Recommendation report on integration of Next Generation EPC in national/regional certification schemes v2

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Recommendation report on integration of NG EPC in national/regional certification schemes v2

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Executive Summary

One of the most important requirements and effective features (in regard to providing information to the end user) of the Energy Performance of the Buildings Directive (EPBD) is the Energy Performance Certificate (EPC). The aim is to raise user-awareness and increase the demand for buildings with excellent energy efficiency performance and the use of renewable energy sources, both in new construction and renovation. As a result, EPCs have become mandatory sales, rentals and building permits in the Member States (MS) of the European Union.

Several years have passed since the EPBD was first published and implemented in Europe. The EPBD has been adapted and amended since its first application and an adapted EPBD is on the way and will be published soon. Certainly, there will be many changes in the requirements for buildings by 2030, 2040 and 2050 in order to decarbonise the built environment. New features and requirements, as well as adaptations will be added to those already in place. This report focuses on the implementation of some aspects of the EPBD and its amendments up to 2021. However, new amendments will remain relevant for the implementation of the D^2EPC project.

The research carried out as a part of the project shows that some of the Member States have adapted the EPC schemes since they were first introduced in order to make them more user-friendly. At the European level different methodologies are currently used to issue an EPC. In some countries, the EPC is issued on basis of calculated energy demand (asset rating) or on actual energy consumption (operational rating). Some Member States store the EPCs in a database at national or regional level. The information available in these databases is being used for different purposes – mostly for research purposes and quality control of the EPCs. Some countries have compulsory training for the experts who issue EPCs. In the light of the new EPBD, the qualification of the EPC issuer will become more important as the new set of indicators as well as the phased renovation measures for a roadmap will be part of the EPC scheme.

This report not only provides an update on the implementation of some aspects of the EPBD related to the EPC, such as quality control of EPCs or training of the EPC issuer, but also addresses other aspects, such as Smart Readiness Indicators, market acceptance, use of smart meters, linking of the EPC database to other databases and use of digital models that are part of the project and its outcomes. For this purpose, a questionnaire was developed for the experts of the participating countries in order to get an overview of these topics. The questions cover the following issues: i) Smart Readiness Indicators; ii) Use of EPCs beyond provision at the point of sale, rental or construction; iii) Methods to verify the application of renovation measures; iv) Use of digital models, use of EPC databases; v) Training of EPC issuers; vi) Use of smart meters and finally; vii) Market acceptance of EPCs.

As stakeholder involvement is crucial – especially for the project exploitation and usability – different aspects of the project's outcome for a "digital dynamic EPC" were discussed and both benefits and opportunities for application were identified during the workshops and meetings with relevant stakeholders (identified during the project period). The feedback and results of these stakeholder interactions were fed into the work and implementation of the project. The aim was to produce a report with recommendations for decision-makers on how the next generation of (dynamic) EPCs could be assessed and integrated into national or regional EPC systems and how countries could benefit from the results of the D^2EPC and the use of the project's platform at the end of the project.

Table of Contents

List of Figures

List of Tables

List of Acronyms and Abbreviations

Term	Description
AECO	Architecture, Engineering, Construction and Operation
API	Application programming interface
BEPS	Building Energy Performance Simulations
BIM	Building Information Modelling
BMS	Building Management System
BSO	Building Stock Observatory
CEN	European Committee for Standardization
CENELEC	European Committee for Electro- technical Standardization
CO2-eq	Carbon Emission Equivalent
dEPC	Dynamic Energy Performance Certificates
DT	Digital Twin
EPBD	Energy Performance of Building Directive
EPC	Energy Performance Certificate
ESCOs	Energy Service Companies
ETSI	European Telecommunications Standards Institute
GIS	Geographic Information System
HC&W	Human Comfort and Wellbeing
HVAC	Heating Ventilation Air-Conditioning
I.A.Q.	Indoor Air Quality
ICT	Information and Communication Technologies
IEC	International Electro-technical Commission
IEQ	Indoor Environmental Quality
IOT	Internet of things
ISO	International Organization for Standardization
KPI	Key Performance Indicator

LCA	Life Cycle Assessment
MSs	(EU) Member States
NG EPC	Next Generation Energy Performance Certificate
NUTS	Nomenclature of territorial units for statistics
nZEB	Nearly Zero-Energy Building
R&D	Research and Development
RES	Renewable Energy Sources
SRI	Smart Readiness Indicator
SWOT	Strengths, Weaknesses, Opportunities, Threats
ZEB	Zero Emission Building

1 Introduction

Energy Performance Certificates (EPCs) are an integral part of the Energy Performance of Buildings Directive (EPBD), which was introduced in 2002, revised in 2010, and amended in 2018. The EPBD is the EU's legislative and policy instrument tool to improve the energy performance of buildings across Europe, focusing on both existing and new buildings. EPCs are a mandatory requirement in Member States (MSs) at the point of sale or rental and at the point of construction of a building. EPCs serve as a transparent information tool for building owners and real estate agents and play an important role in providing information on the energy performance of buildings.

Although the current EPC systems have contributed to the understanding of the energy performance of buildings in Europe, the experience gained since their introduction has revealed a number of constraints and limitations. Looking at existing practices, EPCs for new buildings are issued to an early stage of construction and do not take into account the actual energy use in the building, especially in relation to the occupant's lifestyles. The availability of building energy data and the recording of actual energy consumption through smart meters and sensors opens up several possibilities for the integration of Building Management Systems (BMS) and Digital Twins (DT) into the certification process.

Although the EPC calculation process is based on a comprehensive set of standards, it still overlooks some important aspects that contribute the actual energy use as it varies from user to user, such as indoor air quality and availability of daylight. In addition, there is room for improvement in the information provided by the EPC to the building user in a simple, user-friendly form. Although thermal and acoustic comfort, indoor air quality and daylighting are among the main drivers for building renovation, they are not included in current EPCs.

In general, recommendations for the energy performance of existing buildings in Member States, are automatically generated through a standard list of general measures such as thermal insulation or window replacement, rather than being presented in a tailor-made way that encourages the renovation of the building.

While remarkable progress has been made since the introduction of the EPC in the building regulations of the European MSs, there is still a gap in introducing further schemes and indicators influencing the energy efficiency of the buildings in the EPCs at European level. There is additional work to be done to promote market acceptance of EPCs and the implementation of energy saving measures, as well as to support user behaviour in resources management. As a result, it is critical to examine the design of an EPC, based on new sets of indicators and the monitoring of the building's energy performance.

The aim of the D^2EPC project is to provide and produce practical knowledge that can be integrated into the national and European energy legislation. In particular, three themes will be analysed and developed that will provide the necessary framework to improve the existing set of standards used in the calculation process of the performance of buildings. These include practical ways of linking the results of the project to national and regional certification schemes, linking the planned scheme to building passports and renovation roadmaps, and introducing the polluter pays concept into the new EPC schemes for those users who do not meet their expectations.

The aim of this report in Work Package 6 (Policy implication for the enforcement of the next generation EPCs scheme, Task 6.2 Linking NG EPC with integrated national/regional certification schemes & choices) is to examine the integration of the NG EPCs into the national/regional schemes of the partner countries. In addition, the lessons learned from the stakeholder meetings and workshops held during the project will be taken into account when making recommendations for the implementation of the NG EPC at national or European level.

While an asset rating of a building can provide information on the performance of the building under certain conditions and a possible comparison with buildings of the same category and age group, an operational rating can provide building users with information on the actual energy consumption. The D^2EPC project has created a methodology for generating an operational rating, which includes the criteria or indicators required to incorporate actual energy usage into the calculation. This allows energy demand to be predicted and acted upon.

1.1 Scope and objectives of the deliverable

This report analyses the role and relationship of Next Generation EPCs (NG EPCs) in the Energy Performance of Buildings Directive (EPBD) and examines whether there are any existing constraints to their implementation in European countries. It also highlights the current state of implementation of key aspects of the EPBD and the use of the EPCs in the countries of the project consortium partners. To collect the relevant information for this task, a questionnaire was prepared and sent to the partner countries at the beginning of the research.

In addition, the main policy benefits of NG EPCs in the EU and in the project participating countries (e.g. real time energy consumption instead of theoretical values) on a policy level were identified (taking into account the results of the work within the project). The will then be weighed against market acceptance and user-friendliness, costs and benefits, readiness and training of EPC issuers. To this end, the partners have collected information on the usability of existing EPC systems and their links to national/regional EPC databases (including structure, interfaces, etc.). As part of this task, the stakeholders at national/regional level were identified and invited to share information and discuss the results of the project. These workshops took place during the second phase of the project, when interim results were available. In these workshops, the characteristics of the NG EPCs and related benefits were presented. The results of these workshops serve as an evaluation of the proposed framework for the next generation dynamic digital EPC as envisaged by the D^2EPC project. In addition to the benefits of the dynamic and digital EPC compared to the established EPC systems, its integration into national/regional strategies and recommendations, the results of the aforementioned workshops have been included in this report (Deliverable D6.6).

1.2 Structure of the deliverable

This report (D6.6) is a report with recommendations for the integration of NG EPCs into national/regional certification schemes based on the results of the project. It includes the development of a dynamic digital EPC, its sets of novel indicators and its possible use. It summarises the results of the discussions with the stakeholders involved in the workshops and individual meetings including the strengths, weaknesses, opportunities and threats of the proposed scheme.

This report starts with a description of the role of the Energy Performance Certificate (EPC) in the Energy Performance of Buildings Directive (EPBD), the definition of different EPC systems and the relevant aspects of the EPBD regarding the energy performance assessment (chapter 2).

Later in the report, chapter 3 presents the current status of EPC implementation and other indicators related to an operational rating in the partner countries, exemplary use of EPC-databases and a best practice example in Europe.

In chapter 4, particular attention was paid to the demonstrating the multiple potential benefits of implementing the next-generation dynamic digital EPC as envisaged by the D^2EPC project in the EU Member States (MSs) at the policy level. The characterisation and aspects of this novel EPC system, including the significant improvements resulting from the application of the proposed framework of the NG EPC compared to the currently applied methodologies based on Directive (EU) 2018/844 of the European Parliament and of the Council of May 2018 on the energy performance of buildings, as well as the compliance with the provisions of the recent proposal for the recast of the EPBD are presented below.

In the following chapter 4.4, the benefits are then being evaluated and weighed against various aspects, such as market acceptance and user-friendliness, costs and benefits, readiness and training of EPC issuers, based on the results of the workshops with numerous stakeholders at national and international level.

The report concludes with a summary of the results of the projects and recommendations for the integration of the proposed NG EPC into national/regional certification schemes (chapter 6).

1.3 Relation to Other Tasks and Deliverables

The basis for Task 6.2 and this report are based on the results of several work packages (WPs). The stakeholders who were involved in this WP were identified within WP7 (Project Communication, Dissemination and Exploitation). Stakeholders, especially at the decision-making level, have contributed to improving future policies. These target groups at national/regional level can promote the exploitation of project results and the realisation of their long-term impact. This will lead to the overcoming of barriers and the promotion/application NG EPCs in the market. Furthermore, this task considers the results of WP1 (Fundamentals of next-generation dynamic EPCs (dEPCs): Identifying challenges, needs and opportunities) and WP5 (Demonstration and impact assessment), in particular the comparative assessment of current EPC systems and the evaluation of the impact achieved by the D^2EPC framework in pilot buildings as well as the consolidation of the lessons learned from real-life demonstrations.

2 The Energy Performance Certificate (EPC)

The following sections provide an overview of the role of EPCs and the legal basis for the mandatory energy performance assessment and certification of the energy performance of buildings in EU Member States. The different EPC schemes and calculation methods are presented, followed by the main requirements for EPCs under the current EPBD and the future requirements under the recently amended Directive.

2.1 The role of the Energy Performance Certificate (EPC) in the Energy Performance of Buildings Directive (EPBD)

The Energy Performance of Buildings Directive (EPBD) provides guidance to Member States on how to calculate the EPC in accordance with EU standards (Art.3, Annex I). Since the publication of Directive 2002/91/EC in 2002 the EPBD has required EU Member States to establish certification schemes for buildings. The certification process results in the issuance of EPCs for residential and non-residential buildings. EPCs, which can be issued on a one-off basis or periodically on a mandatory basis for new and existing buildings, provide consumers with energy-related information, and thus the key information on the energy quality of the building, when they are considering buying or renting it.

The Directive and its recast and amendment are:

- Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings [1]
- Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast) [2]
- Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency [3]

In December 2021, the European Commission released a

- Revised proposal for a Directive of the European Parliament and of the Council on the energy performance of buildings (recast) [19]

for consultation[1], with a view to modernising the existing regulatory framework to reflect higher ambitions and more pressing climate and social needs. A deadline of the end of February 2023 has been set for the consultation process. It is now under consideration by the Council and the European Parliament.

2.2 Definition of EPC

According to the EPBD, the energy performance of buildings can be assessed on the basis of an asset rating or an operational rating, associated with a typical use. While the asset rating methodology considers primary energy demand based on various building characteristics, but without taking into account all the losses resulting from energy production, the operational rating is based on the energy delivered to the buildings and therefore also includes the effects of the respective user behaviour.

The EPC, as the result of an energy performance assessment, is the most visible part of the EPBD. An EPC scheme requires a number of tools and services including the EPC software, the EPC registry or

[1] https://ec.europa.eu/energy/sites/default/files/proposal-recast-energy-performance-buildings-directive.pdf

database with recurring operating costs, the website for qualified experts and the public, helpdesks and the operation of an independent verification system, as well as associated software tools for data mining or quality control checks. For a better understanding of the objective of the project, it is necessary to explain the different EPC calculation methods and issuance procedures, which are listed below:

EPC

According to the EPBD, the *'energy performance certificate of a building'* is *'a certificate recognised by a Member State or by a legal person designated by it, which indicates the energy performance of a building or building unit, calculated according to a methodology adopted in accordance with Article 3'* [2]. According to Article 3, '*Member States shall apply a methodology for calculating the energy performance of buildings in accordance with the common general framework set out in Annex I*'.

The EPC can be determined using a methodology based solely on calculated energy demand (**asset rating**) or on actual energy consumption (**operational rating**).

The rating is based on the energy efficiency value, resulting from the calculated annual consumption of supplied energy, weighted according to the coefficients defined for the different types of energy. A set of defined default values (e.g., indoor temperature…) is used for asset rating. Operational rating, on the other hand, is derived from metered data of actual energy consumption and, therefore, reflects user behaviour and potential of equipment malfunction. An operational rating based EPC can be issued for a minimum of 2-3 years of building operation. In the European countries, this method is used for limited building types (e.g., non-residential buildings).

Dynamic EPC (dEPC)

The dynamic EPC allows users to monitor the actual performance of the building on a regular basis, e.g., monthly or every six months, bases on real-time data.

The new dynamic EPC scheme in line with the requirements identified in the D^2EPC project is linked to the regular measurement of a building's performance and the further linking of EPCs to the building refurbishment passports[2] and digital logbooks. We use the term operational EPC to refer to the methodological approach used to collect data on a building in operation. This means collecting actual energy consumption, analysing it and based on the results, proposing measures to combat uncontrolled energy use.

Next-generation dynamic digital EPC envisioned by the D^2EPC project

The NG EPC explored in the D^2EPC project goes further. It is based on the smart-readiness of buildings and the associated data collection infrastructure and management systems. It is fed by operational data and uses the 'digital twin' concept to advance building information modelling. The D^2EPC calculation framework includes a novel set of energy, environmental, financial and human comfort/well-being indicators, and uses these to determine the building's EPC classification. The calculation is based on real time energy consumption and takes into account smart financial schemes linked to performance-based rating. A complete user profile in the system will include a set of comfort/well-being and behavioural indicators, together with the corresponding algorithms. The addition of Life Cycle Assessment (LCA) indicators allows the environmental impact of any system to be assessed throughout its life cycle taking into account input resources required and associated output resources of that system. The introduction of simplified indicators will improve the user-friendliness of the building certificate. A set of financial indicators based on the well-established

[2] 'Renovation passport' means a document that provides a tailored roadmap for the renovation of a specific building in several steps that will significantly improve its energy performance.

concept of whole life cycle costing will allow the interpretation of individual elements of building energy performance into normalised monetary values.

2.3 Relevant aspects of the EPBD regarding EPC assessment

In order to achieve the EU's energy and environmental goals (zero emission and fully decarbonised building stock by 2050), the recent proposal for a recast EPBD should encourage the EU Member States to increase the national renovation rate through the proposed measures. A selection of the current EPBD requirements relevant to the project, including future EPBD requirements under the proposed recast of the Directive, are presented in the following sections:

2.3.1 EPC issuance, indicators and displayed content

EPC issuance

The Directive requires the certificate to be valid for a maximum of 10 years. Under the proposed revised EPBD, the validity of energy certificates in the lower classes D to G will be limited to five years.

According to the EPBD DIRECTIVE 2010/31/EU, the EPC has to be issued for the construction of new buildings and at the point of sale or rent ([2], Article 12). Moreover, when a technical building system is installed, replaced or upgraded, an EPC is required to assess the overall energy performance of the modified part, and where applicable of the whole modified system. According to Article 11, if the improvement is due to a major renovation, the performance should be assessed by issuing EPCs for before and after the renovation.

In addition, the revised proposal for a recast Directive [18] requires that an EPC be issued only in digital form. It requires the issuance of an EPC in any case when a building or building units are '*constructed, have undergone a major renovation, are sold or rented out to a new tenant or for which a rental contract is renewed*'. If the current EPC of a building unit has been issued in compliance with Directive 2010/31/EU it remains valid.

Indicators

<u>Smart readiness of buildings</u>:

The amended Directive (EU) 2018/844 [3]not only stipulates that *'[t]he installation of self-regulating devices in existing buildings for the separate regulation of the temperature in each room or, where justified, in a designated heated zone of the building unit should be considered where economically feasible…'* [3], but also promotes digital solutions for the built environment to provide building occupants and owners with more accurate information about their consumption patterns and to enable them to take steps to improve energy efficiency. The use of a Smart Readiness Indicator to measure the capacity of buildings and of information and communication technologies and electronic systems is strongly recommended.

