18.	Greece	ESCO	No	Yes	No
19.	Greece	Engineer	Yes	Yes	Yes
20.	Hungary	R&D sector	No	No	No
21.	Ireland	ESCO	No	No	Yes

22.	Italy	Researcher/Academia	No financial indicators	No LCA	No, any indicator
23.	Italy	Engineer	No. Just energy performance kWh/m² year	No	No
24.	Latvia	Researcher/Academia	No	CO2 and primary energy but only values are defined, not rating system exists	No
25.	Lithuania	Researcher/Academia	No	The relative value of annual CO_2 emission during the exploitation (per heated area): $kgCO_2/(m^2xyear)$	No
26.	Poland	Researcher/Academia	No financial indicators are included	No, the procedure is not connected with LCA methodology. Only carbon dioxide emissions are calculated.	No, it does not include such indicators.
27.	Romania	ESCO	For the proposed investments in the building retrofit yes, but it is not directly issued in the EPC.	For the proposed investments in the building deep renovation yes, but not included in the EPC procedure.	No
28.	Romania	Engineer	No	No financial indicators. Tariffs/costs are changing over 10 years	No, only CO_2 is associated with the primary energy used in the building.
29.	Slovakia	ESCO	The payback time of proposed measures can be reported. But in practice, it is very rare that this indicator is reported.	No	No
30.	Slovenia	Engineer	No	No	No
31.	Spain	Engineer	Si, voluntario valorar economicamente las mejoras energéticas	De momento no	Si kh CO2-eqv/m2

32.	Spain	Contractors, sub-contractors	No	No	No
33.	The Netherlands	Energy Agency	The new energy label gives an indication of energy cost per month, based on similar dwellings in our country. See the following example (attached)	No LCA related financial indicators in the EPCs procedure.	Yes, the risk of overheating in (new build) dwellings is part of the EPCs procedure.

iv. Qualified experts competence and skills

A/A	Country	Type of Stakeholder	Q9. Do the EPC auditors have access to joint databases concerning the properties of building systems and building elements?	Q10. Is there provision for systematic and regular evaluation/assessment of energy assessor's competencies and skills?
1.	Austria	Energy Agency	No	No
2.	Austria	Energy Agency	Yes, access is necessary for the calculation and exists	Yes, exists
3.	Austria	Contractors, sub-contractors	No	Not to my knowledge
4.	Belgium	Energy Agency	Yes, for declaration of the energy performance of newly built buildings. No for existing buildings	Yes. Assessors need to follow yearly training in order to keep their certification and both random as targeted control schemes are executed by the Flemish Energy Agency.
5.	Bulgaria	ESCO	I have no reliable information	Yes
6.	Bulgaria	State/Governmental Departments	No	Yes
7.	Croatia	Energy Agency	No	Yes, education/evaluation and periodic training for energy auditor is prescribed by legislation
8.	Cyprus	State/Governmental Departments	There is a gradation of the information that the auditors can use, www.energy.dotgov.cy	There is no legal obligation, only general provision. Circulars and workshops are organized for any new development. If needed special recommendations take place
9.	Czech Republic	ESCO	Commercial SW	The energy specialists have an obligation to participate in training sessions and workshops and to collect a certain amount of credits. In case if they do not collect enough credits or if they make repeatedly mistakes in their EPC they would have to pass an exam.

10.	Denmark	Researcher/Academia	Yes	Don’t know
11.	Estonia	Researcher/Academia	No	Energy assessors have to renew their occupational qualification certificates every 5 years. The Commission evaluates occupational qualification based on reference works and participation in in-service training courses.
12.	Finland	Researcher/Academia	A lot of such data is provided in national guidelines. Available on the webpage of the ministry: https://ym.fi/rakentamismaaraykset select: energiatehokkuus	Yes, they have a qualification system. Qualification needs to be renewed after every 7 years.
13.	France	Engineer	I don't know	They receive training to become an assessor and the can be assessors for 7 years. Then they have to receive training again
14.	Germany	ESCO	Yes, but those are not public (until now www.DIBT.de – some legal changes will be next year)-	There is no regular evaluation of my competencies as an energy assessor.
15.	Greece	Engineer	EPC Assessment national framework provides with some tables in the corresponding handbooks with properties of building systems and elements to use if applicable	No
16.	Greece	ESCO	No	No
17.	Greece	Engineer	No	Unfortunately not. There is a legislative gap in both the certification and the regular evaluation
18.	Greece	ESCO	No	No
19.	Greece	Engineer	Books, Instructions	No
20.	Hungary	R&D sector	No	Yes
21.	Ireland	ESCO	No	Yes - must sit registration exam every 2 years

22.	Italy	Researcher/Academia	Yes	No there is no evaluation of assessor's competences, professional with a valid degree can register and become an assessor with a digital signature
23.	Italy	Engineer	No, Just some general annual reports	Not for a standard EPC
24.	Latvia	Researcher/Academia	Yes, bis.gov.lv	Yes
25.	Lithuania	Researcher/Academia	Yes, but it is not a separate database - some data about building elements and systems is included in the regulation	Yes
26.	Poland	Researcher/Academia	No	No. There is no evaluation of competencies and skills.
27.	Romania	ESCO	No	Yes, periodical re-authorization.
28.	Romania	Engineer	No	Yes, at 5 years interval
29.	Slovakia	ESCO	No	No
30.	Slovenia	Engineer	No	No
31.	Spain	Engineer	Yes	No
32.	Spain	Contractors, sub-contractors	No	No
33.	The Netherlands	Energy Agency	General information of all issued EPCs in our country can be found on www.ep-online.nl. The auditor working for a certified body can only see the general information of the connected companies (of the assessor). More detailed information can be found in the project dossiers of the specific building/dwelling. This detailed information is needed for the audit	Yes, organizations issuing EPCs have to be certified, which implies that they have to meet a range of quality requirements. This includes annual checks of EPCs issued based on samples. Also, a system of continuous education of energy assessors will be set up (based on a 'points-system'). The 'points-system' implies that a newly registered energy assessor starts with 12 points and loses 1 point each month. The energy

				assessor has to make sure that his amount of points remains 1 or more. One can earn points by doing training or courses. Upon introduction of the new EPC-system (as of 1-1-2021) all energy assessors that are registered for the present/old EPC-system, and who wish to become registered for the new EPC-system, are obliged to do further training (including exams) to get registered for the new EPC-system.

