Next-generation EPC's user and stakeholder requirements & market needs

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Executive Summary

Energy Performance Certificates (EPCs) are important instruments for the enhancement of the energy performance of buildings. Notwithstanding the positive contribution that current EPCs have had on improving the energy performance of buildings, experience has unveiled a number of constraints and limitations. There is a need for a holistic framework for strengthening and improving the quality and application of EPCs, by introducing novel and cost-effective approaches of assessing the energy performance of building envelope and systems. This report aims to identify current drawbacks of EPCs and future trends of the market and relevant stakeholders. The results of this research are anticipated to identify the needs and requirements for the successful implementation of next generation EPCs.

The report followed two types of methodologies including desk research and field research. The desk research committed as a set of statements with questions relevant to challenging matters of (i), Efficiency of EPC methodologies, (ii) Potential EPC methodologies to overcome past drawbacks (iii) Efficiency of EPC data collection tools and procedures (iv), penalties and sanctions currently in force for EPC non-compliance (v) current EPC databases and access. The statements were answered with as a set of questions relevant to current and future challenging matters of EPCs. Concerning the field research, the circulation of two types of questionnaire was conducted according to the 'Stakeholder identification and prioritization' section to a list of stakeholders. The purpose of the field research was to identify current drawbacks and future trends of EPCs from the end-users and technical stakeholder's perspective. The results of both desk and field research resulted to a set of challenges and recommendations for the next generation EPCs.

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List of Acronyms and Abbreviations

Term	Description
EPC	Energy Performance Certificate
dEPC	Dynamic Energy Performance Certificate
nEPC	Next Generation Energy Performance Certificate
EU	European Union
MS	Member State
BIM	Building Information Model
BMS	Building Management System
GIS	Geographic Information System
HVAC	Heating, ventilation and air conditioning
LCA	Life Cycle Assessment
EPBD	Energy Performance of Buildings Directive
NZEB	Nearly-Zero Energy Building
EED	Energy Efficiency Directive
BER	Building Energy Rating
API	Application Programming Interface
SEAI	Sustainable Energy Authority of Ireland

IEQ	**Indoor Environmental Quality**
IAQ	**Indoor Air Quality**
BEPS	**Building Energy Performance Software**

1 Introduction

1.1 Scope and Objectives of the Deliverable

This deliverable aims to investigate the stakeholder requirements in relation to the next Generation energy performance certificates (nEPCs). It is evident that the current status of EPCs lack up to date alignment with Industry 4.0 digital tools as well as other important features such as Information Impact, user-friendliness and user awareness. D^2EPC aims to implement a user-centric design approach by engage stakeholders during the whole project lifecycle. Following the detailed assessment of current EPC schemes delivered by T1.1, this task aims to identify the needs and requirements of the major players and the market concerning the emerging next generation performance paradigms. The results of this Task will help to understand the potential reach and impact of the new dynamic EPC scheme in accordance to the requirements identified.

1.2 Structure of the Deliverable

This results of this task will represent the basic structure of the project upon which the WPs will be developed. By considering a stakeholder-centric approach, a questionnaire has been prepared and distributed to a list of stakeholder's partner countries. The questionnaire was designed in such a way to extract the most important needs and requirements from a wide range of stakeholders. Taking into account the diversity of the stakeholder perspectives, a prioritization of stakeholders was implemented and the most relevant players were consulted. The following sections present the methodology, tools employed and results of this research.

- Report Analysis for Identifying emerging future requirements of future EPCs: The methodology of report collection was based on the research literature as well as National EU MS and concerted action reports.
- Stakeholder survey and extraction of needs and requirements: The methodology of the stakeholder extraction, prioritization methods and stakeholders engagement is presented as well as the results of the Interviews/questionnaires.