According to the technical study of the European Commission Service (DG ENERGY) on a Smart Readiness Indicator (SRI), the "smartness of a building refers to the ability of a building or its systems to sense, interpret, communicate and actively respond in an efficient manner to changing conditions related to the operation of technical building systems or the external environment (including energy grids) and to the demands of the building's occupants".[12] In the amendment of the EPBD, it is mentioned that the Smart Readiness Indicator should be used to measure the capacity of buildings to exchange information. In addition, information and communication technologies (ICT) and electronic systems should be used to adapt the operation of buildings to the needs of occupants and the network and to improve the energy efficiency and overall performance of buildings. Member States that decide to implement the Smart Readiness Indicator will have to set up an independent control system for SRI certificates. With regard to the expertise required to assess the smart maturity of buildings, professional inspectors of heating, air-conditioning and ventilation systems according to Directive 2010/31/EU, energy auditors under Directive 2012/27/EU [19] or accredited EPC assessors are considered qualified. However MSs shall ensure, however, that training in ICT is included as a competence criterion.

The proposal for a Directive of the European Parliament and of the Council on the energy performance of buildings (recast) requires the Commission to '*adopt delegated acts (...) concerning an optional common Union scheme for rating the smart readiness of buildings'* and further *'adopt an implementing act detailing the technical modalities for the effective implementation of the application of the scheme (…) to non-residential buildings with an effective rated output for heating systems, or systems for combined heating and ventilation of over 290 kW'* ([18], Article 13).

<u>Human comfort</u>

The recent proposal for a revised EPBD recognises the importance of good indoor air quality and therefore, requires EU Member States to *'address, in relation to new buildings, the issues of healthy indoor climate conditions'* ([18], Article 7). It requires *'zero-emission buildings to be equipped with measuring and control devices for the monitoring and regulation of indoor air quality. In existing buildings, the installation of such devices shall be required, where technically and economically feasible, when a building undergoes a major renovation'* (Article 11).

With regard to the calculation methodology of the future SRI to be defined by the European Commission, Annex IV of the proposal for the recast Directive requires one of the three (3) key functionalities – the ability to adapt its operation mode in response to the needs of the occupant – to do so while paying attention to maintaining healthy indoor climate conditions.

<u>Life-cycle assessment</u>:

In order to improve and maximise the environmental performance of the EU building stock, the revision of the EPBD goes beyond the focus on operational greenhouse gas emissions, but goes beyond them: The whole life cycle emissions of buildings should be taken into account when assessing the energy performance of buildings.

As defined in [18] Article 2, the 'whole life-cycle greenhouse gas emissions' means the combined greenhouse gas emissions associated with the building at all stages of its life cycle, from the 'cradle' (the extraction of the raw materials used for the construction of the building) through the production and processing of materials, and the operation of the building, to the 'grave' (the deconstruction of the building and the reuse, recycling, other recovery and disposal of its materials)'. In a similar, the 'Life-cycle Global Warming Potential (GWP)' means an indicator that quantifies the global warming potential contributions of a building over its entire life-cycle.

The new revised proposal for the recast of the Directive requires the inclusion of the life-cycle global warming potential (GWP) in the calculation according to the new Annex III and the disclosure through the EPC. This is important as the proposal also stipulates that from 2027, new buildings occupied or owned by public authorities and from 2030, all new buildings must be zero emission buildings and until then, new buildings must be at least nearly zero energy buildings, meeting the minimum energy performance requirements, as set by the Member States.

Displayed content

The EPC as a document should not only provide information on the performance of the building in terms of energy use and reference values for the user or owner of the building, but also *'make recommendations for cost-effective improvement of the energy performance and the reduction of operational greenhouse gases emissions of a building or building unit'* (as stated in Article 16 of the EPBD recast [18]). These measures should be technically feasible, should provide an estimate of the energy savings and the reduction of operational greenhouse gas emissions, and may also provide an estimate of the range of payback periods or cost-benefits over the economic life of the measure. Information on the steps to be taken to implement these recommendations should also be provided. In addition, the owner or tenant of the building should receive an assessment of whether the heating or air-conditioning system should be adapted to operate more efficiently.

The EPC should provide reference values as benchmarks for energy performance (e.g. minimum energy performance requirements) so that the user or consumer can compare and evaluate the energy use.

In the revised proposal for the recast of the EPBD [18], Annex V provides a list of mandatory and non-mandatory elements that should be displayed in an EPC (mandatory elements on the front page), by the end of 2025 at the latest. Until then, the recent proposal for a recast EPBD (Article 16) also requires that the energy performance class of the building (on a closed scale from A to G) corresponds to the actual existing national building stock of the respective country (e.g. the letter G for the 15% of the worst performing buildings in the building stock).

The amended Directive (EU) 2018/844 requires that the transparency of the EPC to be improved and that Member States *'should adopt adequate measures to ensure, for example, that the performance of installed, replaced or upgraded technical building systems, such as for space heating, air-conditioning or water heating, is documented in view of building certification and compliance checking'*[3]. [3]

2.3.2 EPC calculation scheme, data and digital models

Calculation scheme

The Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings states, that *'The energy performance of buildings should be calculated on the basis of a methodology, which may be differentiated at national and regional level.'* [2]

According to Directive 2002/91/EC, Directive 2010/31/EU and Directive (EU) 2018/844, the energy performance of a building should be calculated based on a methodology (which may differ in different regions) that includes the thermal performance of the building elements (windows, exterior walls, floor and ceiling) and its heating/cooling installations. In addition to aspects of thermal comfort, EPC assessment methods are required to include other Indoor Environmental Quality (IEQ) parameters, such as indoor air quality and adequate natural light. [1][2][3]

According to the Directive 2010/31/EU, the energy performance of a building shall be determined on the basis of the calculated or actual annual energy that is consumed, meeting the different needs associated with its typical use and reflecting the heating and cooling energy needs (energy needed to avoid overheating) to maintain the intended temperature conditions of the building, as well as domestic hot water. The EPC of a building includes an energy performance indicator and a numeric indicator of primary energy use, based on primary energy factors per energy carrier, which may be based on national or regional annual weighted averages or a specific value for onsite production. The methodology for calculating the energy performance of buildings should take into account European standards and shall be consistent with relevant Union legislation, including Directive 2009/28/EC. [2]

Regarding the temporal resolution of the energy balance, the revised proposal for the recast EPBD further specifies, that the calculation methodology should *'enable the use of metered energy to verify correctness and for comparability, and the methodology should be based on hourly or sub-hourly time-steps'* and that *'the benefits of maximising the use of renewable energy on-site, including for other-uses (such as electric vehicle charging points), are recognised and accounted for in the calculation methodology'* ([18], Recital 12). In particular, for the assessment of energy performance based on metered data (operational rating), Annex I requires the calculation to be based on hourly readings, differentiating between energy sources, while it requires that metered energy consumption should be based on monthly readings for the purposes of verification and comparison between calculated and actual performance.

Renovation passport

As defined in Article 2 of the proposal for revision of the EPBD, a renovation passport should provide *'a tailored roadmap for the renovation of a specific building in several steps that will significantly improve its energy performance'*. [18]

Article 10 of the proposal for the recast of the Directive stipulates, that by December 2024, MSs must introduce a scheme of renovation passports based on a common framework, which is to be established by the European Commission by December 2023. This new renovation passport will be issued by a qualified and certified expert, following a site visit, and will include a renovation roadmap showing a sequence of renovation steps that build on each other, with the objective to transform the building into a zero-emission building by 2050 at the latest, indicating the expected benefits in terms of energy savings, savings on energy bills and reduction in operational greenhouse gas emissions as well as wider benefits related to health and comfort and the improved ability of the building to adapt to climate change. It will also provide information on potential financial and technical support.

Motivational schemes

As stated in [18], Article 15, public financial incentives received for a phased deep renovation of a building should only be granted if the steps set out in the renovation passport are followed.

Access to data

According to the proposed revision of the Directive the MSs shall *'ensure that the building owners, tenants and managers can have direct access to their building systems' data'*. It further stipulates, that the building owner, tenant or manager should not be charged for accessing or making available their data to a third party, moreover it is the MSs to be held *'responsible for setting the relevant charges for access to data by other eligible parties such as financial institutions, aggregators, energy suppliers, energy services providers and National Statistical Institutes or other national authorities responsible for the development, production and dissemination of European statistics'*. [18]

Interoperability requirements and non-discriminatory and transparent procedures for access to the data will be detailed in implementing acts to be adopted by the Commission. [18]

The Directive 2010/31/EU requires the MSs to ensure, that owners or tenants of buildings or building units are informed about the different methods and practises that serve to improve the energy performance of buildings. The proposed recast of the Directive includes also all relevant market actors. Tailored information must also be provided to vulnerable households. [2][18]

MSs are also required to provide simplified procedures for the updating of an energy performance certificate available (in case of single or stand-alone measures or when measures coming from the renovation passport are implemented). [18]

2.3.3 EPC databases

The Directive (EU) 2018/844 [3] requires high quality data on the building stock, which could be partly be provided by the EPC databases that almost all Member States are currently developing and managing for the EPCs. It requires these databases to allow data to be gathered on the measured or calculated energy consumption of the buildings covered, including at least public buildings for which an energy performance certificate has been issued.

According to the revised proposal of the EPBD [18], not only a part of the EPCs should be uploaded to a national EPC database, but all of them. The databases should be able to collect data not only on EPCs, but also on inspections, the building renovation passport, the smart readiness indicator and the calculated or metered energy consumption of the building covered. Article 17 of the revised Directive states: *'The upload shall contain the full energy performance certificate, including all necessary data required for the calculation of the energy performance of the building.'* This means that the data to be stored must include at least all the data relating to the energy performance of the buildings (EPC) and the technical building equipment (data on inspections, building automation and control systems, smart readiness indicators, energy consumption of e-mobility charging stations...).

As described in Chapter 2.3.2, the proposal for the revision of the Directive does not allow the building owner, tenant or manager to be charged any additional costs for accessing to their data or for requesting that their data made available to third parties. The aim is to ensure that the building owners, tenants and managers have direct access to the stored data of their buildings and energy systems. In addition, information on the share of buildings in the national building stock covered by EPCs and aggregated or anonymised data on the energy performance of the buildings covered should be publicly available. This public information shall be updated at least twice a year. The proposed Directive requires the MS to ensure the interoperability and integration with other databases, such as the national building cadastre and digital building logbooks, and further the transfer of the information in the national database to the Building Stock Observatory (BSO)[3].It stipulates, that *'Member States shall set up national databases for energy performance certificates of buildings, which also allow to gather data related to building renovation passports and smart readiness indicators. Information from the national databases shall be transferred to the Building Stock Observatory, based on a template to be developed by the Commission.'* [18]

2.3.4 EPC quality control

The Directive (EU) 2018/844 [3] recommends improving the quality of EPCs, possibly by using databases to control the EPCs, to have an overview of the performance of buildings and to provide statistics at regional or national level.

According to the revised proposal of the Directive [18], MSs should ensure the quality of the EPCs and that EPCs are issued by independent experts following an on-site visit. In order to ensure high data quality, it also includes that not only the EPC assessment and the inspections of heating systems and air-conditioning systems should be carried out by qualified or certified (no longer accredited, as per Directive (EU) 2018/844) experts, but also the establishment of renovation passports and the smart readiness assessment.

The European Commission also recommends the use of existing independent control systems for EPCs to check compliance. As reliable data is essential to have an overview of the performance of buildings and the energy savings generated by the measures initiated by the Directive, high quality information stored in EPC databases could be used to verify compliance and produce statistics on regional or national building stocks.

The revised proposal of the Directive also includes the renovation passports and Smart Readiness Indicators, which are to be covered by independent control systems as described above.

2.3.5 Standardisation and EPBD-related standards

Standards are voluntary technical documents that specify requirements for a particular item, material, component, system or service, or that describe in detail a particular method, procedure or best practice. Standards are developed and defined through a process of sharing knowledge and building

[3] The EU Building Stock Observatory (BSO), established in 2016, includes a database, a data mapper and factsheets for monitoring the energy performance of buildings across Europe and aims to provide a better understanding of the energy performance of the building sector through reliable, consistent and comparable data. [https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/eu-building-stock-observatory_en]

consensus among technical experts nominated by interested parties and other stakeholders - including business, consumers and environmental groups [16].

The use of standards in the implementation of legislation and public policy brings benefits to policy makers, including:

- Broad market acceptance
- Simplification of legislation or policy
- Supporting emerging technologies and the promoting of innovative approaches, without changing the regulatory framework
- A close link to international standards, enabling international market access and thus promoting the global competitiveness of the European industry

The standardisation system at both international (ISO and IEC) and European (CEN/CENELEC and ETSI) levels is based on the principle of national delegation. This means that the National Standards Body (NSB) of each country is a member of the supra national standards organisations and defines its position based on the input from industry, research bodies, NGOs, public administrations, etc. The standards are therefore approved through a consensus-based process between NSBs. In Spain, the NSB is UNE (Spanish Association for Standardisation) and, in Austria, ASI (Austrian Standards International). Both organisations are members of the D^2EPC project consortium.

A particular case of standards included in EU legislation are harmonised standards, developed by an ESO (European Standardisation Organisation, such as CEN, CENELEC and ETSI) following a Request (or Mandate) from the European Commission. 20% of all European standards are developed in response to a standardisation request.

An important issue is the revision of current standards related to the EPBD. In 2017, a large number of (EN) ISO and CEN standards have been published to collectively assess the overall Energy Performance of Buildings: the set of EPB standards, managed by the European Committee for Standardisation (CEN). This set of standards and accompanying technical reports provides guidance on the definition, description, exchange, monitoring, recording and securely handling of asset data, semantics and processes with links to geospatial and other external data. In the course of 2022 (5 years after publication), many of these documents have, individually, been subject to a systematic review (SR). This SR process started a ballot in which National Standardisation Bodies assessed whether a published standard should be revised, maintained or replaced.

D^2EPC has actively participated in CEN/TC 371 “Energy performance of buildings”, the horizontal standardisation committee for the energy performance of buildings (EPB). This TC is concerned with the development, alignment and maintenance of a coherent set of standards for the determination of the EPB. It does this by:

1. developing standards at an overarching EPB level and
2. coordinating the activities of related and specialised TCs that are responsible for the development of EPB standards within their scope, thereby ensuring harmonisation.

In particular, D^2EPC proposed the creation of a new working group (WG) 5 for operational energy efficiency, which is developing a European standard covering part of the results of D^2EPC (more information is available in [26]).

3 Current implementation of the EPC and related schemes and tools in EU countries

The identification of the methodologies currently used for the issuance of EPCs and the investigation of the challenges of the current EPC systems in EU countries were based on the results of a field research carried out at the beginning of the D^2EPC project using the survey method (see Annex A). With the assistance and feedback of relevant stakeholders from most EU countries, an accurate picture of the EPC systems and procedures currently in use was obtained, resulting in a total of 25 most typical statements on challenging EPCs matters.

To explore the detailed status of implementation of other important aspects of the EPBD in EU countries, a further survey was carried out among the project consortium partners. One objective was to determine the extent to which relevant aspects of the EPBD, such as the required elements for the inclusion of the novel set of indicators described in Chapter 4 in the NG EPC envisaged by the D^2EPC project, are applied in practice in the respective partner country. Another objective was to further investigate the current use of the EPC systems in these countries. The questionnaire created for this purpose (see Annex B) was prepared and distributed to the partners. In this questionnaire, the project partners were asked to share their knowledge on the status and evolution of the current implementation of the EPC schemes, lessons learned and the steps taken to address the challenges encountered since the start of the scheme in their respective EU Member States. Based on the partners' feedback (see Annex C), the following chapters present examples and best practices, such as the implementation and use of the Smart Readiness Indicator (SRI), methods to verify and establish energy savings and renovation quality, and data and digital models. Other main findings on the use of smart meters, databases, EPC issuer qualification requirements and market acceptance in the partner countries are summarised in the following chapters. Partner feedback is provided in ANNEX C.

The following content gives an overview of the current state of implementation and challenging issues of the EPC and related systems and instruments in the Member States. It is based on the results of one desk study and two field studies carried out as a part of the project, using a survey methodology (see related questionnaires in Annex A and Annex B) and makes respective reference to the applicable regulations of the EPBD as appropriate.

3.1 EPC calculation schemes

Since the publication of Directive 2002/91/EC in 2002 the EPBD has required Member States to establish certification schemes for buildings. By then, most countries had had systems in place for many years. In the beginning, that were common to all building types, such as cost, and some issues about the quality of layout of the certificates. Many countries have opted for calculated energy consumption for the certification of new buildings.

According to the previous research carried out within the project, fourteen (14) out of twenty-seven (27) EU Member States have adopted the methodology based exclusively on calculated energy consumption to calculate the energy performance of buildings (i.e. they have chosen the asset rating method as their national energy performance assessment methodology). In 2 MSs the assessment is based on the operational rating method, and in 13 MSs, including the United Kingdom (UK) both actual and calculated energy consumptions are foreseen. [13]

The methodology for the calculation based on asset rating considers the primary energy demand to be based upon various building characteristics (including defined default values), but without taking into account all the losses derived from energy production. The operational rating is based on the energy delivered to the buildings, real internal gains and includes users' behaviour with minor adjustments.

For new buildings, asset rating is the most widely used EPC methodology as historical energy consumption measurements are not available to perform operational rating calculations.

In many European countries, the calculation of the EPC is based on a standard climate, standard user behaviour, and other default values, which may differ more or less from the actual situation, depending on the specific case/building. In a few countries, the calculation of the EPC is based on both the asset rating and the operational rating (e.g. Latvia) or is carried out after a few years of operation (e.g. after three years in Bulgaria) in order to provide an EPC that is closer to the actual energy consumption.

EPC data and digital models

Building Information Modelling (BIM) is defined as an *'overarching term to describe a variety of activities in object-oriented Computer Aided Design (CAD), which supports the representation of building elements in terms of their 3D geometric and non-geometric (functional) attributes and relationships'* [20]. Well-defined semantic and geometric data for each element and the ability to enable collaboration between stakeholders throughout the lifecycle of the asset can be considered a key feature of BIM.

Building Information Modelling (BIM) is considered an essential part of DT (Digital Twin) with semantically rich and geometrically accurate data. Both BIM and DT concepts can be used to improve energy efficiency in the AECO (Architecture, Engineering, Construction and Operation) industry at different stages of the building life cycle. BIM users can benefit from the calculated reduction in energy consumption due to energy performance related components: analysis and management of building systems ; asset and space management; simulations at the design and operating stages; better investment decisions; reduction of operating costs (including energy)

Regarding the implementation of BIM and Digital Twin concepts in EPCs in the partner countries, the field research conducted within this project revealed that among the project partner countries, BIM is occasionally used for assessing the energy performance of buildings or issuing EPCs only in Austria, Cyprus and Greece. However, the likelihood of using digital models within the next five (5) years is considered to be high in all partner countries.