ANNEX E: Desk research

i. EPCs issuing, quality and control

A/A	Reference number	Country	Comment on: What is the period of validity of an EPC currently issued in your region/country?	Page of the report document
1.	[2]	Austria	An EPC has to be provided for both residential and non-residential buildings (commercial and public) and is valid for ten (10) years. An EPC also has to be issued when applying for a building permit for a new construction and for major renovations, as well as for requesting subsidies.	14
2.	[4]	Belgium – Flemish Region	The EPC is valid for a period of 10 years. Currently, there is no obligation that a new EPC should be issued in case of renovation.	18
3.	[6]	Bulgaria	The “Energy Performance Certificate of New Building” is valid for 6 years from the date of commissioning of the building. The owners of all these buildings are required to obtain an “Energy Performance Certificate of Existing Building” within a three-year period. This period begins three years after the date of commissioning. The energy performance of existing buildings is established by an energy audit, which is completed with the issuing of an EPC of the building. The “Energy Performance Certificate of Existing Building” shall be updated following any change in the energy performance of the building.	5
4.	[7]	Croatia	The validity of the EPC shall not exceed ten years from the date of its issue.	9
5.	[9]	Czech Republic	The EPC must be recalculated as soon as it expires (within 10 years), or in case of major building renovations.	9
6.	[12]	Finland	The EPC is valid for ten (10) years. However, it is recommended, though not required, that the certificate is updated following a major reconstruction of the building envelope or of the technical systems, even if the works take place before the expiry date.	12
7.	[13]	France	Once issued, the EPC is automatically sent to the EPC national database (mandatory since 2013), and is valid for 10 years.	9

8.	[16]	Hungary	EPCs are valid for 10 years unless the building undergoes a major renovation, in which case a new EPC is required. An EPC electronic registration system has been in operation since 2013. An EPC is only valid after upload into the online system.	9, 11
9.	[18]	Italy	An EPC is valid only if the “HAC log-book” from regular inspections is attached.	15
10.	[20]	Lithuania	An energy certificate not older than 10 years must be placed in the building in a prominent place clearly visible to the public.	16
11.	[22]	Malta	The certificate is valid for 10 years and is stored in a central national database.	9
12.	[23]	Norway	The EPC for both residential and non-residential buildings is valid for 10 years, or until major changes are implemented in the building. EPCs are issued by Enova after online registration of building data. The registered data are stored in the database at Enova premises.	7
13.	[27]	Slovak Republic	The maximum validity of issued EPCs is 10 years.	8
14.	[38]	The Netherlands	The Netherlands: For new buildings, the calculation of energy performance (energy performance coefficient) that is used to receive a building permit is valid as a certificate for ten years. The chosen assessment method is calculated rating.	55
15.	[46]	-	The certificate of energy performance of a building in operation has a validity of 3 to 10 years, determined in the Ordinance on the energy efficiency audits, certification and evaluation of buildings.	14

ii. EPCs issuing, quality and control

A/A	Reference number	Country	Comment on: In case of re-assessment of an EPC based on operational data, are there incentives or penalties in relation to the owners' compliance or non-compliance with the certificate assessment / rating?	Page of the report document
1.	[2]	Austria	For the enforcement of inspection laws, penalties are imposed under the relevant laws of some of the Austrian provinces, but there are no statistical data indicating frequency and level of penalties, which have yet to be imposed.	16
2.	[3]	Belgium – Brussels Capital Region	The compliance of the procedure and energy performance requirements are checked by the Brussels Environment Office. The percentage of buildings not meeting one or more of the requirements is less than 6%. The fines are established in the Cobrace Art. 2.6.1. Most of the fines are imposed for not meeting ventilation requirements, whereas non-compliance with the primary energy requirement (E-level before 2015, PEC after 2015) is extremely rare.	4
3.	[4]	Belgium – Flemish Region	Municipal supervisors and supervisors of the police zones may sanction the owner or user of a heating or AC system when a mandatory inspection has not been carried out. A list of possible sanctions is included in the decree of 5 April 1995, concerning general provisions relating to environmental policy (e.g., a fine that depends on the kind of infraction). There are no statistics available on the use of these sanctions.	23
4.	[6]	Bulgaria	The SEDA is the authority that imposes penalties for non-compliance. Although, by the end of 2016, no penalties had yet been imposed.	3
5.	[7]	Croatia	The law imposes penalties for owners who fail to provide an EPC at the time of selling, renting or leasing a building. Penalties are also imposed if the owner fails to deliver the EPC to the buyer, or if they fail to indicate the energy class in the sale advertisement published in the media. Penalties are imposed by law both for owners and for authorised real estate brokers. Supervision is under the competence of the Ministry of Economy, Market Inspectorate. This obligation is commonly followed and no fines have been issued so far. Enforcement and penalties for the owner of a building are the same as for the EPC. No fine has yet been issued.	11, 12, 13

6.	[8]	Cyprus	In the case where appointed inspectors find no compliance with minimum requirements the building owner is notified of the infringement and a deadline is given to comply. If the building owner does not comply within the deadline, then legal action is taken. Another incentive is the establishment of the 5% extra building space allowance for buildings that reach A class, with at least 25% of their primary energy consumption coming from RES, established in 2014. Most of the interest for this incentive comes from developers of large buildings. This incentive can also be used in the construction of new buildings. A fine of up to 30,000 € can be implemented in the case of a central heating system not being inspected. However, no fine has been implemented so far. The aim is to revise the "I save – I upgrade" scheme in order to address existing hurdles, but also to design specialised financial products that could operate together or independently of "I save – I upgrade".	3, 5, 8, 9
7.	[9]	Czech Republic	If the building owner does not fulfil these obligations, a penalty can be imposed by the State Energy Inspection.	9
8.	[10]	Denmark	In Denmark, three different levels of penalties are foreseen: 1. In case of error, companies must correct the certificate. 2. In case of serious errors, the company will get a warning notice and the certifying accreditation agency is informed. 3. In cases where errors are serious and/or repeated, a public notice will be made available online as a “name and shame” sanction. The certifying accreditation agency is informed and is able to suspend the certification of the company if they find it appropriate. Companies must carry out their own quality control according to DS/EN ISO 9001. In July 2012, a new act implemented mandatory advertising requirements and provided sanctions in case of non-compliance. In 2014, the Danish Energy Agency performed a random check of private sales on the internet, which showed a compliance rate of 60%.	11, 12
9.	[11]	Estonia	So far, all the shortcomings are corrected by letter and no precept or penalty payment have been applied. In case the mistakes are not corrected, it is also possible to apply penalty payment up to 64,000 € for a company, or 6,400 € for individuals, until the shortcomings are corrected.	9