1.3 Relation to Other Tasks and Deliverables

Task 1.2 is one of the important stepping stones of D^2EPC project and for this reason, does not have initial input from other tasks at its initial stages. Nevertheless, this task will be the cornerstone for WP1 as well as for all tasks of work package two (WP2) related to the novel set of indicators to be developed within the project

2 Methodology

The methodology employed for the identification of needs and requirements are based on the design and application of a data collection process and included the following main activities:

- **Desk research**: including collection of reports from various reliable sources (National energy related reports of EU countries, scientific research papers etc.) aimed to summarize existing knowledge on current EPC schemes, based on legislation and regulation in the EU countries as well as emerging future requirements of the market.
- **Surveys/interviews** addressing the project's stakeholders, in order to collect missing data concerning future trends and needs as well as to validate the ones identified in the desk research. Through this procedure, an accurate and detailed mapping of current status and future trends was recorded.

The collected data were evaluated in close cooperation with the involved stakeholders in order to identify challenges and limiting factors. The end result was the development of an evaluation report which includes recommendations for the nEPCs.

2.1 End-User Needs and Requirements questionnaire

The purpose of this questionnaire was to define the need and requirements of the users as well as the user acceptance of the new elements of the next generations Energy Performance Certificates (EPCs). The interviewees were stakeholder's defined as 'Directly or indirectly affected parties' (owners, users and real estate agents who can use EPCs for rental, sale or normal use). There was in total 50 answered questionnaires from EU MS. The questionnaires responses were statistically post-processed to reveal the user's needs and requirements as well as the hierarchy of their needs. The sections of the questionnaire cover the main objectives of D^2EPC:

- **Objective 1:** The introduction and establishment of the concept of the dynamic EPC (dEPC), an operational certificate
- **Objective 2:** The enhancement of EPCs through a novel set of indicators which cover smartness readiness of building systems, environmental, financial, human comfort and technical aspects of new and existing buildings, aiming to simplify the understanding of buildings energy performance and to present a more comprehensive overview of the actual energy performance of buildings
- **Objective 3:** The integration of actual operational data from buildings into the EPCs using advanced data collection

- **Objective 4:** The integration of smart readiness rationale into the building's energy performance assessment and certification
- **Objective 5:** Intelligent operational digital platform for dynamic EPCs issuance and actual building performance monitoring and improvement, validated and demonstrated under realistic conditions
- **Objective 6:** User acceptance of data provision in the context of energy performance certificates

Table 1 Objectives of End-User Questionnaire

Section	Target
Section 1	
Usefulness of EPCs **Understanding of the EPC** **Information Impact** **Perceived Reliability**	The first set of questions aims to examine the basic understanding of the users on current Energy Performance Certificates (EPCs), the level of information impact to the users and perceived reliability of the data. A more comprehensive questionnaire will be delivered for this target under T1.1
Section 2	
Understanding/Adoption of smart building technologies and their usefulness	This section aims to examine the understanding of users on smart building technologies as well as their perceived importance of these technologies on the buildings. The results will reveal the level of understanding of these technologies given that users are familiar with the advantages offered by such systems.
Section 3	
New aspects of dEPCs: The dynamic concept **New aspects of dEPCs: Next generation EPC indicators** **New aspects of dEPCs: geo-location services**	This sections aims to investigate the user's perspective on the new aspects of the dynamic EPC. Specifically this section will examine: the user's acceptance of dynamic concepts, the user's perspective on the usefulness of new indicators and geo-location services. These indicators are consider core elements of next generation energy performance certificates.
New aspects of dEPCs: data protection/security issues	This section aims to investigate the user's openness to share energy related data with third parties given that they receive valuable insights on how to save energy
Section 4	
Ranking of important building aspects based on personal preferences	This section aims to investigate which aspects of a building are more important to the user. The result will help us to prioritize our focus on specific domains.
Visual aspects of dEPC	This section aims to examine which type of information and visualization type is preferred by the users. These questions target to

	improve user-friendliness of EPCs towards real understanding of EPC data and energy renovation options.