In addition, the majority of EU countries do not use BIM documentation and literacy or digital logbooks at all for the issuance of EPCs. Even if BIM documentation and digital logbooks are available in some countries, they are used as source of information for the EPC assessment procedure or energy simulations for building permits. There is also no provision, national requirement, or legal obligation for the existence of a Building Management System (BMS) in relation to EPCs based on operational performance. In addition, it has been shown that in most of the EU Member States information related to Geographic Information System (GIS) information is not included in EPCs, and consequently not used for the issuance, validation, monitoring, and verification processes of the EPC calculation. [13]

To improve the way information is exchanged in the construction industry, recent efforts have focused on integrating Building Information Modelling (BIM) with Building Energy Performance Simulation (BEPS) tools. Despite the readiness to integrate BIM with BEPS tools, at present, the calculation of a building's EPC is currently a standalone activity.

3.2 EPC indicators

In several EU countries the energy costs and the carbon dioxide emissions per m² are included as well as financial indicators for the proposed investment in the building retrofit and for the payback time of the proposed measures, economic values of energy improvements, and evaluation recommendations for cost-effective measures are reported, but not directly issued in the EPC process. The research showed that environmental/LCA-related financial indicators are not taken into account in the issuance of EPCs. Environmental indicators, usually linked to carbon dioxide emissions in the EPC, vary from country to country by the factor of the primary to final energy conversion. [13]

Indoor environmental quality (IEQ) parameters, including air quality, thermal comfort – the risk of overheating and ventilation, lighting, and acoustics, are not covered by current EPC schemes in EU countries. [13]

Implementation of the Smart Readiness Indicator

The scope of the Smart Readiness Indicator has been discussed and documented through stakeholder engagement and research carried out in recent years. Since September 2021, a small number of Member States have been putting it this into practice to test how it can be implemented (see examples below).

According to the Directorate-General for Energy, the SRI is currently being officially tested in 6 EU countries: Austria, Croatia, Czech Republic, Denmark, Finland and France. [21]

The analysis of the survey conducted in the D^2EPC project among the project partners showed that the consideration of the smart readiness of the buildings through the implementation of the SRI has not yet taken place: Among the countries of the project consortium partners, Cyprus is the only country that has already implemented the Smart Readiness Indicator (SRI). In the other partner countries, the decision has not yet been taken. As one of the EU MSs, where the SRI is currently being officially tested, Austria has started a test phase for the implementation of the SRI in September 2021. The aim is to develop a national specification for the SRI and to define relevant aspects.

While other partners stated that there is still no decision regarding the implementation of an independent control system for SRI certificates, Austrian and Cypriot partners reported that in Austria and Cyprus SRI is integrated into existing control systems such as EPC databases.

Of the partner countries, only Germany and the Netherlands have targeted incentives to promote intelligent systems. The implementation of building regulations in different countries has increased the need for automation. For example, as part of the adaptation of the German Energy Building Act (GEG) the level of automation in residential buildings will be recorded and used to calculate the energy certificate. This means that anyone in Germany who equips residential buildings with smart home functions, such as heating, ventilation or shading, will receive a positive credit when the energy certificate is issued.

According to the EPBD, the smart readiness of buildings and building parts should be assessed by qualified or accredited professionals under the Smart Readiness Indicator system. In the countries of the project consortium partners, different personnel are considered qualified professionals: The required qualification for SRI certificate assessors varies from “no training required” to “only registered professionals”.

Other information displayed

Refurbishment recommendations are automatically generated when an EPC is issued in all project partner countries. In addition, customised recommendations are also provided by the EPC issuer in three (3) countries.

Of the project partner countries, only Greece includes refurbishment costs into EPC recommendations. In Austria, energy consultants use a tool during energy audits to estimate the cost for energy efficiency measures. In Spain, the pre-defined improvements generated by the tool can be modified by the EPC assessor. Renovation costs can be added by the EPC assessor. In Spain, estimated refurbishment costs can be added to the relevant refurbishment recommendations by the EPC assessor in a subsequent amendment.

3.3 EPC issuing, quality and control

EPC issuing

Previous research carried out as a part of the project has shown, that the period of validity of an EPC issued to obtain 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 renovation of the building envelope or a change in the technical systems. [13]

Concerning the occasions and purposes, for which the issuance of an EPC is mandatory in the partners' countries apart from the provision at the point of sale, rental or for new construction, the project partners stated that EPCs are issued for the approval of major renovations (number of mentions: 6), for the application of subsidies (number of mentions: 5), for the financing of renovation activities (e.g., loans, number of mentions: 5), for the notification of individual energy efficiency measures in buildings (number of mentions: 2) and for mortgage loan rebates (number of mentions: 1).

Quality control

The EPBD requires a statistically significant percentage of all EPCs or inspection reports issued annually to be randomly checked. This sample is used to gain an understanding of the overall quality of the EPCs or inspections [8]. Although an effective independent control system can be organised with or without a central EPC database, MSs using such databases recognize them as an essential element of their EPC system and as an important factor in achieving high compliance rates. Experience shows that without validation rules in the software, experts make a number of avoidable mistakes that can have a huge impact on the EPC rating.

Qualification of EPC issuers

Another very different approach of the MSs surveyed within the project was revealed in the area of training requirements and qualification of EPC issuers. One third of the EU countries do not have provision for systematic and regular evaluation/assessment of the competence and skills of energy assessors [13]. While in some countries professionals with a technical university degree, such as engineers or architects, are considered qualified personnel, in others, EPC assessors are required to have a predefined period of professional experience in the field of construction in addition to their degree to pass a qualifying examination or need to be registered as an auditor/inspector in a national register. Three (3) out of seven (7) countries have mandatory training, such as refresher courses for continuous professional development for EPC issuers.

What builds trust in an EPC is the high quality of the data and information and the tailored recommendations from the experts. In order to improve the quality of EPCs, the education of EPC issuers is crucial. The technical background of the experts must be well adapted to the requirements of issuing EPCs, and their training must be designed to meet the precise needs for energy certification. Experts should be trained to select appropriate boundary conditions and to choose the right default values. Providing good recommendations for energy saving measures for existing buildings is another essential task of the expert when preparing an EPC [9].

Best practice example in Europe: Portugal

In Portugal, the EPC is issued by a certified and trained energy expert and uploaded to a national EPC database. EPCs records are verified at several levels:

Level 1: Automatic input validation for all EPCs

- Platform automatically checks the inputs and identifies inconsistencies or "out of range" values
- EPC issuer can correct the inputs

Level 2: Simple quality checks performed on 5-6% of EPCs

- Analysis performed without the involvement of the EPC issuer
- Performed solely by cross-referencing the documents uploaded by the issuer

Level 3: Detailed quality checks on around 0.5% of EPCs

- Replicates the work done by the issuer
- More interaction between the quality assessors and the issuer
- Fines can be imposed for serious errors.

Errors and other issues identified during this process are recorded in the quality assurance database. The most common errors are evaluated and included in the training of the EPC issuer to avoid these errors in the future.

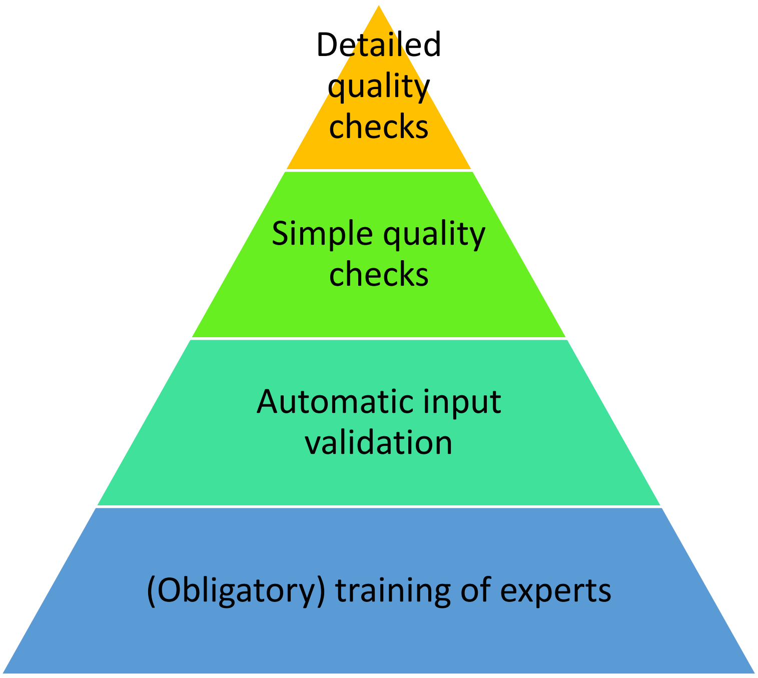
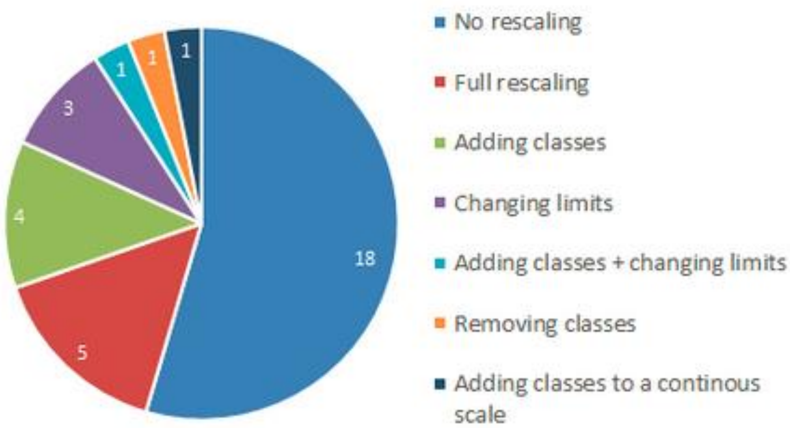


Figure 1: Levels of quality control of the EPC in the Portuguese EPC database (source: ADENE, 2014 [4])

3.4 Market acceptance and user-friendliness

Although EPCs raise consumer awareness of energy efficiency, there is still room for improvement. In terms of market acceptance, many consumers find EPCs too technical and complicated to understand. Wording or the use of easy-to-understand visualisations play an important role in helping end-users to understand the energy performance of their building. Some Member States (around half) have made efforts to make the EPC more user-friendly, such as the UK, Germany and Portugal. The use of technical language has been reduced to a minimum on the first pages of the EPC and more self-explanatory icons have been used, while the technical sections aimed at professionals and authorities have been moved to the end of the document.



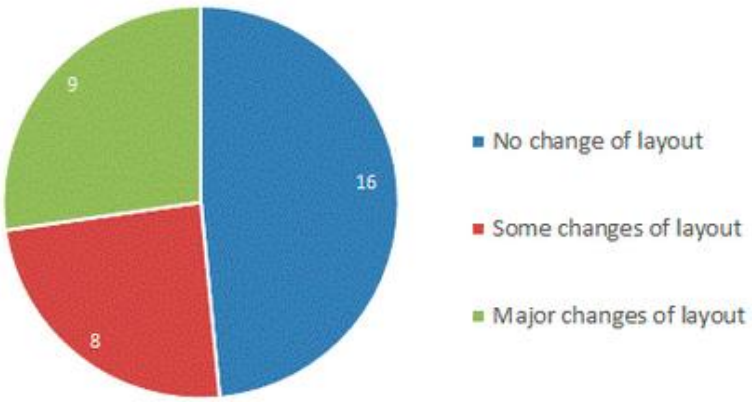


Figure 2: Types of rescaling (top) and layout changes (bottom) made to EPCs between the 2008 and 2014 versions (Source: Heijmans, 2019 [6])

Another handicap for building occupants is the financial impact of the energy used to heat or cool the building. The tailor-made recommendations for intervention and renovation also increase the acceptance of the EPC among building users. This includes an individual roadmap based on actual energy consumption that is easy to follow.

Various modifications have been made to the EPC in four (4) partner countries to increase market acceptance. These changes relate to the indicators included in the EPC, the presentation or illustration of the information and the addition of easy-to-understand descriptions of the indicators. In the Netherlands, for example, some indicators have been added (this concern in particular the indicators CO_2-eq and primary energy demand indicators), while others have been removed. In addition, the presentation/illustration of the information has been changed and easy-to-understand descriptions of the indicators have been added. Further adjustments were required in Spain in 2021: The physical presence of the certifier (EPC assessor) on site to collect technical information is required in order to issue the EPC.

3.5 EPC costs and benefits

Regarding the costs of issuing an EPC in the EU Member States, a survey carried out as part of the project showed that all MSs consider that EPCs should be easily affordable while providing a maximum of specific information to meet different expectations, resulting in a trade-off between cost and content [5]. In 2015 the majority of Member States reported that the cost for single-family houses is between € 100 and €400 per EPC. EPCs for multi-family dwellings would cost more. Several Member States provided information on the costs of EPCs for non-residential buildings, typically in the range of 1-5 €/m^2. Several reasons have been identified for the variation in costs, such as the skills required by the assessor, the hourly rate and the complexity of the methodology used. The economic strength of a country does not seem to have a strong influence on EPC costs [5].

Comparing costs and benefits it can be stated, that issuing EPCs based on asset ratings takes less time and is therefore less expensive than issuing EPCs based on metered data (operational rating based on the actual energy consumption) due to the higher complexity of the methodology [10]. Higher costs are one of the main barriers to operational EPCs in EU Member States. However, the cost savings resulting from a reduction in energy consumption following a thermal refurbishment carried out by the owner of the asset cannot be easily identified using the cost-effective asset rating methodology because the breakdown of energy use is not recorded. This may influence the choice of methodology selection in Member States where cost may be a major constraint on the use of EPC.

Regarding the usefulness of EPC data for policy makers monitoring the renovation of national and European building stock, it should be noted that more than half of the European countries use the EPC to assess the energy savings of building renovations. The majority of these countries use both pre- and post-renovation EPCs produced both before and after the renovation work and link public incentive programmes to the improvement in EPC demonstrated by the before-after comparison [7].

3.6 Motivational schemes

None of the EU Member States apply incentives or penalties to owners for compliance or non-compliance with the certified assessment, in case of reassessment of an EPC, based on operational data. Penalties are rare and are mainly directed at energy auditors. [13]

In order to ensure that public subsidies related to the energy efficiency in buildings are optimally used for building renovation, they should be linked to the quality of the renovation work in terms of the energy savings targeted or achieved. Greece, Lithuania and the Netherlands, have methods to check the quality of the renovation and the energy savings achieved. In Austria, Cyprus and Germany, there is no such method. Lithuanian project partners highlighted a simple but effective way of verifying energy savings by carrying out air leakage tests after completion of renovations funded by the EU or Lithuanian budget.

There are examples that specify the energy performance level a building must not exceed, and which remind the owner to take action to improve it. So far, in these countries owners of buildings above this level are receiving information letters. This is not intended to be a punitive clause and therefore no penalties have been applied to date. The purpose of this procedure is to allow the manager of a block of flats to take mandatory actions without having to go through the usual voting procedure required for flat owners.

3.7 Use of smart meters

The actual level of use of smart meters varies between the countries of the project consortium partners. While in Cyprus and Germany there is no significant implementation or legislation on the use of smart meters, in other EU MSs, such as Austria, Greece, Lithuania, the Netherlands and Spain, smart meters have reached a significant proportion of the country's building stock. For example, the Austrian roll-out rate of around 69% is expected to be exceeded by the end of 2022 in order to reach the target of 95% by the end of 2024 according to the plans submitted by the Austrian network operators (as of the end of March 2021).

3.8 Use of EPC databases

Most EU Member States have developed central databases for the collection, registration, and examination of EPCs. EPCs in EPC databases are considered to be an important source of data, especially if large amounts of data needed on the actual energy performance of the European building stock are needed. However, there is no database describing the energy efficiency characteristics of the building stock as a whole. Nevertheless, in some cases, comprehensive information on the physical state of the existing building stock, is available, collected during the EPC issuance process. [13]

In most the countries regional or national databases have been set up to collect EPC data for various purposes, e.g., research on building performance, applications for subsidies, policy making, (e.g., adapting their policies (e.g., subsidies, energy poverty, energy planning). MSs with regional databases are making efforts to combine them into a central database.

EPC databases, where they exist, are used in different ways across Europe. Best practices in the use of EPC data in EPC databases show the best approaches to analysing and presenting EPC data for effective and useful implementation of energy refurbishment.

At their best, EPC databases allow:

- Governments and academics to monitor the progress of policies to promote energy improvements in Europe's buildings
- Governments and legitimate commercial retrofit service providers of to identify buildings most in need of energy improvements
- Building owners and occupiers, as well as housing market actors to see the energy performance of individual properties and entire communities
- Stakeholders to monitor and assess the quality of EPCs. [4]

In the past, best practice categories have been identified as:

- Open data initiatives
- Statistical analysis
- Policy monitoring for regeneration
- Use of data by municipalities, presentation and use of data by commercial actors
- Quality control [4]

All partner countries have databases (at national and/or regional level) for the storage of EPCs. In Austria, eight out of nine provinces have regional EPC databases in addition to the national EPC database. The file formats of the EPC data stored in the EPC databases in use differ from country to country. Formats used include Microsoft® Excel formats (number of mentions: 2) and other text-based formats such as xml, pdf file format (created by Adobe®) or proprietary formats of various software companies, etc.

3.9 EPC standardisation landscape

As previously described, the European Commission is using a set of standards and accompanying technical reports to support the EPBD called the Energy performance of buildings standards (EPB standards). This set of standards provides guidance for defining, describing, exchanging, monitoring, recording and securely handling asset data, semantics and processes with links to geospatial and other external data. However, in some cases the connection between these standards connected and the tools used to design and construct the building is not clear or there are gaps in implementation.

In order to assess the need for new standards, a screening of the work programmes of the European Committee for Standardisation (CEN), the European Committee for Electro-technical Standardisation

(CENELEC), the International Organisation for Standardisation (ISO) and the European Telecommunications Standards Institute (ETSI) was carried out. Taking into account other relevant sources of standardisation documents (such as regulations, guidelines etc.) a collection of existing standards relevant to the project has been identified, covering energy requirements and thermal quality of buildings, heating systems, the subject area of control and automation systems, and other subject areas affecting the EPC (detailed information can be found in [16]). This identification also reports the relevant standardisation working group developing each document, to facilitate identification of other technical material or potential contacts.

This identification also indicates the relevant standardisation working group developing each document, to facilitate the identification of further technical material or potential contacts.

In order to identify standardisation needs and gaps in the current standardisation landscape addressing the energy performance certification, a questionnaire was prepared and distributed to relevant stakeholders across Europe. The results of the analysis are presented in Chapter 4.3.2.