10.	[13]	France	Penalties are set in the regulation (Art L.226-2 et L.226-8 of the environment code). Controls can be performed by officers of the General Directorate for Competition Policy, Consumer Affairs and Fraud Control. If the regulation has not been properly adhered to, the relevant authority can apply several types of measures.	13
11.	[15]	Greece	By the end of 2016, no penalties were issued regarding the inspection reports, and no statistics are available.	14
12.	[17]	Ireland	Penalties include a fine of up to 5,000 €, or up to three months in prison, or both. Enforcement is complemented by a "rights based" approach, focussed on creating a compliance culture. The Accelerated Capital Allowance (ACA) is a tax incentive for companies paying corporation tax which aims to encourage investment in energy efficient equipment. The ACA offers an attractive incentive whereby it allows companies to write off 100% of the purchase value of qualifying energy efficient equipment against their profit in the year of purchase.	4, 10
13.	[18]	Italy	Incentives for new private buildings, provided in terms of reduced construction tax burdens, both at national and regional level. Tax deductions introduced by the Italian 2007 financial law are key drivers of energy efficiency improvements in the housing sector. The penalties applied by regions range from 300 € to a maximum of 10,000 €, according to the infringement. There is a gradual tolerance of errors depending on number, type and repetition rate, as the system objective is to improve the quality of EPCs, which is considered quite low at present. In case of fraud, the penalty may have penal consequences. The enforcement of maintenance established penalties for the users in terms of payment of the control(s) and fines. Sanctions for the inspection reports consist of suspension or removal of inspectors from the register.	6, 12, 17, 18
14.	[19]	Latvia	In any other building, if a complaint is received, the certification body must check the EPC, energy audit or inspection report received by the qualified experts. In case of a violation, the certification body could apply penalty points.	10
15.	[20]	Lithuania	There are financial penalties in Lithuania of up to 289 € for building owners/managers that do not display the EPCs.	16, 18

			In any other building, if a complaint is received, the certification body must check the EPC, energy audit or inspection report received by the qualified experts. In case of a violation, the certification body could apply penalty points.	
16.	[21]	Luxembourg	With respect to heating systems, non-compliance of the regulatory requirements can be penalised. Luxembourg is preparing for the future by creating financial incentives for new sustainable buildings and sustainable insulation materials for refurbishment.	12, 13
17.	[24]	Poland	The EPC and its compliance with the energy performance levels is checked on the basis of data from the central register.	13
18.	[25]	Portugal	Another type of incentive that currently exists focuses specifically on tax reduction, namely concerning municipality taxation of real estate and building renovations. Some municipalities have tax reductions for better labelled buildings, typically A and A+, or buildings whose renovation improves the energy performance by two (2) labels.	9
19.	[26]	Romania	For new buildings, compliance with technical regulations shall be checked in two phases: first at the time of building permit request, when a study on technical, environmental and economic feasibility of high-efficiency alternative systems should be presented, and secondly after the completion of the building construction works.	3
20.	[28]	Slovenia	A penalty of 300 € is foreseen when the owner of a building or building unit fails to ensure regular inspection of the AC systems of buildings or parts of buildings in which AC systems of a nominal output capacity exceeding 12kW are installed.	15
21.	[30]	Sweden	In case the mandatory requirements are not met, the municipality can prohibit the use of the building or fine the developer until compliance is reached.	6
22.	[31]	The Netherlands	The IL&T can give owners of such buildings a financial penalty in case of non-compliance. To date, several owners of public buildings have received a warning of non-compliance with the requirement for public display of the EPC. They are given a 6 months period to become compliant and will be checked again after this period.	12
23.	[38]	Austria, Belgium, Denmark,	In a lot of countries the enforcement of compliance is a weak point in EPC implementation. When EPCs are (still) only mandatory in the event of new buildings / renovations, the control of compliance is fairly easy to combine with the issuing of the building permit (Spain, Hungary, Czech Republic). However, even in these	38, 42, 43, 47, 50, 52, 56

		Germany, Hungary, the Netherlands	cases, a practical enforcement system often still seems to be missing. In a number of countries there are in theory sanctions for non-compliance. Since an operational enforcement system is unavailable, only in the event of specific complaints will legal steps be taken (Germany, the Netherlands, Poland, Austria, Denmark). In a number of countries there is a sound system of practical enforcement (Ireland, Portugal, Belgium-Flanders). This seems to lead to higher compliance rates. The Austrian legislation does not provide an enforcement system with penalties. Claims can be made in case of non-compliance, which can be brought before a judge. Flanders: There is a strict enforcement system with financial penalties for non-compliance with EPC regulations (for building owners and energy experts). Denmark: For new buildings an EPC is required to get a permit for use, which is not granted in case of non-compliance. For existing buildings, the EPC is obligatory at the moment of the transaction. The possibility of penalties exists in case of non-compliance. However, there is no enforcement system in practice. Germany: In case of the non-compliance of the EPC obligation at the time of transaction there are penalties (inter alia the possibility of fines) set by the government, but there is no operational enforcement system. Municipalities are in principle responsible for the monitoring compliance, but in practice there is often only a check of compliance when a complaint is filed. Hungary: There is no enforcement of compliance for existing buildings because the EPC process is still under development. For new buildings there is a pro forma control of EPCs when the building is ready. The Netherlands: At the moment of transaction, the enforcement of compliance is only possible when a demand for EPC is made based on the civil code. This is seldom done. Otherwise no enforcement and no sanctions are in place.	