2.2 Technical Stakeholder questionnaire

The purpose of this questionnaire was to identify the needs and requirements of technical stakeholders concerning Energy performance certificates (EPCs). The interviewees were the stakeholders responsible for deploying the EPC service (Tool developers, EPC registries etc) as well as service providers (ESCOs, Engineers, Building designers etc). There was in total 20 answered questionnaires addressing technical stakeholders from EU MS.

Table 2 Objectives of Technical Stakeholder Questionnaire

Section	Target
Section 1	
EPC Methodology	This section investigates the needs and requirements of technical stakeholders with regards to EPC methodology. The current drawbacks and improvement suggestions are envisioned to be answered by experienced deployers of the EPC services.
Section 2	
Input Data	This section investigates the stakeholder's view on the effectiveness of current inspection requirements to gather high quality input data to be used for EPC calculations. Furthermore, it explores the technical expertise of stakeholders to reveal major challenges when collecting EPC data as well as their viewpoint whether current EPC methodologies omit important parameters.
Section 3	
Quality control of energy performance certificates	This section explores the technical stakeholder's viewpoint on the effectiveness of current EPC quality check mechanisms. Moreover, this section aims to understand how the quality of EPCs can be improved based on the technical stakeholder's experience and perspective.
Section 4	
Scope of the EPC registries	This section aims to explore the stakeholder's perspective (especially EPC registers) on the effectiveness of EPC registries to foster energy efficiency and trigger energy related policies. Specifically, this section aims to understand the level of adequacy of EPC collected data to perform insightful energy benchmarking and monitor building energy performance.
Section 5	
Access to EPC data	The level of publicly available information in EPC databases varies between Member States. This section aims to understand the stakeholder's perspective on the impact of open access EPC databases towards promoting energy efficiency improvements to the building users/owners.
EPC Policy Implementation	This section aims to understand the level of impact of current EPCs to National/regional energy targets of policy makers.

2.3 Jira platform for digitalization of user requirements

The stakeholder requirements have been collected and documented using a template based on the VOLERE methodology[1]. Such template has been implemented, in a digital way, by adopting the JIRA platform.

Table 3 D^2EPC Requirements template

Summary	description of the requirement
Requirement Type	Functional: Something the system should do
Component/s	Non-functional: How the system works (several sub-types are pre-defined)
Priority	Constraint
Rationale	To which component(s) does this requirement belong?
Source	Based on this association, the responsible assignee will be defined (after the requirement has passed Quality Check)
Fit Criterion	Components defined as of December 2016 are shown in Section 1.1 below
Custom Labels	Priority defines the relevance of the requirement in relation to the other requirements
Description	Scale: Blocker, Critical, Major (= default), Medium, Minor, Trivial, Nice to have
Issue Links	Why is the requirement important? What contributions does it make to the product's purpose?

[1] https://www.volere.org/

3 Report Analysis for Identifying emerging future requirements of future EPCs

Below are the tables presenting the future trends concerning the methodology, input data, registry and quality control of EPCs and of energy experts in the field of EPCs in the EU MSs.

3.1 Minimum Calculation Methods

Table 4 What calculation methods are used by EU MSs to evaluate minimum energy efficiency and primary energy consumption?