4 Characterisation of next-generation dynamic digital EPCs (D^2EPC)

The calculation of an EPC classification based on the proposed framework of the next generation of dynamic digital EPCs envisaged by the D^2EPC project requires appropriate foundations. These foundations consist of the smart readiness of the building and the corresponding data collection infrastructure and management systems. Taking into account the operational data and a calculated novel set of various relevant indicators, the issuance and updating of the NG EPCs discussed here will be carried out via the proposed digital platform. This new approach not only facilitates planning and decision-making at the local and regional policy level. It also increases user awareness and engagement with building energy efficiency, improves the practicability for EPC issuers and provides added-value services such as recommendations for building refurbishment to owners and occupiers.

4.1 D^2EPC calculation scheme and features

The concept of the next generation of dynamic digital EPCs envisaged by the D^2EPC project combines several novel and proven aspects to the energy performance assessment of buildings in a forward-looking way by using digital design and monitoring tools and services in order to make it clear, transparent, self-explanatory, time-saving and as automated as possible. It is therefore fully capable of meeting the requirements for issuing EPCs arising from the national implementations of the EPBD in force in the EU Member States.

EPC calculation methodology

All the necessary information on the building envelope, design, and materials, as well as the building systems, is retrieved via BIM (Building Information Modelling) documentation in a calculation tool. At the same time, operational data collection, data analysis, and simulation/emulation (inverse modelling) are realised through the use of digital twins integrated with BIM approaches. As a key aspect in the EPC assessment methodology, the proposed D^2EPC framework includes both asset and operational energy performance assessment of buildings.

The asset rating calculation is based on the following input parameters:

- General information about the assessed property (Property type, building/space category, climate data)
- Thermal zone division: the spaces in a building or building unit should be grouped into thermal zones (according to their thermal characteristics), in order to proceed with the asset rating
- Analytical descriptions of the elements that make up the building envelope: Depending on their visual transparency, the building elements are divided into two main categories, the ‘opaque’ and ‘transparent’ building elements. A second distinction is made according to the placement of the element on the building topology (e.g., internal, external in contact with the ambient air or external in contact with the ground etc.).
- Installed technical systems: the different categories include technical systems for heating, cooling, domestic hot water, lighting, solar thermal collectors, photovoltaics and automation and control

In addition, the following operational values are given for the EPC’s classification:

- Thermal energy per unit of conditioned building area (kWh/ (m^2a))
- Annual energy per unit of conditioned building area (kWh/(m^2a))
- Annual electricity supply per unit of conditioned building area (kWh/(m^2a))

- Annual primary energy for the operation of the building per unit of conditioned building area (kWh/(m^2a))
- Annual CO_2 emissions due to the operation of the building per unit of conditioned building area (kg/(m^2a))

D^2EPC BIM-based Building Digital Twin

As described in chapter 2.3.5, current methods for assessing the energy performance of buildings do not use information-rich BIM files. In the D^2EPC framework, the D^2EPC BIM-based Digital Twin is a core component, that enables the unification of various forms of user-provided data with dynamic information collected from the building's field devices under a common, digital building model. The Digital Twin is used by various components of the D^2EPC for the calculation of indicators, the asset and operational rating and the Added-value services suite and the Extended dEPCs application toolkit.

This is how it works: The user can provide static building information, such as the building geometry, materials, etc. by uploading the BIM file of the assessed building in IFC format[4]. The BIM Parser, a specially designed tool, is hereinafter used to extract any available data from the above file. The retrieved data is then stored in a secure database, namely the D^2EPC repository. D^2EPC based on static data sets extracted from the associated BIM-files as described above, subsequently integrates smart meters, actual performance-related data and activity profiling into the buildings' digital twins (DT) of the buildings. All information required to assess the energy performance of a building is retrieved from the DT, while any additional or missing information is provided through a user-friendly interface. The use of BIM coupled with a state-of-the-art Internet of Things (IoT) ecosystem will be able to support the automated extraction of the information required for ad-hoc real-time asset and operational assessment results, as well as regular assessment of the building's operational status. For the collection of the required actual performance-related data and activities the DT focuses on linkage to the physical asset through a real-time data flow, connecting all devices, sensors, actuators, and in genera the Internet of Things, and systems (i.e. Building Management System (BMS), Energy Management System (EMS), or even Supervisory Control and Data Acquisition (SCADA)). As weather data is also required, in the absence of accessible weather stations on site, external weather APIs is used to retrieve the necessary information.

[4] As per [23], IFC is a standardized, digital description of the built environment, including buildings and civil infrastructure, which is vendor-neutral, and usable across a wide range of hardware devices, software platforms, and interfaces for many different use cases.

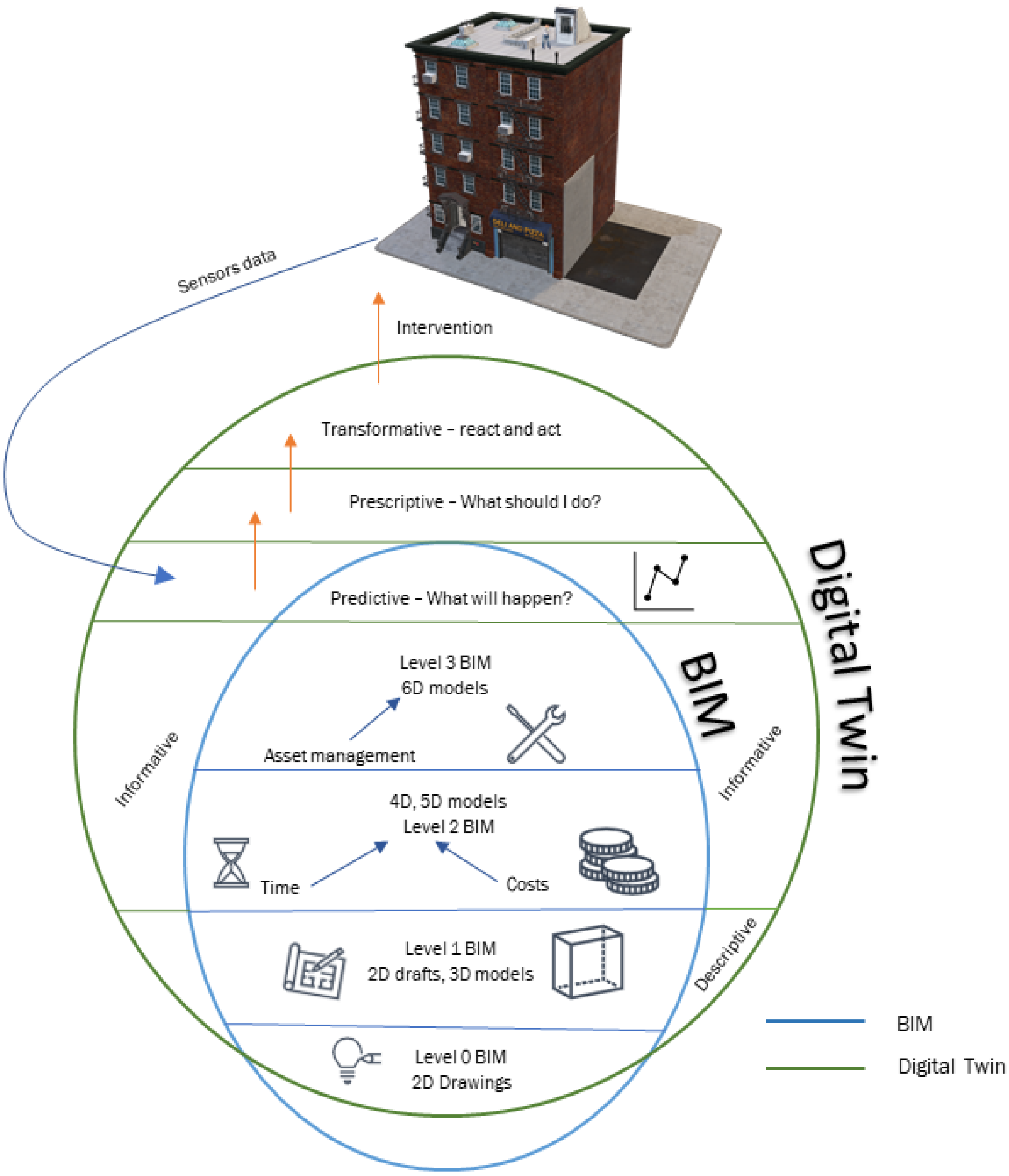


Figure 3: Schematic illustration of BIM integration as a part of Digital Twin [23]

D^2EPC Web platform and additional services

The D^2EPC web platform and additional services comprise an intuitive user interface, where developed functionalities are accessible by end users. It serves as a common user-friendly interactive environment for accessing all the D^2EPC tools. It hosts the presentation of all the results from the different components and sub-components, such as the EPCs, the KPIs, and the additional services. Through the web platform, end users (engineers, building owners, registries, etc.) can not only customise and configure certain components by all the necessary data through the user interface after uploading the building's IFC file, but also request directly the execution of certain processes.

In order to perform the energy performance assessment and issue the asset and operational rating based EPCs, the user can request this respectively via the user interface and – when prompted - manually enter any data required for the calculations, which cannot be retrieved from the previously uploaded BIM file. After completing the necessary input actions, the user can submit the provided information and output either the asset rating based EPC or the operational rating based EPC. In addition to visualising the result, the export of the generated certificate can be exported to other formats (e.g. PDF).

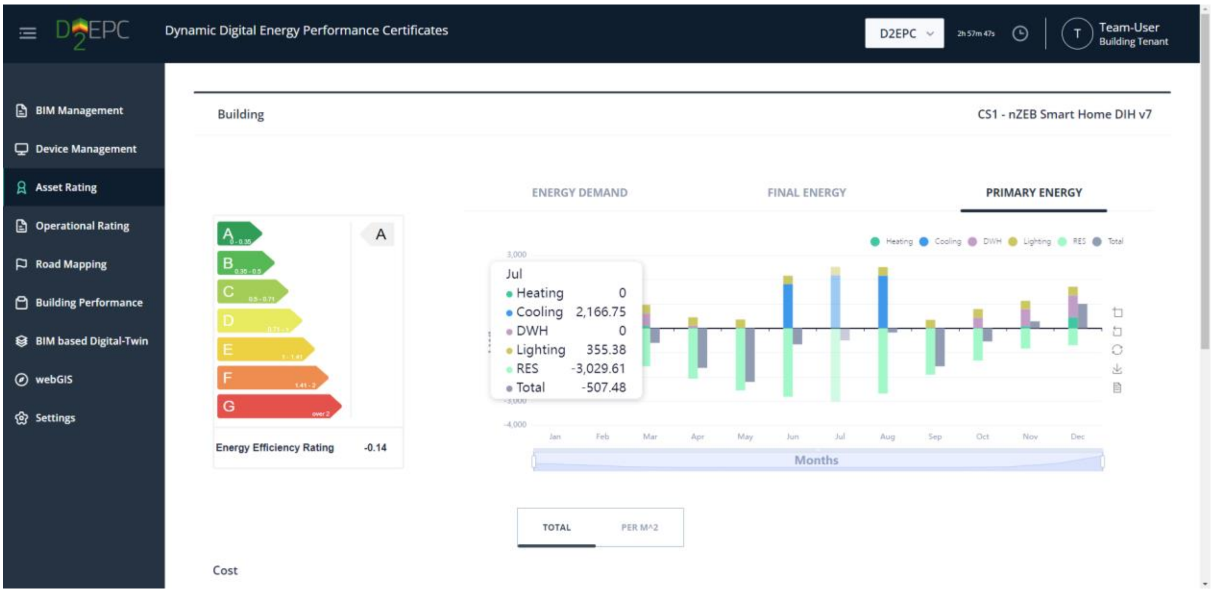


Figure 4: D^2EPC Web platform showing results of asset rating of an exemplary building

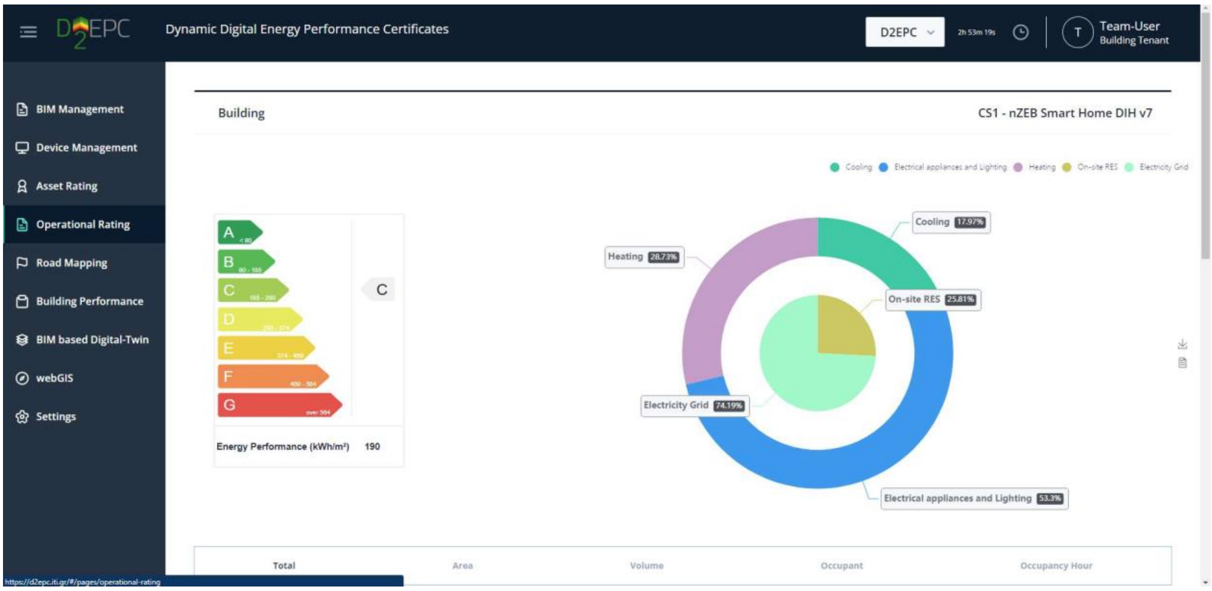


Figure 5: D^2EPC Web platform showing results of operational rating of an exemplary building

Similarly, the calculation of each set of indicators is performed in the **Building Performance Module**: After each data input, the execution of the calculations generates a short report containing all available calculated indicator sets.

The added-value services suite provided by the web platform includes a **road-mapping-tool**, an **AI performance forecasts module** along with performance alerts and notifications. The road-mapping tool provides the user with specific recommendations for possible renovation actions, both in terms of the asset-based rating and in terms of specific sets of indicators.

Using historical data collected from the on-site electrical and thermal energy meters, the AI Performance Forecasts module provides a projection of the future energy consumption along with an estimate of the corresponding operating performance, for a horizon with a time scale of a few months. Using the outputs of the AI Performance Forecasts module, together with the monitored data from the on-site sensors, any expected performance degradation is communicated to the user, to provide insight and encourage self-directed behaviour to offset it.

In addition, a **Building Energy Performance Benchmarking tool** provides a ranking, based on the user role, of buildings that have been assessed using the web platform, in terms of the EPC rating (both asset-based and operations-based), but also in terms of several indicators.

In order to ensure adequate data quality, a data verification process is applied to all data collected by the **Energy Performance Verification and Credibility Tool** from metering/sensing infrastructure. It enables the detection of connection losses and malfunctions of the equipment of assets, ensures the quantitative and qualitative reliability of the collected data collected and generates alerts to warn the end user through the D^2EPC platform.

The D^2EPC WebGIS Tool

The D^2EPC WebGIS tool is an independent sub-component of the D^2EPC platform. Third-party end- users of the platform, such as public authorities, public or standardisation bodies and others are provided with useful tools such as enriched analyses, comparisons and visualisations of statistics about the energy performance of buildings across the EU countries and regions. In addition, the users can visualise the buildings in 3D mode through the enriched BIM on the same platform.

This is how it works: The application connects to the centralised D^2EPC repository and consumes the asset and operational rating, the BIM file and the geolocation for each building and feeds a geospatial database. The information contained in the geospatial database forms a vector layer that can be displayed on the WebGIS map. For the visualisation and analysis of the energy performance results e.g., for control purposes by public authorities, the user can choose between the two levels of NUTS (Nomenclature of territorial units for statistics)[5] used: level-0 (countries) and level-3 (small regions for specific diagnoses) used: level 0 (countries) and level 3 (small regions for specific diagnoses) depending on the spatial resolution of the information required simply by zooming in on the map, as shown in the following figures.

[5] NUTS are preferred to administrative regions because they contain a uniform population (levels 1,2,3) and are therefore more suitable for statistical interpretation. It also avoids the use of neighbourhoods, which are vaguely defined. [22]

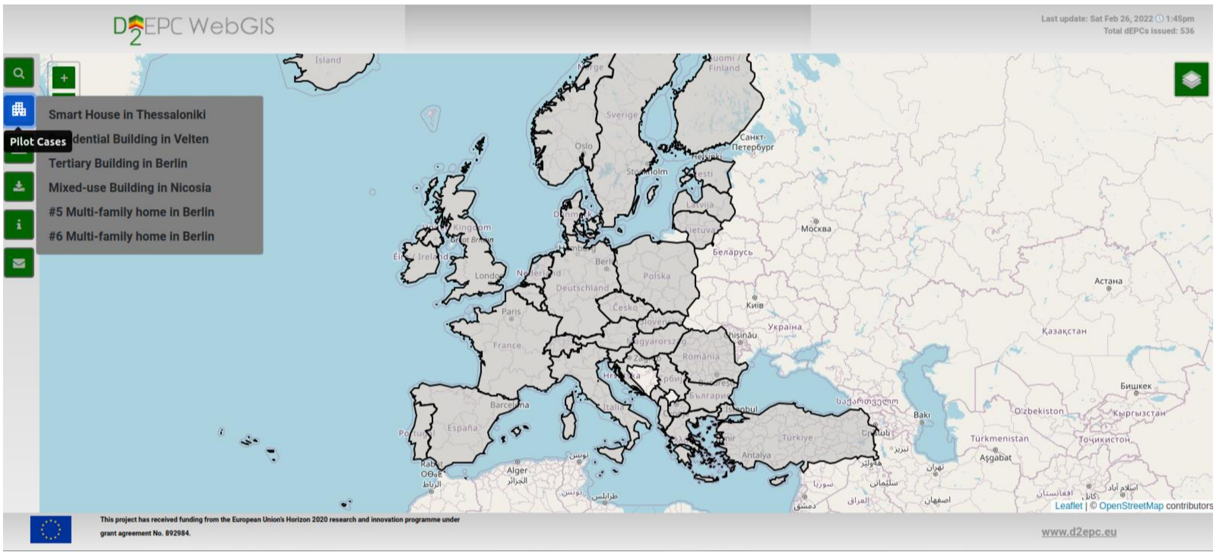


Figure 6: View of the countries (NUTS level-0) in WebGIS map [22]

Figure 7: EPC statistics comparison between two regions of the same NUTS level [14]

Dynamic EPC (dEPC) statistics can be visualised on the map using implemented graphics. Pie charts are used to display the percentages for each dEPC class as calculated from the D^2EPC asset/operational ratings for dwellings within the selected polygon are presented. Hovering over the percentages shows the absolute number of dwellings in each class. In addition, the end user can make a comparison between two regions or two countries by selecting the appropriate polygon on the WebGIS map.