iii. EPCs calculation software and tools

A/A	Reference number	Country	Comment on: Is BIM documentation and literacy or digital log books employed by any means for the issuance of EPCs in your region/country?	Page of the report document
1.	[4]	Belgium – Flemish Region	Only a qualified expert can issue an EPC, and the qualified expert has to use a specific certification software, provided by the Flemish government. All EPCs must be reported to a (non-public) database, which is property of the Flemish Energy Agency. Qualified experts can only view their own files/EPCs. In 2017, a new web application will be launched allowing digital documentation of inspection results and storage of data in a central database as well as the generation of statistics on heating systems.	18, 20
2.	[18]	Italy	The Ministry of Economic Development (MISE) set up a template for a heating or cooling system log-book and another for an energy efficiency report, and asked the Italian Thermotechnical Committee (CTI) to publicise examples for the most common types of systems to facilitate and standardise completion of the log-books and energy efficiency reports. Beyond various EPC features, the public consultation asked for better coordination of the action at national level and for a harmonised national EPC information system (named SIAPE) that could improve analysis and use of EPC data, as well as knowledge of the building stock.	12, 18
3.	[19]	Latvia	The Building Information System (BIS), which is an electronic site that brings together all the information about the construction process and the parties involved, including a Register of Independent Experts in the Field of Energy Performance of Buildings and a Register of Certificates of Energy Performance of Buildings, has been implemented since 2016. With an aim to digitalise the documentation of the entire construction process, Latvia has introduced the BIS which also offers public access to the Register of Independent Experts in the Field of Energy Performance of Buildings and the Register of Certificates of Energy Performance of Buildings.	10, 12
4.	[39]	-	Recently, building information modelling (BIM) has become a trending technology in construction. BIM is an intelligent 3-D model-based process for the digital representation of physical and functional characteristics of buildings which could potentially be linked to the IEQ. BIM allows individuals (architects, engineers and construction professionals), government agencies and businesses to effectively design, plan and construct buildings and infrastructure such as roads, tunnels, electricity, water communication utilities etc.	14, 15

			Moving towards a digital society in which sensors are far more widely deployed, IEQ monitoring is becoming mainstream.	
5.	[48]	-	Building logbooks are considered a highly promising tool to boost the availability of information to a broad range of market participants such as owners, real estate companies and facility managers, among others. Better information flows are a necessary part of improving the quality assurance system for buildings and the construction industry overall. Logbooks have been recognised – and developed in some EU countries - as a way to engage building owners and stakeholders to maximise the value and accessibility of EPC data. Projects such as iBRoad and ALDREN have explored the potential benefits of building logbooks across the EU. Countries like Belgium (Flanders) plan to fully develop building logbooks as part of a "building renovation passport", while France include a digital logbook for building monitoring and maintenance as part of its EPC system. The Flemish Energy Agency (VEA), in cooperation with a wide network of stakeholders, designed and implemented the "Renovation Pact" (2014-2018) with the aim to improve the region's building stock. Flanders (Belgium) established that by 2050 the existing building stock should become as energy efficient as the current requirements for new buildings (E608). One of the main actions launched in the Renovation Pact is to develop the Woningpas, a logbook, as well as the EPC+, which is a more user-friendly version of the EPC, including a clear overview of measures, ordered by priority, needed to reach the 2050 objective. The Woningpas is a unique integral digital file of each individual building. The file can be retrieved by the building owner and by individuals who have been granted access. The logbook features energy performance, renovation advice, the housing quality (such as stability, humidity, safety) and data on the environment. In the future other building aspects such as durability, water, installations and building permits will be included. The Woningpas makes it possible to track the evolution of each individual building. The first version of the instrument was launched in 2018.	43
6.	[49]	-	Digital log books for buildings are usually intended to provide a simple, easily accessible summary of a new or refurbished building rather than the detail contained in operation and maintenance manuals. In some Member States the provision of such information to building owners has become mandatory through the form of a building log book (which needn't necessarily be electronic but increasingly is). The log books will typically cover how a building is intended to work and how it is meant to be maintained and serviced. They also provide a means to record the energy use and maintenance of the services within the building. A typical building log book might include:	77, 80, 200

			• a description of key responsibilities • a schedule of contacts • a description of the overall building, including zoning and occupancy • a description of the building's operational strategy • a description of the building's services plant, controls and management systems • changes that have been made to the building • health and safety considerations • maintenance requirements • metering and monitoring strategy • the recommendations report produced along with the construction EPC • building performance in use investigations and targets • references to other documents and digital logbooks are relevant to the SRI with regard to implementation as the information they contain can overlap with SRI needs and in utilising a digital platform opens the possibility of sharing relevant datasets in a manner that is beneficial to both. Acquiring the data needed by BIM entails a site visit and inspection for existing buildings and in principle this process could be done in common for both BIM and an SRI. Once the data has been acquired it is stored digitally and this could facilitate future updates as systems are added or amended as from a technical perspective only a partial assessment (of the part which has changed) is needed. BIM also entails management of data confidentiality in a digital environment and hence has lessons for potential implementation pathways that could be used by the SRI. As previous sections have described the currently most viable assessment method for an SRI requires a person on-site to conduct the assessment. The only exception to this is the case of a person who is off-site with access to all the requisite information through pre-collected data available via BIM (e.g. a digital twin model), digital logbooks, building renovation passports etc.; however, in the start-up phase of the SRI such instances will be extremely rare if not inexistent. For assessments to be conducted on site there are options with regard to how qualified and how independent the assessor is. If a certified SRI is to be issued the assessor would need to be a certified 3rd party assessor, suitably qualified to do the assessment. If a certified SRI is not required, then the SRI would not have the same status and external market value and hence it is more of a matter for the agency procuring the assessment as to the degree of qualification and	

			independence required. Many building owners, occupants, portfolio managers, or facility managers might wish to conduct self-assessments of the properties they have responsibility for. The degree of technical competence of those delivering such self-assessments could vary appreciably.	

iv. EPCs calculation software and tools

A/A	Reference number	Country	Comment on: In case of a Building Management System (BMS) existence, to what extent is the data documented by BMS employed in the issuance or reissuance of operational EPCs?	Page of the report document
1.	[17]	Ireland	For buildings with a heat demand of more than 100 kW a full Building Management System (BMS) should be installed to control the boiler(s). A BMS linked to the heating plant will provide sequential controls of multiple boilers, full-zoned time control and weather compensation where applicable, frost protection or night set-back optimisation and monitoring and targeting.	9

v. EPCs calculation software and tools

A/A	Reference number	Country	Comment on: Is Geographic Information System (GIS) information exploited for issuing, validating, monitoring and verificating processes of the EPC calculation?	Page of the report document
1.	[25]	Portugal	The geographical location data is now present in the EPC database, enabling buildings to be located precisely on a map, and this is a very important step towards having a better understanding of the building stock.	17
2.	[28]	Slovenia	In 2017 the beta version of the visualisation of building energy efficiency was being prepared based on linking the EPC database with GIS data.	11
3.	[44]	-	In several countries, the EPC databases are connected to other data sources, such as in Portugal to national census and GIS online database, or in Denmark and in Italian Lombardy region to the official cadastral register (EPC database), construction and housing register, the joint municipal property register and many others. A comprehensive building portfolio, available in the database, is a useful source of information both for the real estate owner, building owner or manager.	63