A/A	No. rep.	Country	Comment	Page
1.	20	Belgium	The three regions cooperate to establish a common methodology for new and refurbished buildings, leaving each region free to define its own requirements. Also, the three regions use a jointly developed single software tool.	2
2.	21	Belgium-Walloon	The EPC is based on operational rating being converted into primary energy per m^2.	18
3.	21		It is mandatory under the technical building system requirements to ensure that energy metering is undertaken for large installations. Smart metering is currently not mandatory.	11
4.	20	Belgium-Flemish	Two energy performance methodologies are described in the energy law: one for residential buildings, and the other for non-residential buildings (with a new method substituting for the former method for offices and schools and based on CEN methods). The primary energy factor for electricity is 2.5, and for other sources 1.	4
5.	20		The energy score on the EPC is based on a calculation (asset rating).	18
6.	19	Belgium-Brussels	For all new (or considered as new) non-residential buildings and units, the primary requirements are specified by means of a virtual reference building or unit, which coincides with the actual unit in geometry, floor area, orientation and functionality. Due to this reference building approach, each new building or unit has an individual energy performance requirement that takes its specific details into account.	4
7.	01	Austria	Asset rating is the EPC methodology.	25
8.	14		The calculation methodology for EPC, 'Leitfaden Energietechnisches Verhalten von Gebäuden,' uses building standards that account for calculation procedures for many advanced building technologies.	56

9.	01	Czech Republic	Calculated rating is the EPC methodology. Certification is only mandatory for new and existing renovated buildings larger than $1000m^2$ and public buildings.	25, 27
10.	n/a	Denmark	Asset and operational rating are the EPC methodologies [2].	22
11.	01	France	A combination of calculated and measured rating is used.	25
12.	29		The current thermal regulation in response to the EPBD is the RT 2012 (Réglementation Thermique 2012). It has been mandatory only for some public buildings since the end of 2011, and for all new buildings since 2013. The structure of RT 2012 is based on three performance requirements. The three coeffecients; minimum energy efficiency of buildings (B_{bio}), primary energy consumption (C_{pe}), summer comfort (T_{ic}), are calculated through $\mathrm{TH-BCE}^5$, a dynamic hourly methodology (calculations are run every hour of a full year), which describes each component of the building envelope, as well as its energy systems.	2
13.	29		Issuing an EPC for both existing and new buildings requires the qualified expert to assess the thermal efficiency of the building following an on-site visit, by inspecting the envelope, HVAC and domestic hot water systems.	9
14.	01	Germany	Combination of calculated and measured rating.	25
15.	15		Germany normally requires asset ratings but permits ratings calculated from energy consumption data for multi-family housing.	17
16.	n/a	Hungary	Asset rating is the EPC methodology [2].	22
17.	n/a	Ireland	Asset and operational rating are the EPC methodologies [2].	22
18.	14		Especially for existing buildings, the BER includes individual energy and water use into the calculation. The recommendations are quite detailed.	96
19.	33		For new buildings the Dwelling Energy Assessment Procedure (DEAP) and Non-dwelling Energy Assessment Procedure (NEAP) methodologies and software calculate primary energy use and associated CO_2 emissions for space heating and (where applicable) cooling, ventilation, associated motive power and lighting under standardised conditions of use. DEAP and NEAP, compliant with EN 13790, serve the dual purpose of demonstrating compliance with Part L (Conservation of Fuel and Energy) of the Building Regulations and the generation of the Energy Performance Certificate (EPC) and Advisory Report. In DEAP the electricity primary energy and CO_2 factors are calculated using forecasts from SEAI's Energy Modelling unit.	2, 3
20.	n/a	UK	Asset and operational rating are the EPC methodologies [2].	22
21.	n/a	Poland	Asset and operational rating are the EPC methodologies [2].	22