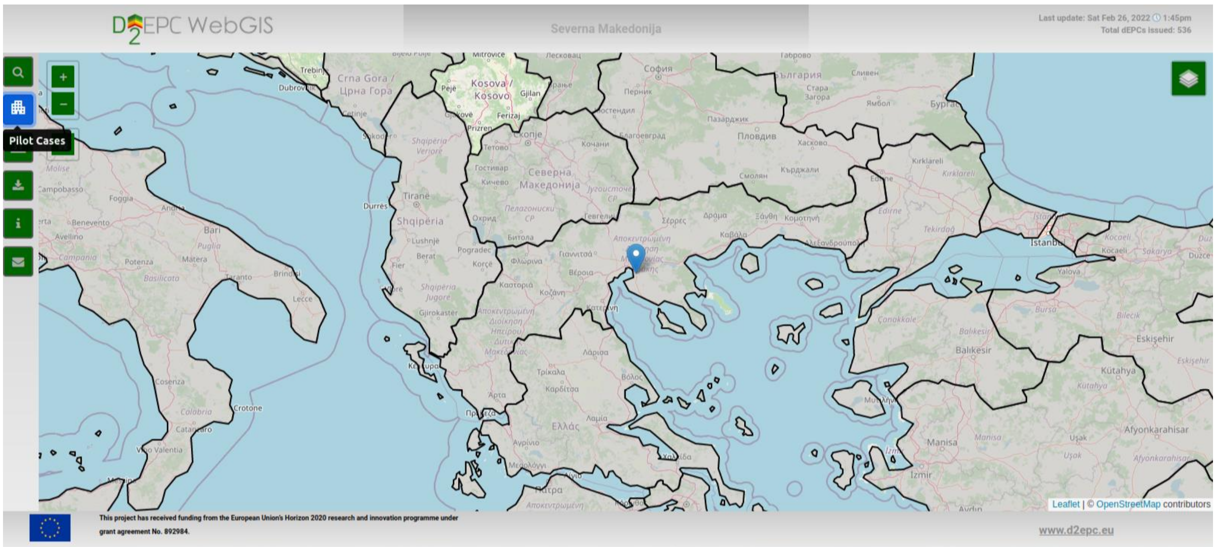


Figure 8: Position on map (2D) of a pilot case building [14]

The BIM visualisation button in the toolbox (see above) provides a drop-down list of buildings available for 3D visualisation. These include the pilot case buildings as well as files uploaded by the end user. Selecting a building from the drop-down list triggers the fly-to feature on the leaflet map, and selecting the marker starts the 3D rendering of the building. The BIM model is fully interactive, allowing users to click to view various aspects of the building through clicking on them.

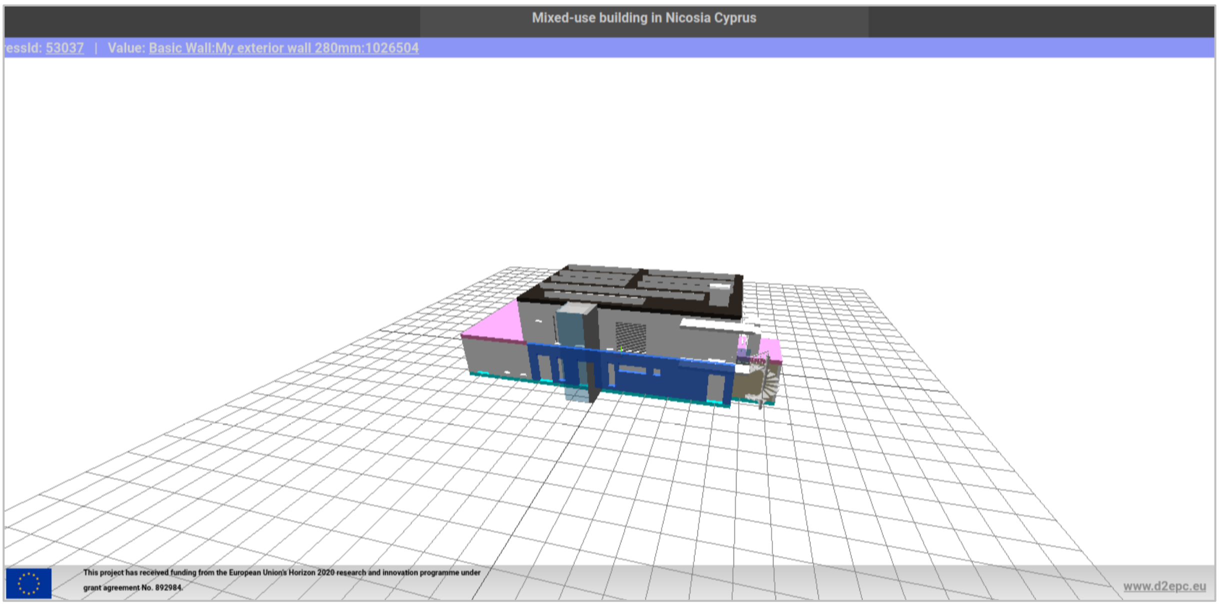


Figure 9: Visualisation of a pilot case building [14]

4.2 D^2EPC set of indicators

One of the main objectives of D^2EPC is to provide an indicator-rich certificate that includes elements beyond energy, covering sustainability aspects of building units, thus demonstrating the environmental performance of buildings by enriching the current methodologies for both asset and operational rating. The improvement of its user-friendliness and conformity with national and European legislation can be achieved by an additional set of indicators to be included in the NG EPC as envisaged in the D^2EPC project. In particular, the inclusion of the Smart Readiness Indicator (SRI), human comfort and wellbeing indicators, energy and environmental indicators and financial indicators aims to raise awareness of the benefits of smart technologies and ICT in buildings, to consider the whole life cycle of the building as a structure, to focus also on the "human-centric" nature of the next generation EPC and to increase the user-friendliness of the EPC by using terms that are widely understood and accepted by the public, such as the monetary indicators related to the main energy consumers of the building(heating, cooling, lighting, appliances).

Smart Readiness Indicator (SRI)

The Smart Readiness Indicator (SRI) is one of the innovative indicators for NG EPCs that will provide added value for building users. The planned D^2EPC SRI assessment is based on 'Method B' of the final SRI technical study, which was carried out by a consortium consisting of "VITO NV and Waide Strategic Efficiency" and completed in June 2020. [12]

Smart buildings and smart cities represent a major challenge for the construction industry in the future. The digitalization of small-scale and domestic energy solutions enables the coordination of supply and demand in real time giving rise to smart grids. As the energy transformation of the EU's building stock aims to ensure that all EU citizens have access to energy services regardless of their income, the Smart Readiness Indicator (SRI) is expected to become a low-cost measure to promote healthier, more comfortable, low-carbon and low energy-efficient buildings capable of integrating renewable energy sources.

Digital smart home systems optimise the use of renewable energy installations (RES), battery storage, heating systems and electric vehicle (EV) charging helping to integrate renewables into the power grid through data-driven energy services. It is envisaged that real-time consumption data will reveal consumption patterns and improve energy management at the building level, and that users will be empowered through easy-to-use and informative tools to better monitor and control their energy use and benefit from energy costs savings. The requirement to integrate SRI into the energy calculation procedure is also a requirement of the latest EPBD recast.

The digitisation of cities and the increasing ubiquity of data have facilitated the intensive development of massive datasets and data streams associated related to the urban environment. The digitalization of the process of EPC issuance process and the integration of smart infrastructure into the certification process would support the harmonisation of EPC data collection, enable automatic uploading to a central database and simplify the statistical analysis of the data from a technical perspective.

The next generation of EPCs should establish the necessary framework for calculating Smart Readiness based on a list of parameters for the level of smartness of buildings, which allow for comparable EPCs of good quality in order to create confidence in the market and stimulate investments in energy efficient buildings.

The assessment criteria for SRI should be based on a set of criteria, including the heating, cooling, ventilation, lighting, electric vehicles, smart grid integration potentials of buildings and the share of renewable energy consumed in the buildings [15].

Human Comfort/Indoor Environmental Quality/Wellbeing Indicators

The Comfort and Well-being indicators framework touches on three district areas of Indoor Environmental Quality (IEQ), namely thermal comfort, visual comfort and indoor air quality (I.A.Q.). Thermal and visual comfort correspond to the occupant's level of satisfaction with the indoor thermal and visual conditions while I.A.Q. examines the parameters that affect the functioning of the human respiratory system and the ability of the building to refresh the inhaled air.

D^2EPC's HC&W framework is aligned with European and national environmental and sustainability standards, that have emerged from a thorough review of the literature. In particular, Level(s)[6] a voluntary European framework for measuring and reporting a building's environmental performance that is being progressively adopted by building professionals, is strongly considered. The literature findings and the intended data-driven approach are integrated into a hybrid methodology that provides the complete framework. On the one hand, KPI reporting methodologies and relevant environmental variables together with their recommended operating limits are obtained from the standards/frameworks. On the other hand, if it's deemed feasible, the limits are replaced with personalised limits derived from a comfort profiling engine that identifies patterns and trends in the user data. The engine includes of state-of-the-art clustering algorithms and introduces several innovations to the D^2EPC.

Energy-related and Environmental/LCA-related Indicators

The set of indicators proposed by the project aims to improve the user-friendliness of the EPC and to increase user awareness by providing more knowledge. A literature review was carried out to provide an initial overview of the state-of-the-art, including a search for existing standards, legislation, and schemes. The Level(s) approach was used to develop the D^EPC environmental indicators.

The embodied energy and environmental footprint of the building is taken into account by integrating LCA indicators into the efficiency improvement road-mapping methodology. Real-time data collected for the development of energy indicators for EPCs will contribute significantly to optimising energy savings and achieving carbon reductions of the buildings, and will complement SRIs, social and economic indicators, for the issuance of truly sustainable EPCs. Key accomplishments to date include (i) the proposal of LCA-related indicators that reveal the environmental performance of buildings for inclusion in the next generation EPCs, (ii) adopting of the LCA methodology in all aspect of services related to the construction industry and the EPC process, (iii) identifying the gaps and shortcomings of current BIM documents in terms of their information for LCA and how they can be enriched, and (iv) defining LCA. The D^2EPC energy indicators have been developed to fill a gap in the market for metrics that measure energy efficiency in buildings and can be used in conjunction with the system-level data made available by the widespread installation of sensors and meters.

Financial Indicators

The aim of the set of indicators developed in the project is to increase user awareness by providing additional information and to improve the user-friendliness of EPCs. At the current stage of implementation in the EU Member States, the financial indicators in the EPCs are based on the design values and assumptions.

The financial KPIs of the NG EPCs, allow the user to compare the monetary value of actual consumption with the monetary values of design consumption.

The user can also get an overview of projected costs based on the inflation and discount rates. Finally, the user can obtain an estimate of future costs, associated with the building's systems. These data will increase the user's awareness of energy consumption and help him/her to plan future expenditures related to building systems (detailed information can be found in [27]).

[6] Level(s) uses core sustainability indicators to measure carbon, materials, water, health, comfort and climate change impacts throughout a building's full life cycle: https://environment.ec.europa.eu/topics/circular-economy/levels_en

4.3 Standardisation development for NG EPC

4.3.1 Background

In order to identify standardisation needs and gaps in the current standardisation landscape related to energy performance certification, a questionnaire was prepared and distributed to relevant stakeholders across Europe.

As described in Chapter 3.9, a screening of the work programmes of the European Committee for Standardisation (CEN), the European Committee for Electro-technical Standardisation (CENELEC), the International Organisation for Standardisation (ISO), the European Telecommunications Standards Institute (ETSI), and other relevant sources of standardisation documents (such as regulations, guidelines etc.) carried out within the project, has resulted in a collection of existing standards relevant to the project, which provides an overview of the current standardisation landscape.

4.3.2 Identification of EPC Standardisation gaps

Based on this research, the project carried out an analysis of standardisation gaps and needs and identified some significant gaps in the current standardisation landscape regarding the energy performance assessment of buildings. The analysis showed that the calculation methods used in different EU countries are not very transparent and therefore not comparable.

These gaps have been identified as follows:

Operational rating standards

A major gap identified was the lack of existence of common standards and rules for operational rating.

Standards for information and automation systems

There is also a lack of integration of standards that take into account the SRI through smart meters and customer information and the information-rich BIM data as well as standards for data exchange between design CAD from planning and EPC software, EPC software and EPC registries and EPC Data repositories and owner needs.

Standards for additional issues affecting energy performance

A further gap has been identified in relation to the energy demand beyond lighting (where necessary for operating of the building) and the associated costs distributed to tenants (energy demand and costs for surveillance, lifts, pumps, etc.).

Standards for sustainability

Last but not least, there is a lack of standards for a viable method of providing advice on sustainable renovation without having LCA for old existing building elements.

4.3.3 Contributing to standardisation and filling standardisation gaps

The dissemination of the D^2EPC results in the European and international standardisation environment was a primary objective, in order to make available the information generated by the project available to industry and other market players (such as architects, facility managers, construction companies, etc.), to public administrations and the end-users of the building, as well as to society as a whole. The aim was to facilitate and promote the acceptance and use of the D^2EPC project results through contributions within the standardisation system, to receive feedback from industry, public administrations and other stakeholders participating in the standardisation community and to provide a basis for future developments.

The approach for the standardisation of the results of the project was based on the assessment of the state of the art in the European and international standardisation community and in the information gathered through formal and informal contacts with experts and members of standardisation committees, documents (drafts, minutes of meetings, etc.) and attendance at meetings.

Following the state of the art assessment described above, one of the main tasks of the D^2EPC project was to identify working groups and committees, for the purpose of disseminating feedback and establishing contacts with the main committees or working groups related to the activities and results of D^2EPC.

Establishment of EU standards for the operational classification requirements of buildings

To address the gaps mentioned above, D^2EPC has been actively promoting European standards that should include the link between digital data and energy assessment. To move one step closer to this goal, D^2EPC has participated in the CEN/TC 371 (Energy performance of buildings), technical committee, which deals with standardisation related to the energy performance of buildings (EPB). It ensures the development, harmonisation and maintenance of a coherent set of standards for the determination of the EPB and produce and maintains documents providing guidance and requirements to be met by EPB standards. In the identification of standardisation documents and committees developed in [16], this CEN/TC 371 was identified as the most relevant committee for D^2EPC.

A new standardisation working group (WG) for operational energy assessment of buildings was proposed to CEN/TC 371 and approved in August 2022, with members of the D^2EPC project acting as convenor (FRC) and secretariat (UNE). This WG is CEN/TC 371/WG 5. This new WG deals with procedures and requirements for data (e.g., quality) and other criteria for requirements for energy performance in use.

Standards for digital formats (for BIM, digital twins, etc.) will be developed in other working groups. The most important technical committee in this area is CEN/TC 442, BIM, in which D^2EPC collects information and participates in their meetings. In particular, the Austrian Standards Institute (ASI) provides the secretariat for Working Group 3 "Information Delivery Specification", and the Spanish Association for Standardisation (UNE) has the secretariat for the Working Group 9 "Digital twins in the built environment". WG 9 is developing a technical report collecting examples of use cases of digital twins in Europe. D^2EPC has submitted two use cases. D^2EPC has developed digital twin models as part of the project. A summary of this development has been submitted to CEN/TC 442/WG 9.

4.4 Enhancements, facilitation and compatibility

Despite the positive contribution of current EPCs to improving the energy performance of buildings, experience has revealed a number of constraints and limitations. Within the D^2EPC project, several challenges (CH1 to CH9) of the existing EPCs have been identified and solutions, presented as policy recommendations based on the results of the project's research and progress, have been proposed to address these challenges (see Objective 1 to 7, published D^2EPC Policy Brief [17]). How the solutions developed in the D^2EPC project can address these challenges is briefly described below.

How the solutions developed in the D^2EPC project can address these challenges is briefly described below.

The main challenges of current EPC systems are:

- Limited information on the actual energy performance of buildings (CH1)
- Insufficient information for building users and limited usability (CH2)
- Need to harmonise of EPCs with the smart city concept (CH3)
- A human-centred certificate (CH4)
- Limited data quality (CH5)

- Credibility and quality of software (CH6)
- Data discrepancies due to subjectivity of energy auditors (CH7)
- Lack of connection between sustainability assessment and energy performance (CH8)
- Need to establish and harmonise the operational rating within MS (CH9)

The D^2EPC objectives are:

- Objective 1: To introduce and establish the concept of the dynamic EPC (dEPC), an operational certificate to be calculated and issued periodically (addressing CH1, CH2, CH5)
- Objective 2: To define the shortcomings and discrepancies of the current EPC system and to update of EU standards on the classification requirements of buildings (addressing all challenges)
- Objective 3: The extension of the EPC through a novel set of indicators which cover environmental, financial, human comfort and technical aspects of new and existing buildings aims to simplify the understanding of the energy performance of buildings and to provide a more comprehensive overview of the actual energy performance of buildings. (CH2, CH4, CH5).
- Objective 4: The integration of intelligent operational reasoning into building energy performance into the EPCs using advanced data collection infrastructure and BEPS tools integrated into BIM (addressing CH5, CH6, CH7)
- Objective 5: The integration of intelligent operational reasoning into building energy performance assessment and certification (addressing CH1, CH3)
- Objective 6: Intelligent operational digital platform for dynamic EPC issuance and actual monitoring and improvement of building performance, validated and demonstrated under realistic conditions (addressing all challenges)
- Objective 7: Promotion of European standards to include the link between digital data and operational energy assessment (addressing CH5, CH6)

Complies with current and future regulatory requirements

Through the proposed framework envisaged by the D^2EPC project, a way forward is presented on how to overcome the identified challenges or to further improve the existing solutions. In line with the policy recommendations and objectives set out in the policy brief [17], key benefits, features and characteristics of the D^2EPC framework are being developed to implement current and future provisions of EU legislation (see Chapter 2.3) today. For example, it meets the requirement for digital-only certification.