vi. EPCs indicators

A/A	Reference number	Country	Comment on: Does the EPCs procedure in your region/country include any energy related financial indicators (e.g. energy €/m²)?	Page of the report document
1.	[4]	Belgium – Flemish Region	The cost-optimal studies of 2015 on residential and non-residential buildings resulted in a revision of the energy performance indicator (E-level) for non-residential buildings and buildings of public administrations, defining the following requirements	6

vii. EPCs indicators

A/A	Reference number	Country	Comment on: Does the EPCs procedure in your region/country include any environmental/LCA related financial indicators (e.g. embodied energy/m²)?	Page of the report document
1.	[9]	Czech Republic	Energy indicators to be met are the same as for new buildings. However, in the case of NZEB, the Czech legislation demands a gradual decreasing of the non-renewable primary energy for the reference building. The assessed building must meet this stricter requirement either by increasing the share of RES or by improving the building envelope.	3
2.	[13]	France	The carbon footprint assessment is based on a complete life cycle analysis, from the manufacture of components to the recycling of rubble. The first level of the label is easy to reach and aims at having all the stakeholders involved in the construction to implement an overall reflexion on the environmental impacts of a building. The second level is however more challenging and requires a real decrease of the carbon emissions of the building.	15
3.	[28]	Slovenia	The update suggested developing quality assurance protocols for construction and building energy renovations with a building life-cycle perspective (building elements, systems, processes, and skilled workforce).	8
4.	[30]	Sweden	Focus will be on improving the energy efficiency while performing renovation works, and on energy-efficient construction with the use of sustainable materials with low environmental impact from a life-cycle perspective. Sweden is also investigating the possibilities of implementing a life-cycle assessment of the building requirements.	7, 13

viii. EPCs indicators

A/A	Reference number	Country	Comment on: Does the EPCs procedure in your region/country include any indoor air quality indicators (e.g. CO2 concentration/m²)?	Page of the report document
1.	[4]	Belgium – Flemish Region	Energy performance requirements for new and renovated buildings in the Flemish Region first started in January 2006. The legislation was consolidated in the energy decree of 2009 and the energy law of 2010. Each new building must fulfil requirements on energy performance (E-level) and insulation (U-values and global insulation 'K-level'7) as well as on the indoor air quality and thermal comfort (risk of overheating and ventilation). Each building that undergoes a renovation with a permit must fulfil requirements on insulation levels (U-values) and on the indoor air quality (ventilation).	4, 13
2.	[7]	Croatia	Provisions for indoor environmental quality (including air quality, thermal comfort, lighting and acoustics) are also provided.	2
3.	[12]	Finland	Calculations also include thermal comfort requirements, indoor-air quality requirements and infiltration, thermal bridges and shading devices.	3
4.	[16]	Hungary	For new buildings and major renovations, thermal comfort and minimum requirements on fresh air supply are set, but these values are not included in the calculation procedure for certification.	3
5.	[19]	Latvia	The regulations have determined that the building energy performance calculation procedure shall include thermal comfort, indoor air quality, infiltration, thermal bridges and shading devices. The building energy performance class indicator corresponds to the value which was established according to the energy consumption used to heat the building.	2
6.	[24]	Poland	The fifth database of the publicly available central register shows, on the basis of issued EPCs in Poland, information about these buildings (among other things, the parameters of the energy performance, the share of RES, the value of CO_2 emissions, etc.).	15
7.	[25]	Portugal	Additional requirements exist for air renovation rates and minimum indoor air quality.	5

8.	[29]	Spain	One of the main changes that occurred was the inclusion of a second indicator for energy performance, complementing the CO_2 emissions indicator with one for non-renewable primary energy consumption. The criteria established to evaluate and limit the technical quality of the renovations is the energy performance rating. The actions supported must improve the total energy performance rating of the building by at least one (1) energy class measured in the scale of carbon dioxide emissions (kg CO_2/m^2.year).	2, 15
9.	[38]	Portugal	Portugal: The EPCs cover indoor air quality as well as energy performance. The chosen assessment method is calculated rating. The calculation procedures are defined in building regulations.	59
10.	[39]	-	Acceptable indoor air quality refers to air without harmful concentrations of known contaminants and with which the great majority of exposed people are satisfied. Sources of contaminants in residential buildings include the occupants themselves (e.g. CO_2 released from human respiration); emissions from indoor combustion sources and activities such as cooking or smoking; and emissions from furnishings, construction materials or cleaning products.	10
11.	[45]	-	A study conducted in Estonia concluded that ventilation airflow in apartment buildings built during the period 1990-2010 often does not meet the indoor climate category II (EN 15251:2007) requirements. Although the EN 15251 standard is not a regulation, it is often referred in the building design documents as input source for ventilation design.	8
12.	[48]	-	Aspects like indoor environmental quality (comfort, health etc.) and smart data usage are not covered in current EPC regimes. Although ensuring adequate levels of indoor air quality, thermal comfort, lighting and acoustics within buildings are among the most potent drivers for renovation, they are rarely covered by EPCs. While comfort is one of the shortcomings identified in the Greek EPC, their template features a dedicated area for comfort and other indoor environmental quality parameters (e.g. thermal comfort, acoustics, lighting and air quality). Specifically, for thermal comfort, set points for indoor temperature and values for fresh air needs are set in the official software tool, varying by building type. The provided information only consists of a tick-box based on the subjective evaluation of the EPC expert. The evaluation is based on the registered equipment, visible operational condition, and an interview with the occupant. The 'comfort' feature is not taken into account in the calculation methodology for the energy performance of the building	4, 7, 40