22.	14		According to the new regulation the calculation of the energy audit can be done using EPC methodology.	96
23.	01	Portugal	Asset rating is the EPC methodology.	26
24.	n/a	Spain	Asset rating is the EPC methodology [2].	22
25.	14		In 2016 the Technical Building Code, RD 564/2013 was further adapted to improve processes, make the methodology more transparent and eliminate barriers to new technological systems. Spain's calculation methodology is included in 6 official computer software programs, which are mandatory for energy certification. The steps to be followed by this calculation methodology are firstly, to calculate the energy demand, both thermal and for domestic hot water and lighting; then, to calculate the energy consumption of the systems necessary to cover the demand. These calculations are made by integrating the building's needs on an hourly basis and by a transitory time-scale regime. The final energy consumption is calculated and extrapolated to non-renewable primary energy consumption and CO_2 emissions. Since the energy simulation software in Spain calculates the final energy consumption, it is necessary to have adequate conversion factors to obtain the non-renewable primary energy consumption and CO_2 emissions.	21
26.	n/a	Netherlands	Asset rating is the EPC methodology [2].	22
27.	47		The energy calculation method for new and existing buildings is defined in Standard NEN 7120 that is in line with the CEN standards. This calculation of the primary energy consumption of a building is based on monthly climate data that is adjusted for physical processes with a shorter timeframe, e.g., solar gains and heat accumulation.	3
28.	n/a	Malta	Asset rating is the EPC methodology [2].	22
29.	38		Where a building is not yet constructed, the certificate is based on a design rating, while certificates for completed buildings are based on an asset rating.	9
30.	n/a	Luxembourg	For residential buildings, the energy performance calculation for new and existing buildings is based on the calculated energy needs for heating, domestic hot water, ventilation and auxiliary needs. The results are expressed in terms of primary energy needs, heating energy needs and $C0_2$ emissions. Since 2016, photovoltaic production can be partly taken into account (only the part which is consumed by the technical equipment of the building). For non-residential buildings, the energy performance calculation for new buildings is also based on the calculated energy needs for heating, domestic hot water, ventilation, and auxiliary needs, but also on AC, lighting, humidification and dehumidification. For existing non-residential buildings, the real energy consumption (metered energy) is taken into account [2].	4, 5

31.	01	Estonia	Operational rating is the EPC methodology for existing buildings, whereas, new buildings use calculated rating.	26
32.	27		Energy calculations for non- residential buildings must be executed by use of a dynamic energy simulation. For residential buildings, the monthly methodology is also accepted. Estonia has not set minimum requirements for U-values. The building has to meet the minimum energy performance requirements as a whole. For detached and terraced houses, compliance with the minimum energy performance requirements can also be demonstrated by a simplified calculation of the specific heat loss through the building envelope. Specific conduction (average U-value of building envelope including thermal bridges) and infiltration heat loss values calculated per heated floor area.	2, 3
33.	27		The 'Calculation Methodology for Building Energy Performance Calculations' Act includes all the necessary information about the calculation of the energy performance, e.g., efficiencies of heating and ventilation systems, infiltration airflows, tabulated values of thermal bridges and standardised patterns of use of the nine (9) different building types and other energy calculation input data, as well as detailed calculation formulas and guidelines for energy calculations. Basically, this act provides guidance on how to run dynamic energy simulation that results in energy needs as well as calculation rules and methods from energy needs to energy usage for delivered, exported and primary energy.	4
34.	n/a	Slovenia	Operational rating is used for non-residential buildings and asset rating is used for all other buildings [2].	22
35.	n/a	Sweden	A measured energy consumption is used for the issuing of an EPC [2].	22
36.	11		the EPC for new buildings is based on metered energy after two years of use and energy performance calculations prior to construction must reflect the expected metered energy use. The calculated energy demand deviates from the measured consumption, primarily due to user behaviour that varies from the standard assumptions. Building data models can then be used – after modifications of the standard input parameters, i.e., internal gains and losses, usage patterns, indoor and outdoor climates – to calculate realistic energy demand and potential savings.	7
37.	n/a	Latvia	Asset and operational rating are the EPC methodologies [2].	22
38.	35		The energy performance calculation methodology is described in Regulation No. 348. The energy performance calculation methodology is based on the corresponding CEN Technical Report CEN/TR 15615:2009 and on Standard EN ISO 13790:2008 conditions and includes references to the 16 other CEN standards. The energy performance calculation methodology uses the primary energy factor	2, 7