The D^2EPC improved rating methodology

Current EPC schemes are based on a cradle-to-site rationale, completing their mission after the certificate is delivered to the building user, overlooking user behaviour and the actual energy performance of the building, which may change dynamically over time. D^2EPC has created and introduced a new concept of the next generation of dynamic EPCs that allows for the monitoring of the actual energy performance of buildings and the calculation and issuance of an EPC on a regular basis.

Existing buildings are prone to change of use or different performances due to unexpected failures. This leads to significant deterioration in overall system performance, inefficient operation, and unacceptable human comfort conditions. These facts underline the need for the application of operational rating, as well as the shortcomings of asset rating. To this end, D^2EPC uses an operational rating, which is updated regularly or at individual issue intervals using the D^2EPC intelligent operational digital Web platform and the added-value services suite.

➔ Meeting Objectives 1, 4 and 6

Expanded content and informative value through the inclusion of a new set of indicators in D^2EPC

The D^2EPC framework allows for an improved multi-parameter assessment by including of new indicators, covering environmental, financial, human comfort and technical aspects of new and existing buildings.

The EU Commission is promoting digital solutions aimed at providing building users and owners with more accurate information on actual energy consumption, enabling them to take steps towards greater energy efficiency. Supported by the availability of enhanced content and real-time-data, the D^2EPC framework helps to simplify the understanding of the energy performance of the user's building.

The use of a Smart Readiness Indicator to measure the performance of buildings and of information and communication technologies and electronic systems is strongly recommended by the EU Commission. The inclusion of the SRI in the proposed scheme for a next generation of dynamic EPC meets this requirement. In addition, the proposal for a recast EPBD requires at least new buildings (zero emission buildings) to be equipped with measuring and control devices to monitor and regulate the indoor air quality and also requires the inclusion of a yes/no indication of whether an intelligent readiness assessment has been carried out for the building and the value of the intelligent readiness assessment (if applicable in the relevant Member State, see also chapter 2.3.1);.

In order to meet the further requirements of the EPBD recast regarding the consideration of the whole life-cycle greenhouse gas emissions of buildings, the D^2EPC framework also includes LCA indicators as well as financial and human comfort indicators as described in Chapter 4.2, thus providing added informative value to the building owners and users.

- ➔ Meeting Objectives 3 and 5

Enhanced actual energy performance of buildings through user-centric features

An operational dynamic EPC, as developed by the D^2EPC project, can be issued on a regular basis (e.g. each heating or cooling season). The information for the dynamic EPC comes from the monitoring tools and devices, including lighting systems or electrical appliances that respond to the user's behaviour. The implementation of these user-centric features will foster energy saving awareness among building users by providing them with regular information on the actual energy performance of their buildings. The dynamic character of the calculation procedure will enable a holistic approach for the calculation of EPCs which will allow the enhancement of the actual energy performance.

The developed scheme offers suitability for all building types (SFH, MFH, non-residential buildings, etc.) and the ability to cope with national requirements/circumstances.

- ➔ Meeting Objective 3

Improved usability, practicability of energy performance assessment and EPC quality

With regard to the issuing of an EPC, the Directive requires that independent qualified and/or accredited experts carry out the task as described in Chapter 2.3. In order to provide a high quality assessment, the assessors need to be regularly trained. D^2EPC has developed a manual for the issuance of the dynamic EPC. This manual assists issuers in providing input to the system and in preparing the system for end users.

- ➔ Meeting Objective 6

Cost-effective assessment and issuance

In order to meet the market and user needs in a cost-effective way, D^2EPC has developed integrated software solutions by offering modules separately (e.g., road mapping tool, performance notifications and alerts, tools for energy performance verification and credibility tools). In addition, three business and use cases have been formulated to address the aforementioned requirements by capturing these needs:

- Issuance of EPCs (core functionality of the D^2EPC)
    - Definition of building energy class and whether minimum requirements are met for Asset Rating
    - Definition of building energy class and whether minimum requirements are met for Operational Rating
- EPC Monitoring, Assessment and Recommendation
    - Provision of (near) real time building information, deviations, and recommendations for general preventive and corrective actions
- Valuing and benchmarking of more certificates for policy making/marketing/business purposes using anonymised energy performance as a service in volume
    - Provision of district/area level of EPC statistics to third party stakeholders by delivering data sets through the Web GIS tool. This will be used, for example, as a basis for regional policy-making targeting energy poverty, energy transition and renovation plans, enhancing the information provided with additional dimensions (3D) and levels of detail (5D) as well as information for benchmarking and standardisation purposes
    - Provide dEPC statistics on materials, assets, etc. to promote “greener” equipment campaigns:
        - Provision and Visualisation of correlation between building materials and energy performance
        - Provision and Visualisation of correlation between building assets/systems and energy performance

Increased user awareness and engagement with buildings energy efficiency and benefits, and motivational programmes for building users and relevant stakeholders

Using the developed D^2EPC framework, recommendations for improvements and more efficient energy performance will be provided in an automated and user-centric approach. By exploring multiple alternative scenarios and AI-driven energy performance analysis, recommendations for optimal comfort and energy-efficient building operation will be provided. This can lead to a significant increase in user-awareness and involvement in the energy efficiency of buildings, which in turn can lead to energy savings.

In the EU Member States, there is no widespread system for assessing the operational efficiency of buildings. During the D^2EPC project, a working group under CEN TC 371 (WG5) has been established to create a new standard for the practical use of performance rating. The aim is to implement a system of rewards and penalties based on the behaviour of tenants (not landlords), as shown by the building's performance rating of the building. Data collected over several years shows how the same building has performed over time. The measures can be linked to existing procedures in EU MSs, and a wide range of options will be proposed. Possible proposals include tax breaks for reduced consumption, penalties for polluters, or other forms of monetisation based on carbon dioxide and ETS (EU Emissions Trading System) values in EU legislation.

The next steps in this activity will be to develop a synthesis of the proposed novel methodology to regularly assess the energy behaviour of building users and to further develop motivational schemes to enforce continuous improvement of building energy performance. The next step in the development of this methodology is its implementation in the form of case studies derived from the D^2EPC pilots.

The financial indicators developed in D^2EPC compare the asset and operational rating of the building and translate the difference into monetary values. Given that tenants operate with money on a daily basis, such an interpretation of energy use can be clearer and more understandable to them than other units such as kWh or m³. Better understanding of their own consumption can lead to increased awareness of energy consumption in general.

➔ Meeting Objectives 3, 4 and 7

New perspectives in the use of EPCs and facilitated planning and decision-making on a local and regional policy level

The developed D^2EPC scheme provides a sufficient basis for the redefinition of EPC-related policies, through regular benchmarking and updating of the reference buildings, as well as through the integration of geo-location and polluter-pays practices into the EPC rationale and the formation of EPC databases into consistent policy-feeding mechanisms. At present, the functionalities of the D^2EPC system do not have a link or interface with the existing national systems, and so this will be the objective of further projects in the future.

The results provided through the D^2EPC Web Platform (asset-based/operation-based EPCs), for each registered building, are accessible through the provided Application Programming Interface (API) to any eligible user without the need to physically access the platform. The acquired results are dynamic, i.e. they may be updated over time. To this end, any third party service, which has been authorized by the platform, is able to retrieve the list of registered buildings and their corresponding EPC results. Additionally, through the integrated Energy Performance Benchmarking tool, policy-related stakeholders have access to building classification services, being able to extract useful insights for building groups based on predefined criteria, e.g. primary usage, geographic location, construction decade, building area etc.

5 Evaluating the next-generation dynamic digital EPCs through stakeholder engagement

In order to evaluate the envisioned D^2EPC scheme for the next generation of dynamic Energy Performance Certificates for buildings scheme by receiving feedback from relevant stakeholders such as policy makers, energy experts, EPC issuers, designers, several workshops and face-to-face interviews were held.

Following a presentation of the D^2EPC framework proposed by the current project, related questions were posed and the participants were invited to reflect and provide their feedback. A total of 22 stakeholder workshops were held with more than 690 participants.

Based on the discussion results of these stakeholder workshops, a SWAT analysis was carried out to assess the stakeholders' views on the D^2EPC framework in relation to the EPC schemes currently implemented in the EU Member States. Relevant categories (strengths, weaknesses, opportunities and threats) were identified, and the stakeholder and expert statements were mapped (see Table 9 in ANNEX D). A list of key statements from the participating stakeholders is shown in Figure 10 (see below).

"The NG dynamic digital EPC is always up to date and valid, and the accurate data provides the opportunity to better compare the actual data of different buildings."

"Flexible energy generation and consumption and thus reduced generated CO2 emissions etc. can also be mapped."

"Together with a forecasting tool, it enables optimization of the energy consumption and load management. By providing data about the energy performance based on actual data to the building, it is expected, that users and owners will be more motivated to renovate."

"Future coupling of measurement and simulation is very important to learn more and use services."

"Given a sufficient density of mapped buildings, it allows an overall optimisation of entire residential areas."

"A dynamic EPC is better for lager objects such as multi-family buildings or office buildings. For single-family homes, it makes the things more complicated. Is it suitable for residential buildings? It may require too much effort and therefore be too expensive."

"It is important to have an overview of the construction materials used in construction of the building and how they can be separated during renovation or demolition. Use BIM for construction material!"

"The data quality determines the result. More complexity leads to more sources of error. As for the training of the assessors, it is important to have a specific training for them so that reliable data can be entered into the tool."

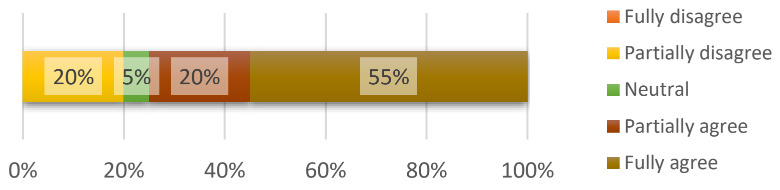
"Only meaningful and useful data should be collected and not everything just for the sake of collecting data (no data cementaries). More data requires more energy for transmission, storage etc. Who maintains the data? Possible work overload for administrators, acessors, asset managers? How does the ongoing updating process work?"

"For customers, it is not characteristic values (indicators) that are important, but the improvement measures that provide an easily understandable result. Don't provide too complex and confusing data to end customers!"

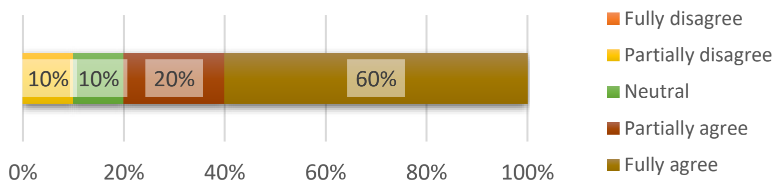
Figure 10: Stakeholders key statements in the 2nd project year

Workshops held in the course of the 3rd year of the project provided participants with more detailed project results and a fully developed tool, as well as a deeper insight into the features of the D^2EPC ecosystem, which includes the Asset and Operational Rating Module, the BIM-based Digital Twin, the Building Performance Module, the D^2EPC WebGIS tool, the Building Performance Benchmarking, the Performance Alerts and Notifications, the Road-mapping Tool for Performance Upgrade and AI-driven Performance Forecasts and the Energy Performance Verification and Credibility could be provided. The stakeholders were asked to participate in a survey that was held at the end of the workshops. The overview in Figure 11 and Figure 12 (see below) shows the results and requested feedbacks from the participating stakeholders.

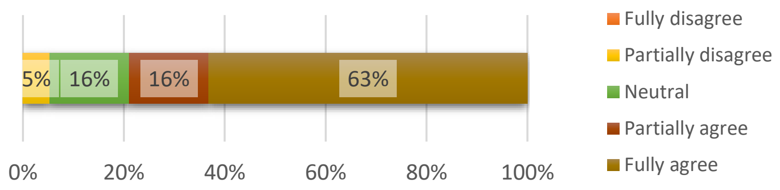
"The energy performance information provided by the improved EPC format is concise and clearly understandable."



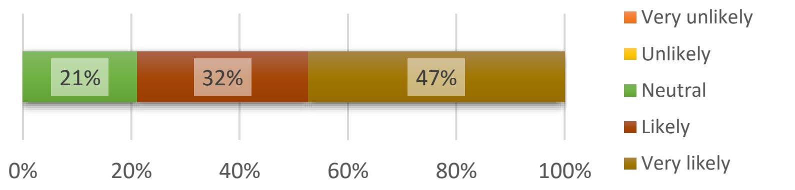
"The D^2EPC tool provides a clear and comprehensive dynamic EPC calculation process for operational features."



"Incorporating environmental, financial, and human comfort indicators into EPCs will increase their attractiveness for the users."



"The use of the D^2EPC tool will facilitate the integration of BIM into EPC procedures."



"The role of the EPC Assessor in the process of issuing an EPC through the platform is clearly defined."

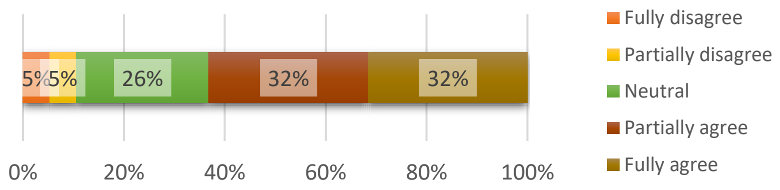
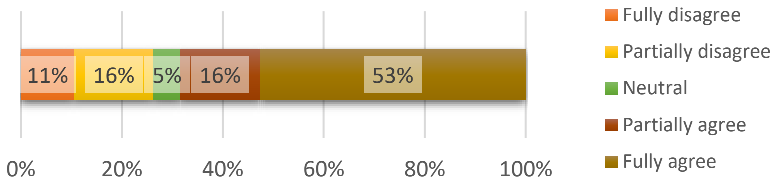
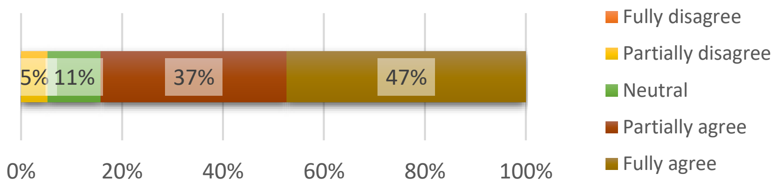


Figure 11: Statements and weighting of stakeholders consent in the 3rd project year (Part 1)

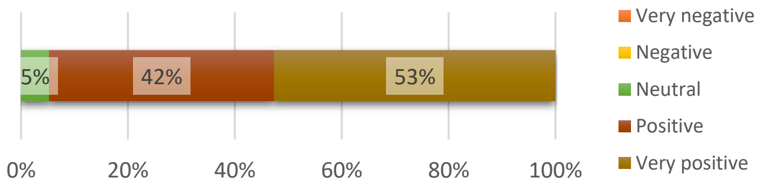
"Integrating smart readiness indicators into building energy performance evaluation procedures will improve EPC accuracy."



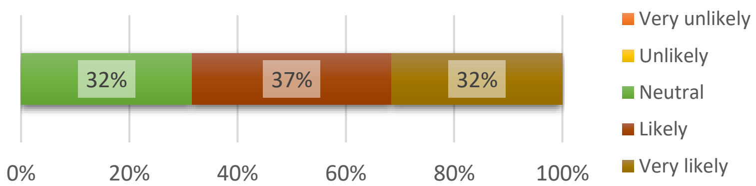
"D^2EPC extensions will have an added-value and increase user acceptance rate of EPCs."



"How do you rate the interactivity of the D^2EPC tool (recommendations for improving energy efficiency, alerting engine, real time monitoring)?"



"Recommendations provided in the new generation EPCs will motivate building owners to undertake energy retrofitting measures."



"The implementation of the D^2EPC solution will influence policy makers to adapt renovation policies."

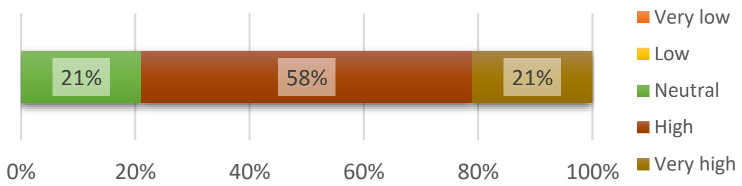


Figure 12: Statements and weighting of stakeholders consent in the 3rd project year (Part 2)

Overall, workshops that took place towards the end of the project period showed that the developed D^2EPC platform was well received by the stakeholders.

6 Conclusion and Recommendations

The EPC is an important and effective tool for informing end-users about the performance of a building. An EPC can be based on calculated pre-defined parameters or on actual energy consumption. A dynamic EPC based on real-time energy consumption can take the presentation of a building's performance to the next level by providing end-users with information on how behaviour affects energy consumption. Policy makers and public authorities can benefit from a reliable EPC based on real data when monitoring and enforcing building efficiency policies and renovation measures.

The D^2EPC scheme is 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 main objectives of the project is to conclude with a specific set of proposals and actions to be used for the update of the ISO/CEN standards developed under Commission Mandate M/48014.

The implementation of the D^2EPC framework as a major innovation in EPC calculation, EPC issuance and quality control, providing services to policy makers all over the EU for the assessment of national and EU-wide building stock can potentially help to achieve the maximum reduction of energy consumption of the EU building stock. The project team hereby provides these recommendations:

Collection of real energy consumption data: In order to establish the concept of a dynamic EPC (including the operational information), it is necessary to understand the current EPC system in every country and to identify the existing gaps and discrepancies. The basis for the implementation of a dynamic EPC scheme should not only be based on filling the gaps but also on the adapted laws and regulations. Within the research activities carried out during the project, the main gap identified was the lack of real-time data collection (lack of monitoring equipment), compounded by the lack of enforcement of national regulations. Therefore, access to data for end-users (building owners, tenants, utilities, developers, authorities) – as in the revised EPBD – is the first step.

User-friendliness: In order to bring the energy efficiency closer to the user of a building, the EPC must provide information that is easy to understand and use. The use of actual energy consumption data to assess the performance of buildings will highlight opportunities for adaptation and fine-tuning of the heating system to meet the needs of the user. An EPC based on real energy consumption (as operated) can be calculated and issued on a regular basis. Building users can be informed about the actual energy performance of their buildings through a dedicated platform and can regulate their energy habits.

Additional information such as the indoor air quality and financial aspects of the energy use could support understanding and therefore, lead to changes and/or actions and implementing renovation measures. A dynamic EPC can be the basis for a renovation roadmap, based on the real situation of the building.