ix. Qualified experts competence and skills

A/A	Reference number	Country	Comment on: Do the EPC auditors have access to joint databases concerning the properties of building systems and building elements?	Page of the report document
1.	[3]	Belgium – Brussels Capital Region	Moreover, since January 2015, the administration has a new database to follow up the inspection reports.	9
2.	[10]	Denmark	All EPCs are registered in a central database and displayed on the public website. Data from the inspections is submitted to a database in the Danish Energy Agency. Information on the physical stage of the existing building stock is collected by energy experts while carrying out an energy audit for issuing an EPC. All data from the certification scheme is gathered in a common database, so a wide range of information is available with respect to the building stock.	10, 13, 14
3.	[14]	Germany	Germany does not have a database describing the energy efficiency features of the building stock as a whole. The independent control system works efficiently and allows keeping both efforts and costs as low as possible. It works without general data storage in a central database.	6, 11
4.	[16]	Hungary	Airtightness measurements are not required, but the quality of windows is examined visually by experts on-site and the estimated infiltration is taken into account in the calculation. EPCs issued before 2016 have been automatically rescaled, but unfortunately owners are not automatically informed about the change because of technical barriers of the database. Since January 2013, EPCs are registered in a central database operated by the Lechner Non-Profit Organisation. The database is partly public. In the public part, a building´s energy performance class can be searched by using its address. From building permit until commissioning (which may take years), the market conditions, e.g., availability and cost of some elements, may change: this is why reliable but simplified calculation tools are and will be necessary in the early stage of design (application for building permit), when lack of input data does not facilitate the application of many standards.	2, 9, 10, 14

5.	[18]	Italy	Best practice in EPBD implementation in the period 2015-2016 reside in the inspection of technical building systems, extended to cooling systems, that also resulted in improved maintenance, security and employment, and in the wider use of databases (both EPC and inspections) in some region, integrated at the national level by the establishment of a new national EPC-technical building system centralised database.	20
6.	[20]	Lithuania	Collection and registration of EPCs in the central database allows for quality control, statistical analysis and monitoring of processes.	9
7.	[21]	Luxembourg	Requirements for technical building systems and building envelope elements are set in multiple regulations concerning the respective buildings or technical elements. Every new individual building element has to fulfil minimum requirements defined in these regulations. A national database has been developed which collects all EPCs (existing and new) issued by the experts for residential buildings and aims to draw statistics from the national building stock in the future. In a later phase, the database shall be extended to non-residential buildings.	7, 10
8.	[32]	-	MSs have already set the minimum performance requirements for existing buildings, including technical building systems, and have created regular inspection schemes or equivalent alternative measures. More recently, efforts have been made to improve them, and to fill any gaps. -EPC/inspection databases being used to provide input data for other databases: property valuation and taxation databases, building stock statistics, monitoring and quality controls, planning procedures, and reporting of progress in National Energy Efficiency Action Plans; -existing databases (other than EPC) used to provide input data to the EPC database: property identification details, including address, building type, names of owners and former owners, maps, local climate correction factors, and the credentials of the energy expert who produced the EPC; -databases used to help achieve national policy targets, or implement EU directives other than the EPBD: development of building codes, the renovation strategy for the EED, setting energy-saving goals for different stakeholders, energy-saving targets and planning, and other actions to evaluate and improve the quality of buildings; A single database containing all building information would be ideal, but the reality of trying to achieve this poses many problems. Data is usually acquired at different times by different agencies and for different purposes, meaning that underlying assumptions may be incompatible, and content and data formats different. Preventing further divergence through future development requires strong overall control.	3, 8, 9

			The main difficulties experienced by MSs in setting up, maintaining, and combining databases for buildings include: • changing or conflicting rules (e.g., EPC rating scale, different definitions of treated floor area); • privacy barriers to free circulation of information; • not being able to locate all buildings, or all heating and air-conditioning systems; • building ownership data not sufficiently up to date; • low level of assessors' technical skills; • industry resistance to supplying new information demands; • independent control systems (and quality control more generally) for databases, and successfully applying sanctions.	
9.	[46]	Austria, Denmark, Poland	Austria: Default values are available from prescribed standards. In addition, an online public database, called baubook that provides characteristics of construction products, such as walls, floors, roofs, and of some building systems, such as wood heating appliances, heat pumps, ventilation fans, ducts and pipes is available. baubook GmbH is owned by the Energy Institute of Vorarl-berg and IBO (Austrian Institute for Healthy and Ecological Building) and is financed by fees from product and system manufacturers that uses the platform. Denmark: Danish Energy Agency has provided a Hand-book for Energy Consultants (HB2019) that is used as a reference guide for obtaining input information for EPC labelling of new and existing buildings. In addition, indicative default values for heat transmission values for building elements are provided in a website dedicated for HB2019. Poland: An independent body exists and the following factors are checked during EPC control: calculation results, efficiency of technical building systems and U-values compared with requirements concerning thermal insulation of the building envelope components, energy demand indicators, energy consumption and categories of cost-effective recommendations, correctness of description, etc.	33, 34, 71

x. Qualified experts competence and skills

A/A	Reference number	Country	Comment on: Is there provision for systematic and regular evaluation / assessment of energy assessor's competences and skills?	Page of the report document
1.	[3]	Belgium – Brussels Capital Region	Since 2017, an independent organisation performs an inspection of the quality of the work on a randomly selected amount of EPB-advisors. The EPB-advisor can be suspended if the requirements are not met. A mandatory training for updating the knowledge has therefore been planned for already approved experts. They must have attended this training and passed the subsequent exam before mid-2018 in order to keep their accreditation.	4, 8
2.	[4]	Belgium – Flemish Region	Finally, other continuous NZEB actions cover quality control, including education (competences and knowledge), execution (study as well as execution on the building site), and defining regulations for good practice (ventilation, airtightness and RES installations). These projects are executed in close collaboration with the Department of Education, educational institutions and the professional federations of architects, contractors and energy experts. The Flemish Energy Agency executes a quality check on the work of a number of qualified experts, based on possible illogical inputs of data as well as at random. In order to further improve the quality of the EPCs, experts must attend continuing education from January 2017. Since 2014, annually approximately 600 randomly selected recognised technicians as well as technicians against whom complaints have been made are subjected to quality control by an accredited inspection body, which is appointed by the government. If quality requirements are not met, the technician will be warned, fined or prosecuted and/or the recognition can be suspended or withdrawn (sanctions have been issued to 64 technicians since 2013). Non-recognised technicians performing any of the aforementioned mandatory inspections that are reported to the government are prosecuted (15 non-recognised persons have been prosecuted since 2013).	9, 19, 23
3.	[12]	Finland	The ARA is the administrative authority ensuring the quality of EPCs and qualified experts and the appropriate preparation and use of the certificates. To apply for accreditation, the expert must have adequate training and a suitable educational background (e.g., a degree in building technology or architecture or, for the higher level, a master's degree in building technology or a related field), the lack of which can be compensated with work experience. The qualification has to be	13