			for the non-renewable part. The energy performance calculation methodology for existing buildings is the same as for new buildings.	
39.	n/a	Lithuania	Asset rating is the EPC methodology [2].	22
40.	n/a	Slovakia	Asset and operational rating are the EPC methodologies [2].	22
41.	14		Calculation for EPC are carried out in accordance with CEN standards fully integrated into the Slovak technical standards system (STN), and amended by the respective national annexes.	36
42.	n/a	Romania	Asset rating is the EPC methodology [2].	22
43.	n/a	Bulgaria	Asset and operational rating are the EPC methodologies [2].	22
44.	14		The national methodology for calculating energy consumption indicators and the energy performance of buildings was developed on the basis of BDS EN ISO 13790 and the best European practices in the field of determining the annual energy consumption for heating, ventilation, cooling and hot water.	56
45.	n/a	Greece	Asset rating is the EPC methodology [2].	22
46.	n/a	Italy	Asset rating is the EPC methodology [2].	22
47.	34		Current calculation methodologies are based on national standard UNI/TS 11300 (series from 1 to 6), and the calculation of artificial lighting is based on standard UNI EN 15193:20086. This set of standards is in line with the ones developed by CEN to support EPBD implementation. For new buildings is an updated energy performance calculation methodology, according to EPBD Annex I: • The global annual energy use is calculated for each energy service on a monthly basis and expressed in primary energy. The renewable energy produced within the boundary of the building system (on-site) is calculated in the same way. • Compensation between energy needs and renewable energy produced on-site is allowed only for the same energy carrier on a monthly basis and up to cover the total energy demand for that carrier (the exported energy is not taken into account).	2
48.	n/a	Croatia	Asset rating is the EPC methodology [2].	22
49.	23		The methodology for carrying out energy audits on construction activities with the algorithm for calculating the energy performance of buildings (June 2014), which includes the algorithm for calculating the energy performance of buildings based on CEN standards, except in individual cases where CEN standards were not appropriate, in which case other solutions were used (e.g., the application of the roof standard, ventilation and AC). This algorithm is updated occasionally. For the purpose of primary energy calculations, a set of primary energy conversion factors was determined. The calculation used three-year average data from actual annual energy balances of Croatia in 2009-2011.	3

50.	23		The national calculation tool has been developed and is in a test phase; due to complex calculation procedures it will only cover the most commonly encountered combinations of RES and combined heat and power systems, so there is a need for a more comprehensive calculation tool to complement this tool.	15
51.	14 24	Cyprus	"Methodology for Calculation of Energy Efficiency of Buildings" and "Building insulation guide (2nd Version)" is used for calculation of ECPs. The guide documents all the algorithms and assumptions used to calculate energy consumption and to issue an EPC for new and existing buildings. The methodology for calculating U-values, effective thermal mass as well as general information about different insulating methods is documented in the "Guide of Thermal Insulation of Buildings."	34 2
52.	28	Finland	The overall energy consumption is calculated using standard user profiles and primary energy factors (weighting factors) for different energy sources. For single-family homes and apartment buildings an alternative method was introduced that is based on requirements for building components. Calculations also include thermal comfort requirements, indoor-air quality requirements and infiltration, thermal bridges and shading devices. Balancing calculation is used for acquiring energy consumption requirements for a building-by-building class. Calculations for overall energy consumption by building type include the use of RES. For existing buildings, information on the available measured energy consumption has to be reported alongside the calculated energy consumption if the information is available.	3, 12
53.	11		Innovative technologies found significant differences in ways in which the systems' impacts on building energy demand were calculated. Four categories of technologies were discussed: •Demand-controlled ventilation is mainly divided into mechanical exhaust systems and balanced mechanical ventilation systems with heat recovery coupled to different control strategies. The calculation is often performed using a detailed dynamic simulation method as part of the simplified standard calculation method, although a few countries use fixed factors as rough estimates. • Building automation systems can be grouped according to EN/ISO 15232 into classes A to D, with class A being the most advanced holistic building automation systems and class D being simple manual controls. Classes A and B are mostly applied to new non-residential buildings. Some MSs are considering introducing requirements concerning levels of building automation. The calculation of the impact of building automation systems varies among use of fixed factors as rough estimates, detailed calculations within the assessment method and use of external dynamic simulation tools. In several MSs, building automation systems cannot be assessed directly using the national method and hence, provision must be calculated in alternative ways.	10