Harmonization of EPCs with the smart city concept: As the energy transformation of the EU building stock aims to ensure that all EU citizens have access to energy services regardless of their income, the Smart Readiness Indicator (SRI) is expected to become a low-cost measure to promote healthier, more comfortable, low carbon impact and low energy use buildings capable of integrating renewable energy sources (RES). Digital smart home systems optimise the use of RES installations, battery storage, heating systems and electric vehicle (EV) charging and thereby helping to integrate renewables into the power grid through data-driven energy services. The SRI is complementary to the EPC as both systems are applied to improve the energy efficiency of the EU building stock and thus sharing the goal of promoting decentralised, renewable-based, consumer-centric and interconnected, essentially, smarter buildings. The SRI could be a good monitor for understanding the potential of a building as it is, linked to the current EPC.

The visualisation of EPCs in a GIS environment will provide a comprehensive view of the actual performance of buildings, facilitating efficient energy planning.

Integration of further infrastructure and indicators for human centric EPC: To calculate a dynamic NG EPC, it is necessary to collect adequate information (real data) by monitoring tools and to define a set of new indicators. In D^2EPC these additional indicators are used: smart readiness, human comfort, and financial indicators. The use of 6D Level 3 BIM and a full integration (BIM) of the information in a cloud-based environment, as well as the use of advanced digital construction design tools, could improve the effectiveness of certificates. These tools could strengthen and modernise the EPC and can provide a better link to the user needs and requirements.

The information should be processed on a digital comprehensive and transparent platform for the actual performance of the building in order to monitor and apply improvement measures. All the solutions should be promoted to improve the European standards and include the link between digital data and operational energy assessment.

Data quality: The accuracy of the EPC is determined by the level of detail and the quality of the input data. Linking to IoT or other relevant information improves the potential for building evaluation of and comparison between the designed building and the actual as-built building. Therefore, the provision of BIM documentation and digital logbooks can improve the data quality.

Software credibility and quality: The calculation methods on which the EPCs software is based, follow the monthly model of the ISO 52000 standard, where the description of the building is simplified and based on aggregated values (in terms of areas of building elements, thermal zones, etc.) and look-up tables (in terms of thermal properties of materials, infiltration rates etc.), while correlation factors or predefined schedules are also used for the modelling of dynamic effects. The EPC calculation should be combined with the building energy performance simulation for the design of the HVAC equipment and the thermal comfort of the building.

This will ensure the quality of the EPC. In addition, BIM models need to include energy-related information, and a digital twin should be used to have an as-built model of the asset. The building-related information needs to be collected and managed in a consistent manner such as BIM and digital twin.

Training of the EPC-assessors: Currently, most EPC calculations are based on a set of standard inputs or default inputs. The process of delivering to EPC can be subjective, and, as a result, the data quality can be easily influenced by the energy assessors due to the default assumptions made in the process of producing the certificate. Regular training of energy consultants and assessors, especially in the area of digitalisation, is required to deliver the EPC and a high quality energy assessment of the building. Currently, the qualification and training requirement are defined differently by the EU Member States.

Connection between sustainability assessment and energy performance: As we move towards an era where resource efficiency receives greater attention and it is integrated into all major aspects of the energy sector, further progress in the field of EPCs with the integration of LCA-related indicators are of vital importance. D^2EPC proposes the introduction of a set of LCA-based indicators for the energy performance of buildings. These indicators will be based on well-established European databases on the environmental impact of building materials, with focus on the Level(s) scheme, and they will result in a life cycle assessment of buildings, as well as of individual building components (building envelope, building technical systems, building materials etc.). This assessment also provides the building designers with the opportunity to improve and optimise the environmental performance of the building, based on changes to be incorporated at the initial design stages of the building. To meet the requirement of a building shell and building technical system oriented approach, novel indicators could be divided into building shell and building technical system oriented indicators. This will also allow the extraction of additional indicators such as the proportion of renewable energy used.

Harmonising the operational assessment of buildings across Europe: The asset rating of the buildings at national level has been developed since the provision of an EPC became mandatory under the EPBD. Harmonising the asset rating method across EU-countries is a difficult task, due to calculation methods and national standards and specific terms. D^2EPC is one of the first tools developed for the dynamic calculation of the EPC. It has therefore paved the way for the development of a harmonised dynamic EPC.

D^2EPC envisages and proposes the development of all necessary structures that will allow for the development of standardised procedures, that can be used by all Member States (MS), or the development and adoption of operational rating systems for the energy assessment of buildings among all MS.

The proposed framework should provide specific answers regarding applicability, common methods for calculating the operational rating of buildings, minimum requirements and indicators that should be provided and the time step of the assessment, weather and occupancy normalisation practices as well as guidelines for reference values, on which the classification will be based. The development of this information requires the establishment of standardisation working groups in the field of operational rating.

Motivational schemes: There is concrete evidence of the need for stricter motivational schemes to combat buildings' energy consumption. The robust and rigorous motivational programmes can support compensating escalating energy consumption in buildings. EU Emissions Trading Scheme infrastructure could galvanize a tangible change by dint of financial penalties coupled with equally potent rewards. The efficacy of the penalty and award approach based on real energy consumption can orchestrate swift and transformative shifts in behaviour.

There have been many European projects for improvement of the EPCs, considering new indicators, features and uses. The results of these research projects can help the policy makers to redesign the national implementation of the EPBD. The practical implementation in the form of the described in D^2EPC platform, characterised in Chapter 4, has the ability to cover all the needs and requirements arising from the research conducted in the project, to respond to current and future legislation and to unify in one tool the recommendations for the integration of Next Generation EPC in national/regional certification schemes as listed above.

The implementation of the D^2EPC framework as a major innovation in EPC calculation, EPC issuance and quality control, providing services to policy makers across the EU for the assessment of national and EU-wide building stock can potentially help to achieve a maximum reduction in energy consumption of the EU building stock.

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ANNEX A: Survey 1: Questionnaire (Task 1.1)

In order to collect data on the integration of information beyond the EPBD requirements regarding EPCs, a questionnaire was sent to stakeholders in the European Member States. This was the starting point of the project (in Work Package 1: Foundations for next-generation dynamic EPCs). This set of questions was designed to investigate the challenging matters of EPCs, which are subject of the project. The questions below are the first round of collecting information (see also D1.1: Comparative assessment of current EPC schemes and relevant emerging building performance paradigms v1):

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. Are BIM documentation and literature or digital logbooks employed in any way for the issuance of EPCs in your region/country?

4. If a Building Management System (BMS) exists, to what extent are data documented by BMS employed in the issuance or re-issuance of operational EPCs?

5. Are Geographic Information System (GIS) data exploited for issuing, validating, monitoring and verifying processes of the EPC calculation?

6. Does the EPC procedure in your region/country include any energy-related financial indicators (e.g., energy €/m²)?

7. Does the EPC procedure in your region/country include any environmental/LCA-related financial indicators (e.g., embodied energy/m²)?

8. Does the EPC procedure in your region/country include any indoor air quality indicators (e.g., CO_2 concentration/m²)?

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

10. Is there a provision for a systematic and regular evaluation/assessment of energy assessors' competencies and skills?

ANNEX B: Survey 2: Questionnaire (Task 6.2)

For the purpose of collecting relevant information on the current status of implementation of important aspects of the EPBD and use of the EPCs in the project consortium partners' countries, a questionnaire was prepared and distributed to the project consortium partners. In this questionnaire, the project partners were invited to share the status of implementation of EPC schemes and its evolution, lessons learned and steps taken to tackle the challenges seen since the start of the scheme in the respective EU member states. The objective is to demonstrate possible advantages of NG EPCs in the MSs (e.g., real-time energy consumption instead of theoretical values) on a policy level. These advantages will be weighed against market acceptance and user-friendliness, costs and benefits, readiness and training of EPC issuers. To do this, information on the usability of existing EPC schemes, the linkage with national/regional EPC databases (including structure interfaces) and all the aforementioned aspects were collected using the following questionnaire:

Questions:

Paragraph 29 of the EPBD amended in 2018 requires that targeted incentives should be provided to promote intelligence-enabled systems and digital solutions in the built environment.

1. To what extent is this requirement met in your country?

Please explain: (free text)

2. In order to ensure that financial means related to energy efficiency are used in the best possible way for building renovation, they should be linked to the quality of the renovation work in terms of the energy savings sought or achieved.
   Is there already a method in your country to check and establish the energy savings/the quality of the renovation?
   - Yes
   - No
   - The method is in progress.

Please explain: (free text)

3. Implementing the Smart Readiness Indicator is optional for partner countries. Will the Smart Readiness Indicator be implemented in your country?
   - Yes
   - No
   - It is already being implemented.
   - There is no decision yet.

4. Under the Smart Readiness Indicator system, the smart readiness of buildings and parts of buildings should be assessed by qualified or accredited professionals with a view to issuing the SRI certificate.
   Who is defined as a "qualified or accredited professional" in your country?

Please explain: (free text)

5. Member States that decide to implement the Smart Readiness Indicator will set up an independent control system for SRI certificates.

Which control system will be implemented in your country?

- Newly set up control system
- Integration of the SRI in existing control systems

6. The Commission Delegated Regulation (EU) of 14.10.2020 supplementing Directive (EU) 2010/31/EU states that to facilitate the calculation of scores for the SRI it should be possible to use digital models of buildings, including building data modelling and digital twins.
   How far is the implementation of using data from digital models like BIM (Building Information Modelling) in EPCs in your country?
   - Not started yet
   - Occasionally applied
   - Applied
   - I don't know.

Please explain: (free text)

7. In your opinion, how likely is the application of digital models in your country in the next 5 years?
   - Not likely
   - Likely
   - Very likely
   - I don't know.

Please explain: (free text)

Use of EPC:

8. What is EPC used for in your country besides provision at the point of selling, renting or for new construction? (multiple choice)
   - For the building notification of individual energy efficiency-related measures (e.g., replacement of heating system, change of windows, etc.)
   - For the approval of major renovations
   - For the application of subsidies
   - For financing renovation activities (e.g., loans)
   - For tax reduction
   - Others (free text)

9. How are the renovation recommendations created?
   - Tailor-made
   - Automatically generated

10. Are renovation costs integrated into EPC recommendations?
    - Yes
    - No

Connection with smart meters or other databases and tools:

11. Are EPCs stored in a database?

- Yes
- No

12. In which data format are data stored in the EPC database? (free text)

13. Is the EPC database connected to other databases?
    - Yes
    - No

14. To which other databases is the EPC database connected? (free text)

15. What is the information used for? (free text)

16. How far is smart metering implemented in your country? (free text)

Education of EPC issuers

17. Which education is required to be allowed to issue an EPC? (free text)

18. Are there obligatory trainings for EPC issuers?
    - Yes
    - No

Please explain: (free text)

Market acceptance

19. Has the EPC recently been changed in order to be better accepted on the market?
    - No
    - Yes

20. If yes, what was changed?
    - More indicators were added. Please choose the applicable indicators:
        - CO_2-equivalent
        - Primary energy demand
        - Real energy consumption
        - Smart Readiness Indicator
    - Indicators were removed
    - Display/illustration of information was changed
    - Easy-to-understand descriptions of indicators were provided
    - Other (free text)

21. What are lessons learned and steps taken to tackle the challenges seen since the start of the EPC scheme? Please explain: (free text)

ANNEX C: Survey 2: Evaluation of the survey results

For evaluation of the survey carried out (see Annex B) the data was summarized and presented in the 1st version of this report (Task 6.2) in details as follows:

Smart Readiness Indicator

Implementation of the SRI

Among the project consortium partners' countries, Cyprus is the only country that has already implemented the SRI. In other partner countries, the decision has not yet been made. Since September 2021, a testing phase for implementing the SRI has started in Austria. The aim is to examine how and where the SRI can be displayed.

Incentives to promote intelligence-enabled systems

Paragraph 29 of the EPBD amended in 2018 requires that targeted incentives should be provided to promote intelligence-enabled systems and digital solutions in the built environment. This issue has been addressed differently. The updated EPBD stipulates that targeted incentives should be created to promote smart systems and digital solutions in the built environment. While these requirements have not been implemented in Austria, relatable incentives have been created in the partner countries.

Austria: In Austria, no targeted incentives have been created.

Cyprus*:* In Cyprus, no targeted incentives have been created, but rather evaluation recommendations for cost-effective measures.

The 5% extra building space allowance for buildings that reach Class A und obtain at least 25% of their primary energy consumption from RES was established in 2014. Most of the interest in this incentive comes from developers of large buildings. This incentive can also be used in the construction of new buildings.

The aim is to revise the "I save – I upgrade" scheme in order to remove existing hurdles, but also to design specialised financial products that could operate together or independently of "I save – I upgrade" schemes.

Greece*:* In Greece, no targeted incentives have been created, but smart metering of energy consumption has been incentivised and plans for smart and nearly Zero-Energy Building (nZEB) building investments have been developed.

Germany: The EPBD has led to the adaptation of the Energy Building Act (GEG) in Germany. This has significantly increased the requirements for automation. As a result, the GEG now records the degree of automation of residential buildings and uses it to calculate the energy certificate. This means that anyone who equips residential buildings with smart home functions, for example for heating, ventilation or shading, will receive this positive credit when preparing the energy certificate and thus a "better" energy certificate.

Lithuania*:* Due to the update of the EPBD, public clients are obliged to apply Building Information Modelling (BIM). For other clients, this requirement has only a recommendatory character.

Netherlands*:* In the Netherlands, EPBD III has been fully implemented in building regulations.

Independent control system for the SRI

Member States that decide to implement the Smart Readiness Indicator have to set up an independent control system for SRI certificates.

While in Austria and Cyprus the SRI is integrated into existing control systems like EPC databases, a new control system was set up in Greece. Other partner countries stated that there is still no decision regarding the control system for SRI certificates.

Professionals assessing the SRI

According to the EPBD, under the Smart Readiness Indicator system, the smart readiness of buildings and parts of buildings should be assessed by qualified or accredited professionals. In partner countries, the SRI is assessed by the following professionals:

Austria: Any professional with a technical background, e.g., architects, engineers, are considered qualified professionals.

Cyprus*:* Energy auditors, EPC assessors, qualified experts (EPC), energy managers

Greece*:* Only licensed professionals registered in the national database are allowed to assess the SRI.

Germany: Energy performance certificates are issued by experts who are qualified according to Section 88 of the Building Energy Act – GEG.

Lithuania*:* According to Lithuanian legislation, there is no requirement to assess the smart readiness of buildings.

Netherlands: So far, there has been no decision about the qualification of the SRI assessor.

Method of checking and establishing energy savings and the quality of renovation

In order to ensure that financial means related to energy efficiency are used in the best possible way for building renovation, they should be linked to the quality of the renovation work in terms of the energy savings sought or achieved. In Greece, Lithuania and the Netherlands, there are methods of checking and establishing energy savings and the quality of the renovation. In Austria, Cyprus and Germany, there is no method in this regard.

Greece: Quality control takes place through on-site visits and collection/check of new data/inputs.

Lithuania: Air leakage test must be performed for the buildings that are renovated using EU or Lithuanian budget grants.

Spain: Since there are financial aids that covers part of the cost of the renovation, it is mandatory to deliver the EPC of the building before and after the renovation. In addition, the financial aid is directly related with the improvement in energy efficiency, covering more part of the expenses when the improvement is bigger. Furthermore, in certain regions of Spain, a third-party company must verify that the real building and the information of the EPC are aligned, especially in buildings with high performance (energy class A, B or C).

Data and digital models

Using BIM in the EPC

The use of digital models such as BIM (Building Information Modelling) in EPCs differs among partner countries. In Austria, Cyprus and Greece, BIM is occasionally used in contrast to Germany, Lithuania and the Netherlands.

Austria: There are additional modules for BIM for the calculation of EPCs.

Cyprus: BIM documentation and literature or digital logbooks are not employed in any way for the issuance of EPCs. Building Management System (BMS) is not mentioned in the legislation in connection with EPCs. BMS can be a source of relevant data (heating efficiency recording) for newly issued EPCs. There is no legal obligation to use Geographic Information System (GIS) as a tool for EPC assessment.

Lithuania: According Lithuanian legislation there is no requirement to use digital models (like BIM) while issuing building EPCs.

Netherlands: Software suppliers for the calculation of energy use and savings use data from digital models; however, these digital models are not used for EPCs.

Spain: Some of the software that are used to deliver an EPC can get the geometrical data of the building from a 3D model. This model only has basic data about the building (distances, heights, etc.), all the remaining information that is needed in the calculation process has to be provided by the EPC assessor.

Likelihood of applying digital models

The likelihood of applying digital models is high in all partner countries.

Table 1: Likelihood of applying digital models in partner countries

Austria	Greece	Germany	Lithuania	Netherlands	Cyprus	Spain
likely	likely	no answer	likely	likely	very likely	not likely

Austria: Digital models such as BIM are increasingly used in the design and construction phase of buildings.

Lithuania: There is a commitment to using BIM technologies for certain types of projects.

Netherlands: This will be strongly influenced by legislation and the overall penetration grade of digitisation in the construction and real estate sector. Government and umbrella organisations, for example housing associations, can act as role models.

Spain: There is no plan to develop new software that can get the information of a building from the digital twin.

Regarding the use of the EPC, beside provision at the point of rent or sale or for building permits, the following purposes have been listed:

Table 2: Purpose of use of the EPC in partner countries

Austria	approval of major renovations, application of subsidies, financing renovation activities (e.g. loans)
Greece	building notification of individual energy efficiency-related measures, approval of major renovations, financing renovation activities (e.g. loans)
Germany	approval of major renovations, application of subsidies, financing renovation activities (e.g. loans)
Lithuania	approval of major renovations, application of subsidies
Netherlands	application of subsidies, financing renovation activities (e.g. loans), discount on mortgage

Cyprus	building notification of individual energy efficiency-related measures (e.g. replacement of the heating system, change of windows, etc.), approval of major renovations
Spain	approval of major renovations, application of subsidies, financing the renovation activities (e.g. loans)

The answers as follows were given regarding the provision of renovation recommendations:

Table 3: Provision of renovation recommendation

Austria	Greece	Germany	Lithuania	Netherlands	Cyprus	Spain
Automatically generated	Automatically generated	Tailor-made and automatically generated	Automatically generated	Tailor-made and automatically generated	Automatically generated	Tailor-made and automatically generated

Only in Greece, renovation costs are integrated into EPC recommendations. In Austria, energy advisors use a tool during energy audits that can provide an estimation of costs of energy efficiency measures. In Spain, the predefined improvements generated by the tool can be modified by the EPC assessor. The renovation costs can be added by the EPC assessor.