			approved by a test administered by the accreditation bodies, and is valid for seven (7) years, after which it needs to be renewed. Qualification and accreditation for qualified experts is the same for all building types, public and private.	
4.	[13]	France	According to a regulatory requirement, the work of each qualified expert must be checked on a continuous basis. New experts are checked 4 times during the first year, and 4 more times in the following 4 years. Following this first cycle of certification, experts are checked 4 times every 5 years. The certifying body must verify that each point of the regulation is abided by and it can withdraw the expert's certification temporarily or permanently in case some fields in the EPC are not properly filled. Experts are certified (for 5 years) by certifying bodies, which are accredited by COFRAC (French committee for accreditation) according to ISO standard 17024 "General requirements for bodies operating certification of persons". There is also a continuous assessment of the tools and measures by the ministries with studies evaluating the reliability of the calculation, or through constant contact with professionals, with the goal to identify and correct any dysfunctional points in the EPBD implementation.	10, 14, 16
5.	[17]	Ireland	SEAI may, under its Quality Assurance System and Disciplinary Procedures, require EPC Assessors to participate in mentoring visits arranged by its auditors to facilitate further training. Suspension or termination of registration of an EPC assessor may result where 10 penalty points or more are accumulated within the previous 2-year period.	12
6.	[28]	Slovenia	In the secondary EPBD regulation only minor changes have been implemented (since December 2015), including an update to the rules on the training, accreditation and register of accredited independent experts for regular inspection of AC systems, completed in January 2016. There is a system of licenced independent experts for the inspection of AC systems in place; the regulation of training and accreditation of experts was revised in 2016.	1, 15
7.	[30]	Sweden	If a certified energy expert does not meet the requirements concerning competence, access to the register and the EPCs issuing permit can be withdrawn.	8
8.	[31]	The Netherlands	Accredited inspectors have to take a new exam every 5 years. If they fail, they will be removed from the RVO database.	14

9.	[38]	Belgium, France, Germany, Ireland, the Netherlands, Portugal	Belgium: The Walloon region has approved the energy experts. Approval is given by the Energy Administration of the public services of the Walloon administration (Service public de Wallonie). An approval is valid for 3 years. To become a government approved expert one has to be: a person with qualifications in the energy audit field, have the technical knowledge and equipment to perform the audits and has to submit an approval dossier to the Energy Administration. When failures by the approved expert are noted at quality/performance checks, the energy expert has to explain this and can receive a warning, or even lose his approval temporarily or definitively. France: Only qualified experts can issue a certificate. They have to pass a test for certification. The French government publicised a list of competences the experts have to fulfil. They must prove this in the exam. Experts are not obliged to take a specific training course before the exam. Germany: The German regions set the accreditation requirements for experts, therefore the rules and qualifications may vary considerably by region. Ireland: Sustainable Energy Ireland sets requirements for assessors. They have to follow initial accreditation training with examination and follow-up periodic training courses and pay a fee to be re-registered annually. Assessors have to sign a 'Code of Practice', which includes requirements to act in a professional and independent manner, to comply with the scheme rules and ensure confidentiality. Furthermore the national database is used for practical quality control of issued certificates. Audits are taken both on a random basis and as a result of any unusual or suspect data. Every active energy assessor is on average assessed at least once a year. The Netherlands: Advisors/energy experts who issue EPCs need to have a higher building-related education and pass an additional exam. Accredited bodies control these advisors by checking the internal process of issuing the EPCs and checking the quality of the EPCs on a random basis by means of the database and visits on site. Energy performance inspectors need a valid NL-EPBD certificate. The requirements that they have to meet are stipulated in a regulation. Portugal: Only qualified experts may issue certificates. They must be recognised architects or engineers with at least five years of relevant experience. Qualified experts must attend courses and pass a national exam. ADENE coordinates the training of qualified experts. The license which experts have is valid for five years and will only be renewed when they can provide proof of continued training and a lack of malpractice.	44, 48, 51, 55, 56, 60
10.	[41]	-	Ireland: They have to follow initial accreditation training with examination and periodic follow-up training courses and pay a fee to be re-registered annually (also IEA, 2010). Assessors have to sign a Code of Practice that includes requirements to act in a professional and independent manner, to comply with the scheme rules and ensure confidentiality.	92, 121

			All the countries/regions have focused on improving quality assurance of assessors and EPCs, including accreditation of assessors (Flanders, France, Ireland, Portugal, UK), a code of practice for assessors (Ireland), quality control of EPCs via EPC databases (Flanders, France, Ireland, Portugal), penalties for inaccurate EPCs (Flanders, Ireland, Portugal), and banning experts who have made a high number of errors (Flanders, Portugal). Efforts targeted specifically at the public include greater transparency of the information available on the label (France), and an awareness-raising campaign about EPCs aimed at the public (Flanders, Portugal).	
11.	[46]	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden	Austria: Professionals from the listed sectors, such as builder, electrical engineering, civil engineering, and architecture are eligible to issue EPCs. Mandatory training is not required (Government of Austria, n.d.). Belgium: Mandatory training and examination are required to qualify as an EPC assessor. Separate training and exams are conducted for different building typologies, such as type A certification for residential buildings and type C certification for public buildings (Flemish Energy Agency, n.d.-c). Continuing to receive annual training has been mandatory since 2017 in order to retain recognition as type A energy expert (Flemish Energy Agency, n.d.-d). Type A experts should take part compulsory annual training for stipulated number of hours and context to retain certification (Flemish Energy Agency, n.d.-c). Bulgaria: An initial and mandatory training on assessment and recommendations is required for certification. A periodic training is not required. Croatia: Authorized natural persons who carry out energy certification, energy audits of buildings and regular inspections of heating systems and cooling or air-conditioning systems in buildings are obliged to at-tend once a year the training programme (Ministry of Construction and Physical Planning, n.d.). Cyprus: EPC assessors are required to pass a qualifying examination under the categories for residential, non-residential buildings or both. Training is not mandatory (Ministry of Energy, Commerce and Industry, n.d.). Czech Republic: Mandatory training is not required. Taking an ex-amination is compulsory. Continuing professional education is required (Energy Management Act, 2001). Continuous education is provided by the State Energy Inspectorate to deepen and updates expertise in the field of energy management and use to ensure the operation of buildings, energy savings, energy performance of buildings and energy management, etc. Credits are awarded for such education programmes (Energy Management Act, 2001). Assessors have to undergo further education and pass an examination (Svoboda et al., 2015). Denmark: Mandatory training is not required. However, it is mandatory to pass an examination depending on the building typology they wish to issue EPCs for. Qualified energy consultants must attend mandatory courses and meetings in accordance with the Danish Energy Agency's decision (Order on energy labelling of buildings, n.d.). All energy consultants must pass a refresher course no later than every 3 years (Order on energy labelling of buildings, n.d.).	61, 67