			Generally, energy savings seem to be overestimated and only occur after a thorough commissioning of the system. • Information on seven (7) different types of reversible heat pumps was collected and discussed, and categorised according to the supply source and the heat delivery system. The use of specific systems differs among MSs. In Sweden, reversible heat pumps can be calculated by using a dynamic external simulation tool. Other MSs assess the impact of heat pumps either by using a detailed method within their calculation procedure or by using a fixed factor as rough estimate. The obvious advantage of a reversible heat pump is that only one system is needed for heating and cooling. • Several still-innovative advanced solar shading systems were discussed by the participants, for example inter-panel shading devices, semi-transparent PV, double façade systems with integrated shading systems, movable sun-protection glazing and bio-shading. Most systems can be modelled fully only by using an external dynamic simulation tool. As an example, bio-shading is calculated in one MS within the regular calculation method by using a rough factor, and in another MS by using an external dynamic simulation tool. However, most MSs do not take bio-shading into account in their national calculation standard.	
54.	11		A methodology targeting all building types results in simple cases being overly complicated and necessitating an excessive amount of input information. The intention among a few MSs is to use hourly simulations only for complex buildings (e.g., non-residential) and for NZEBs, where more precision is required to accurately model the buildings, while using simplified calculations for existing buildings. In some MSs, hourly simulations are used only for parts of the calculation (e.g., cooling and summer comfort).	15

Data analysis of Table 4

The data collected in Table 4, answers the question on the EPC methodologies adopted by different MSs and national standards followed. The table also includes information on the specification of methodologies for different building types and classes, calculation guidelines regarding various technical systems and innovations in calculation standards.

Countries in the EU are able to select EPC calculation methodologies that best suit their needs whilst adhering to current CEN and EPB standards. This gives rise to a variety of methodologies across MSs. The resultant EPCs produced by each member state may not be comparable in order to give valuable information pertaining to the overall state of EU building stock, monitor progress towards energy performance goals set in the EPBD or develop energy efficiency policy [5]. 14 MSs use asset rating as the energy performance methodology, 2 make use of operational rating, and 13 MSs, including the UK, use a combination of calculated and measured rating.

For new buildings, asset rating is the EPC methodology most widely used because measurements of previous energy consumption are not available to perform operational rating calculations. An asset rating EPC calculation involves calculating the global annual energy demand of individual technical energy systems on a monthly basis according to a standard building use, as primary energy per kWh/m^2, according to EPBD Annex I [6]. Operational rating, on the other hand, is derived from metred data of actual energy consumption and, therefore, reflects user behaviour and potential malfunctioning of equipment. Ideally, asset rating and operational rating methodologies yield the same results with differences being attributed to building management, however, in reality corrections to parameters such as unregulated energy must be applied for comparability. Asset rated EPCs consume less time and are cheaper than EPCs produced from metered data, however, energy savings are not easily identified because the breakdown of energy use is not recorded [7]. This may influence methodology selection in MSs where cost could greatly impact EPC use.

Through applying asset rating as the EPC methodology for all buildings, countries such as Cyprus, may be aligning this methodology to building stock for which EPCs are mostly issued. As stated in [7], most EPCs in Cyprus have been issued for new buildings where calculated energy consumption is the most appropriate methodology. A smaller percentage of EPCs are issued during building transactions as most homes are owner-occupied. A lack of public awareness of EPCs may also influence the uptake of asset rated methodologies that are applied to new buildings where there is a low number of EPCs issued for existing buildings.