Use of smart meters

Austria: At the end of 2020, the roll-out rate of communicative smart meters for Austria as a whole was only around 28%[7]. According to the plans submitted by the network operators (as of the end of March 2021), a roll-out of around 69% will be exceeded by the end of 2022 in order to reach the target of 95% by the end of 2024.

Cyprus: In Cyprus, there is no law in place concerning the use of smart meters.

Greece: Law 4342/2015 foresees the provision of individual metering devices to customers for electricity, natural gas, district heating, district cooling and domestic hot water, whenever an existing meter is replaced or a new connection is made. The Hellenic Electricity Distribution Network Operator (HEDNO S.A) is the responsible body for electricity meters.

Germany: There is no significant implementation of smart meters.

Lithuania: The current accounting situation for individual utilities in Lithuania is diverse in terms of modernity: out of 1.6 million household electricity meters, only 5,800 are smart. 11,000 out of 21,000 heat (input) meters have a remote reading function. 247,000 out of 665,000 hot water meters have a remote reading function, and all gas (582,000) and cold water (989,000) household meters are not smart. The situation also differs concerning suppliers: most electricity and gas meters throughout Lithuania are maintained by one supplier, and separate companies in different cities provide other utilities.

By the end of 2023, residents consuming more than 1,000 kWh of electricity per year and all business customers will be upgraded from old meters to new smart ones (about 1.2 million). Starting from 2024, old meters will be exchanged at the end of their metrological validation for the remaining residents.

[7] Source: E-Control; Report on the introduction of smart meters in Austria 2021

Upgrading the meter will not entail additional costs for the residents – it is part of the network investments performed by ESO (state-owned energy supplier of electricity and gas).

Netherlands: In 2015, network operators began offering smart meters on a large scale to households and small businesses. By 2020, smart meters are to be offered for around 8.5 million connections.

Spain*:* The only type of smart metering that is available in households are the electric smart meters provided by the electrical company. You can check in real time the consumption of your home directly from a webpage.

Use of databases

All partner countries have databases (at national and/or regional level) for storing the EPCs. In Austria, six of nine provinces have regional EPC databases in addition to the national EPC database.

For storing the EPC, the following formats are used in partner countries:

Table 4: Format of storing the EPC in EPC databases

Austria	Greece	Germany	Lithuania	Netherlands	Cyprus	Spain
Microsoft Excel	XML	Proprietary formats of the software companies	Microsoft Excel	EP-Online	There are no open data sources. The assessment is based on relevant estimations.	PDF file

Some of the EPC databases of partner countries are linked to other databases:

Table 5: Linkage of the EPC database to other databases

Austria	Greece	Germany	Lithuania	Netherlands	Cyprus	Spain
yes The EPC database is connected to the construction material database called Baubook and heating products database[8].	no	no	yes The EPC database is connected to the real estate registration database	Yes EP-online is connected to the database of the Netherlands' Cadastre, Land Registry and Mapping Agency	no	no

Use of information stored in an EPC database

The information available on EPC databases are used for:

[8] www.produktdatenbank-get.at

Austria: For research and policy making, for the proof of the quality (in terms of energy efficiency) in case of obtaining subsidies and for registering the site in the EPC database

Greece: For random EPC inspections and reviews of specific EPCs following complaints

Germany: Information only accessible to database managers and not offered for any purpose other than quality checks

Lithuania: The information in the real estate database is used for selling, renting contracts.

Netherlands: To verify and use the correct address notation as contained in the database of Cadastre.

Spain: To have a general vision about the building´s energy performance.

Education requirements and qualification of EPC issuers

Education of EPC issuers

Austria: Any professional with a technical background, e.g., architects, engineers, is considered as qualified professional.

Cyprus: EPC assessors are required to pass a qualifying examination under the categories of residential, non-residential buildings, or both. Training is not mandatory (Ministry of Energy, Commerce, and Industry, n.d.).

Greece: Qualified engineers registered as auditors/inspectors in the national register; further examination for higher classes of EPCs

Germany:
a) During the degree, a focus on training in the field of energy-saving construction or, after studying without such a focus, at least two years of professional experience in essential construction or plant engineering areas of structural engineering

b) Successful training in the field of energy-saving construction

c) Public appointment as a sworn expert for a subject in the field of energy-saving construction or in essential construction or plant-related areas of activity in building construction

Lithuania: University degree in civil engineering

Netherlands: Requirements for the education of EPC advisers are laid down in BRL9500-W and BRL9500-U[9] (depending on the education level and EPC exams).

Spain: Some education degrees are considered to give the necessary knowledge to deliver an EPC. These degrees are more likely with a technical background such as engineering and architecture.

Obligatory trainings for EPC issuers

[9] These BRL's are part of the legislation that has been developed in The Netherlands as Elaboration of the EPBD. They describe the requirements for the certification of companies who offer energy labels for dwellings (W) and utility-buildings. Every energy advisor also needs is own education and to pass an exam, has to follow NTA8800 (method of doing a building survey and energy performance calculation) and has to connect with a company or organization who has a certificate in accordance with BRL9500-W and/or BRL9500-U. Connection means that the energy advisor is employed or otherwise associated (e.g. because the energy advisor is self-employed). NTA8800 (>1000 pages) also describes the formal rules who are elaborated in the BRL9500-W and -U. To make the NTA8800 easy to use, has ISSO made the publications ISSO82.1 and ISSO75.1 who give a more workable (easy to read) description of the method of doing building surveys.

Not all partner countries have obligatory trainings for EPC issuers.

Table 6: Obligatory training for EPC issuers in partner countries

Austria	Greece	Germany	Lithuania	Netherlands	Cyprus	Spain
no	yes	no answer	yes	yes	no	no

Austria: There are EPC calculation trainings on a voluntary basis.

Cyprus: There is no legal obligation for a systematic and regular evaluation/assessment of energy assessors' competencies and skills, only a general provision. Circulars and workshops are organised for each new development. If needed, special recommendations are made.

Greece: Law 4409 (July 2016) includes training requirements of energy auditors.

Germany: Depending of the background of studies

Lithuania: There are obligatory trainings that include 47 academic hours for those who want to be attested as EPC issuers.

Netherlands: The refresher course for continuous professional development of the EPC adviser is obligatory.

Spain: There are trainings for each one of the software available, but they are not obligatory.

Market acceptance

In these partner countries, there have been changes to EPCs in order to be better accepted on the market:

Table 7: EPC changes in partner countries for better acceptance on the market

Austria	Greece	Germany	Lithuania	Netherlands	Cyprus	Spain
no	no	yes	yes	yes	no answer	yes

Lithuania:
Indicators were added:

- $CO_{2\text{-eq}}$
- Primary energy demand
- Energy demand for cooling
- Renewable and non-renewable energy demand
- Renewable and non-renewable energy rate

Netherlands:

Indicators were added:

- $CO_{2\text{-eq}}$
- Primary energy demand

However, some indicators that were not described by the partner country have also been removed. Moreover, the display/illustration of information has been changed and easily understandable description of indicators has been provided.

Spain:

The Royal Decree 390/2021, issued in June 2021, sets the obligation of carrying out a visit by the EPC-issuer. In Spain is well-known that many times, the EPC-issuer didn't even visit the building, so the EPC credibility was very low.

Lessons learned

Lessons learned and steps taken to tackle the challenges seen since the start of the EPC scheme in partner countries are:

Austria: In the beginning, consumers were not particularly interested in the information contained in energy certificates. It was seen only as a document to be presented when selling, renting, obtaining building permits or subsidies. Since the information is calculated based on default values or predefined assumptions, the energy demand does not match the energy consumption. As a result, consumers use the energy bill as a source of information and the EPC does not yet influence user behaviour. This has led to the calculation method and default values being adjusted to minimise the gap between calculated and actual energy consumption.

Greece: EPCs are obligatory in building transactions and have been fully integrated in the current building market. Energy auditors are qualified professionals and have a high level of knowledge. Implementing EPC recommendations is a great challenge, which is mainly addressed through financial incentives and information campaigns. There are some open issues, e.g., EPCs for domestic buildings do not include the energy consumption of important consumers, such as lighting systems and electrical appliances. Also, statistics regarding building characteristics (e.g., U values, HVAC systems of buildings) could be made more easily available.

Germany: Depends on the position: we as Cleopa would prefer a standardisation of APIs and a shift away from the pure kWh/square meter description. Sustainability indicators should also be implemented and tested.

Lithuania: Some procedures that were previously not specified as mandatory for certification scheme, have now been specified as mandatory for certification (e.g. inspection of the object); the accuracy of some values has been increased (e.g., the indicator of building tightness).

Netherlands: Since the implementation of the EPC scheme, the standards have changed very frequently, which made it difficult for certain companies to maintain their software for the calculation processes. When developing the new determination method, attention was paid to simplicity, unambiguity, transparency, and applicability within the requirements of the EPBD guideline.

Spain: EPCs are mandatory when buying or renting a home, in addition, every 10 years is mandatory to recalculate the EPC. The general public don´t see the EPC as a valuable information tool because of the lack of education in the energy field.

Depending on the software that has been used to deliver the EPC, some simplifications or default values may have been taken, as it is not mandatory to check the construction materials that have been used in the building. There are some predefined values depending on the year of construction, but this can cause a deviation from the real performance of the building.

Recently, the legislation has changed in other to have a more realistic image of the buildings in the country (Spain), by making mandatory visiting the building. Despite this, there is a lack of information regarding the building construction or systems, that can be solve by implementing the digital twin in EPCs.

ANNEX D: Involvement of stakeholders in workshops

The project partners have identified a wide range of people and organisations across the EU in order to have a holistic approach to the drawbacks and requirements of the current EPCs. Capturing stakeholder requirements from each stakeholder's perspective is paramount. The range of the stakeholders include:

- Energy experts/consultants for new construction and renovation
- Software producers, tool developers
- Policy makers, state/governmental departments – public bodies
- Facility managers, real estate agents (rental and sales of buildings)
- Standardisation bodies
- Research and Development (R&D) sector, researchers/academia
- Energy service companies (ESCOs)
- Owners/users/tenants
- Building services industry
- Suppliers
- Building material industry
- Energy agencies
- Environmental/social campaigning organisations
- EU Commission

In the questionnaire sent to the identified stakeholders at the beginning of the project, the following challenges were identified regarding the next generation of EPCs:

- Quality of EPC data
- Human-centric certificate
- Software credibility and quality
- Limited information on the actual energy performance of buildings
- Insufficient information for building users and limited user-friendliness
- Assessor's subjectivity during calculation procedures
- EPCs as an active part of a smart city concept

Partners will select the most relevant stakeholders for the level of implementation and invite them to national workshops to introduce the concept of the digital dynamic EPC as envisaged in the D^2EPC project. In these workshops, a brief explanation will be presented in order to show the structure, used data, outputs, and usability of the project's product (see figure below **D^2EPC context diagram**).

In these workshops, stakeholders will discuss the identified gaps and challenges under the objectives of the D^2EPC project. The outcomes of these workshops will be incorporated in the development of the dynamic digital EPC.

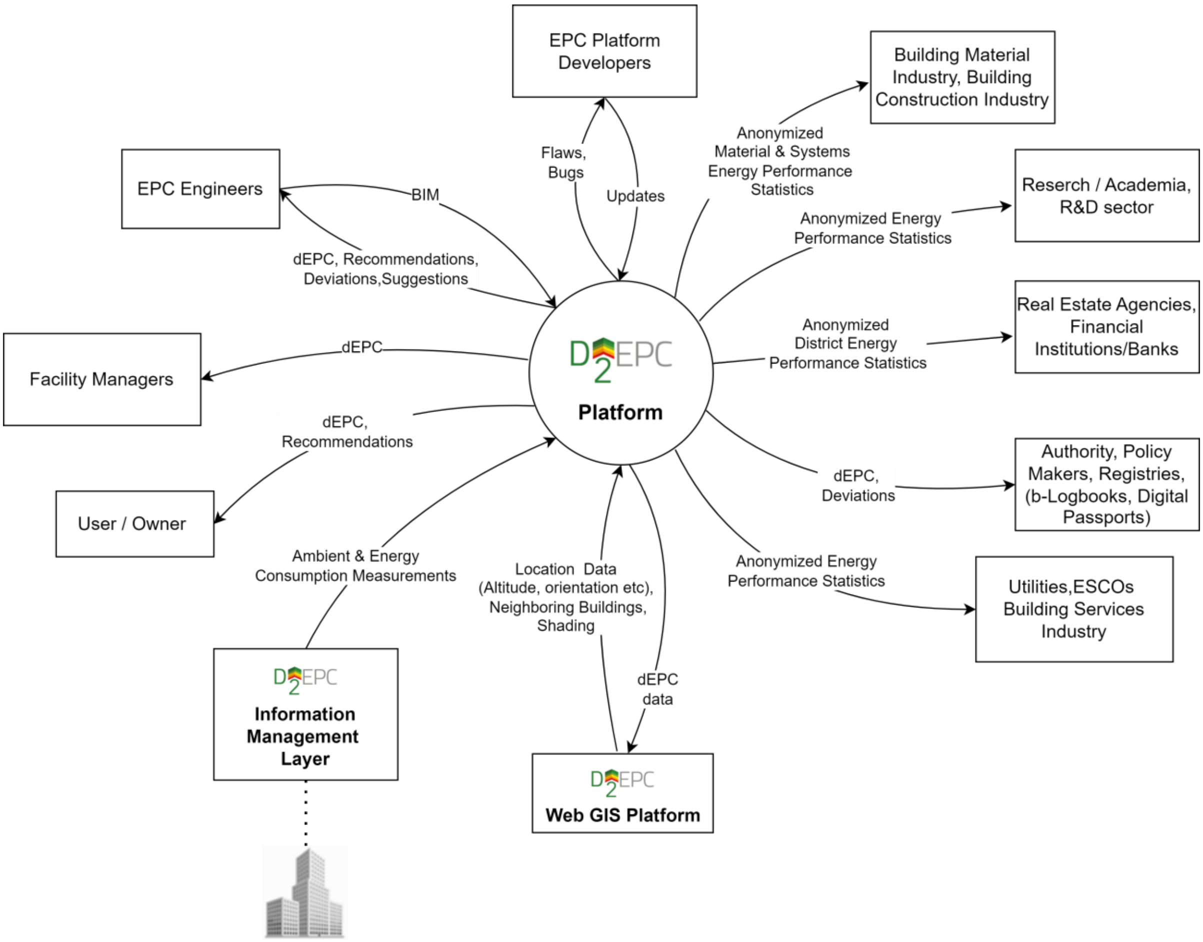

Figure 13: D^2EPC context diagram (Source: CERTH, 2022 [11])

Recommendations for discussion in the workshops: Results of the questionnaires

Below are the subjects of discussion recommended for the stakeholder workshops, including results of the questionnaires and advantages or strengths of the digital dynamic EPC.

These recommendations result from the detailed analysis of users and technical questionnaires as well as from the desk research conducted within the project. The recommendations and guidelines target the following issues:

- Establishment of an operational dynamic EPC issued on a regular basis
- Establishment of EU standards on the classification requirements of buildings
- Establishment of a novel set of indicators covering environmental, financial, human comfort and technical aspects of new and existing buildings
- Issuance of EPCs based on real-time data and advanced BEPS tools integrated into BIM
- Integration of Smart Readiness Indicators in the building's energy performance assessment and certification
- Intelligent operational digital platform for dynamic EPCs issuance and real-time building performance monitoring and improvement
- Education of EPC issuers
- Quality control of EPCs

The energy efficiency rating can easily be converted into a dynamic, electronic format as in D^2EPC. Converting existing data from each source into a compatible format makes it possible to create a dynamic energy performance certificate that adapts to any changes in the conditions. The energy consumption of a building changes according to current conditions. The types of energy and energy consumption vary, which may also result in changes in the energy efficiency rating. Instead of ordering a new energy performance certificate (which could be costly) each time the property is sold, an up-to-date energy performance certificate is always available in the existing system. This information is available throughout the whole life cycle of the building.

Recommendations for discussion in the workshops: Comparison of EPC, Dynamic EPC & D^2EPC

A methodology targeting all building types may complicate the energy performance assessment of simple buildings because of the large amounts of input data necessary. By employing a combination of calculated and measured rating, countries are able to define different methodologies depending on building type, stage, construction year, etc., leading to an improved representation of the building stock's energy performance.

In a previous chapter, different types of EPCs were described. All these calculations and provisions have their advantages and deficiencies. In the tables below, the advantages, deficiencies and opportunities that can be used to improve the EPC scheme are listed. These tables will be discussed in the workshops:

Table 8: SWOT analysis of EPCs

EPC asset rating	
Identified Strengths	Identified Weaknesses
Identified Opportunities	Identified Threats
Dynamic EPC	
Identified Strengths	Identified Weaknesses
Identified Opportunities	Identified Threats
D^2EPC	
Identified Strengths	Identified Weaknesses
Identified Opportunities	Identified Threats

Results of Stakeholder workshops: SWOT analysis of stakeholder views

Table 9: SWOT analysis of stakeholder views on the next generation of dynamic digital EPCs (interim results)

NG Dynamic digital EPC	
Strengths • The EPC is always up to date. • Flexible energy generation and consumption and thus reduced generated CO2 emissions etc. can also be mapped. • Exact data • Actual comparison, forecasting, optimization, load management • Could replace a scoring / other evaluation tool • Possibility of better comparability of the actual data of different buildings	**Weaknesses** • Too much effort, suitability for residential buildings? • Data quality determines result - uncertainties, errors • Too much work and cost for smaller objects • Too complex and expensive • Possibly a lot of effort to ensure up-to-dateness, how can this be implemented in practice with as little maintenance or administration as possible? • Must be operated by really well trained people, but is developable • User behaviour, how can this be objectively mapped? High effort for data collection and input • Who should / can maintain it? The administrators? or always only externally
Opportunities • with sufficient density of mapped buildings, overall optimization of entire settlement areas • through real representation of the buildings - higher motivation to renovate them • EPC is always "valid" - no expiration date • good planning possibilities • Use of benefits of digitization • Environmental assessment, energy, waste, planning • Future coupling of measurement and simulation is very important to learn more and use services. • 1 tool for many agendas around the building	**Threats** • Data volumes are huge and how large is the amount of energy that is required for this? • Data Privacy, vulnerabilities, hackers • possibly too confusing for end customers • is only a calculation tool, must not become an end in itself, energy consumption reduction and resource optimization must be in the foreground • Complicated input of data and problems with the quality of data collection. More sources of error, is the EPC also really presented realistically - how can user behaviour be dealt with? • Ongoing updating, overload, for administrators/asset managers. • Too complex • Too expensive