			Estonia: The Open University, of Tallinn University of Technology, provides mandatory training and the examination is conducted by the Estonian Association of HVAC Engineers (Ministry of Economic Affairs and Communications, n.d.-a). Mandatory amount of academic points has to be collected during a period of time (five years). Finland: It appears that mandatory training is not required, however, Finnish Association of HVAC Engineers provides training for taking the mandatory examination for qualifying as an EPC assessor. However, as initial certification is valid for 7 years, periodic training is one of the options for continuing as EPC assessor after the completion initial 7 years (Motiva Oy, n.d.-a). The certificate is valid for seven years. To renew the qualification after that the EPC assessor should maintain their professional skills by issuing certificates, undertaking training etc. (Act on Building Energy Certification, 2013). France: Taking an examination is mandatory, but not training. EPC assessors are required to keep abreast of technical, legislative and regulatory developments in the field concerned and completes training lasting at least three days (five days for certification with mention) during the certification cycle, including at least one day (two days for certification with mention) in the last eighteen months of the certification cycle (Decree of December 13, 2011 amending the decree of October 16, 2006 as amended defining the criteria for certification of the skills of natural persons carrying out the energy performance diagnosis and the criteria for accreditation of certification bodies, 2018). The certificate is renewed upon satisfactory clearance of a documentary exam and a practical exam (Decree of December 13, 2011 amending the decree of October 16, 2006 as amended defining the criteria for certification of the skills of natural persons carrying out the energy performance diagnosis and the criteria for accreditation of certification bodies, 2018). Germany: Training is not mandatory for experts certified for proving energy performance of new buildings or who are a sworn public expert. Proof of expertise through references in the field of energy-efficient construction and renovation or participation in further education, similar to the evidence supporting the renewal of the entry in the EEE list. Greece: Although not mandatory, training seminars are organized by vocational centres and academic institutions and attended on a voluntary basis by interested auditors. EPC assessors are certified only once. Hungary: EPC assessors must undergo mandatory training for certification. Further regular trainings are available, but taking part in them is not a condition to remain an assessor. They can be attended on a voluntary basis. Ireland: Training course is mandatory for Domestic BER Assessors and recommended (nor mandatory) for Non-Domestic BER Assessors. BER assessor registration is valid for one year. Renewal may be subject to additional educational or administrative requirements, but not definitive (SEAI, n.d.-b). Renewal of registrations is subject to payment of fees, in-date insurance policies, and may be subject to additional educational or administrative requirements (SEAI, n.d.). However, a BER/DEC -Assessor is required/expected from time to time to update, at	

			his/her own cost, their skills and/or resources to meet the standards required on an on-going basis by SEAI; this may be subject to verification by SEAI or its appointed agents or contractors in order to approve renewal of registrations (SEAI, 2018). Italy: Regional and autonomous provinces have their own approach towards mandatory training, but usually mandated especially for people with relevant professional qualifications. Periodic training is not necessary. Latvia: It is mandatory to work under (train) for 2 years under the guidance of a certified EPC assessor to be able to take the exam for becoming an energy auditor. Periodic training is not required. EPC assessors are certified only once and then can issue EPCs for the rest of their life. Lithuania: Undertaking training course organized by designated organizations and passing a qualifying examination is mandatory (SPSC, 2020a). EPC assessor must undertake an additional 20 hours of training and pass an examination every 5 years (Meškauskienė et al., 2015). Luxembourg: Architects and consulting engineers whose profession is regulated by the Law of 13 December 1989 on the organization of the professions of architects and consulting engineers are not required to take a mandatory training. However, other experts are approved by the Ministry of Economic Affairs to issue EPCs after taking mandatory training (Guichet.lu, n.d.). Periodic training is not required. Malta: Undertaking a training that is approved by the Building Regulation Board is mandatory (Energy Performance of Buildings Regulations, 2018). It is unclear from the legislation or the available information if such training is necessary. There appears to be no requirements for mandatory periodic training. The Netherlands: Only a qualifying examination is required. For certification as an EPC assessor for non-residential buildings, optional voluntary training is available after clearing the qualifying examination (RVO, n.d.-a, n.d.-b). Poland: There is no need to complete a mandatory course and pass an examination, according to the Act on Energy Performance of Buildings. Portugal: EPC assessors should undertake mandatory training courses. Besides mandatory courses, there are also complementary training courses. Periodic verification is not mandatory (ADENE, n.d.-a). Romania: An initial mandatory training in short-term courses of 80 hours, or master classes in 1 to 2-year programmes on energy efficiency, or the energy performance of buildings and an examination are required. EPC certification is awarded for a period of 5 years, which may be extended upon evidence of continuous training (Tenea et al., 2015). Slovakia: Training is only optional. Additionally, an examination at a test committee has to be done. (Sternova et al., 2015).	

			Slovenia: One-week training with a written and oral exam is needed for certification (Šijanec & Potočar, 2015). Periodic training is not required. The license for EPC assessors is valid for unlimited time (Decree on the promulgation of the Energy Act (EC-1), 2017). Spain: The only prerequisite to become EPC assessor is to have the academic degree of engineer, architect or technical vocational training in Spanish FP. Sweden: It is, however, mandatory to pass an examination before being certified, which means that nearly all assessors are doing training provided by academia or commercial education bodies before doing the examination. Furthermore, a 2 year technical degree from university and 5 years of practical experience within the building sector thereof 2 years should be within the energy use and indoor climate are required. However, the EPC assessor needs to report any updating of skills and send in assessed EPCs to the national certification body once a year. The certificate is valid for 5 years. After that it needs to be renewed with a new theoretical test. The test for recertification is a less comprehensive than the first certification test. Also, the EPC assessor needs to report number of performed assignments and any updating of skills and send in assessed EPCs to the national certification body once a year.	