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 according to building type, stage, construction year, etc., leading to an improved representation of building stock's energy performance. In Bulgaria, for example, asset rating is used for new builds and operational rating for old buildings [8]. On the other hand, Latvia, which uses a combination of methodologies, uses the same calculated rating to evaluate both new and existing buildings [8]. In Sweden, the EPC for new builds is calculated using metered data after two years of building operation, and the energy performance calculations performed prior to construction are expected to reflect metered energy use [5]. Of the 13 MSs that use a combination of methodologies, 2 were identified in the study that specify how dynamic simulation modelling is incorporated into calculations. France requires a dynamic hourly methodology over a full year, for new buildings, describing the energy performance of each element of the building envelope and energy systems [9]. Dynamic energy simulation in Estonia is performed for non-residential constructions and a monthly methodology is used for residential buildings [10].

Further distinctions can be formed between residential buildings and non-residential buildings, and separate energy performance calculation methods can be assigned. In Germany, operational rating instead of asset rating is accepted for residential, multi-family housing as user behaviour; occupancy rates and energy management, has a greater weighted impact on energy consumption and, therefore, EPC rating [11]. Operational rating is advantageous for buildings with low tenant turnover because new building use patterns would require a new EPC assessment for an accurate energy performance evaluation. Slovenia and Luxembourg take into account-metered data for new and existing non-residential constructions, respectively, and calculated rating is used for all other buildings [2]. The Finnish asset rated methodology is unique to flats and single-family homes, being based on requirements for building components and calculations for IEQ, shading and thermal bridges. Metered data and calculated energy consumption, if available, are together used to issue an EPC for existing buildings [21].

Italy's calculation methodology of RES use in new buildings is in accordance with EPBD Annex I. Renewable energy generated onsite of the boundaries of the building system are calculated on a monthly basis as primary energy. Compensation of energy needs covered by renewable energy produced onsite do not consider exported energy in the case of excess production [6].

Calculations on building systems' impact on energy demand using innovative technologies were compared within MSs. Results showed that calculations for demand-controlled ventilation are mostly performed using a detailed dynamic simulation method, whereas fewer MSs used less accurate fixed factors. Calculations for reversible heat pumps in Sweden are performed through a dynamic external simulation tool, whereas other MSs compensate the lack of dynamic simulation by use of detailed calculation methods, and others use fixed factors [13]. It may be more advantageous for MSs to employ a similar calculation model as Sweden for reversible heat pumps in order to collect more accurate results and promote the use of a single system for both heating and cooling needs.

The impact of building automation on energy consumption are not covered in the national methodologies of several MSs, creating a need for accurate alternative assessment methods. The calculation of building automation systems incorporate fixed factors as rough estimates, external dynamic simulation tools and detailed calculation procedures. Energy savings are generally overestimated and this may negatively affect the reliability of EPC data.

3.2 Overcoming Drawbacks Identified in the Past

Table 5 What EPC methodologies and scope of methodologies must be addressed to overcome drawbacks identified in the past?

A/A	No. rep.	Country	Comment	Page
1.	14	Bulgaria & Latvia	EPC results are only conditionally comparable, as different boundary conditions may differ for EPC and audit. That consumes extra time and entails further costs for the building owner. In the same direction go arguments by several other stakeholders. In many countries it is a general view among EPC assessors that an EPC reflects the building's performance with regards to its thermal envelope and technical systems, regardless of its occupant behaviour and use of the building. As an audit also mirrors the habits of the occupants, recommendations should be based on building's performance with some care and abstraction from the occupant behaviour.	95
2.	14	Croatia	An energy audit is a pre-condition for producing EPCs as an audit mirrors the habits of the occupants, recommendations should be based on building's performance with some abstraction from the occupant behaviour.	95
3.	23		The national calculation tool has been developed and is in a test phase; due to complex calculation procedures it will only cover the most commonly encountered combinations of RES and combined heat and power systems, so there is a need for a more comprehensive calculation tool to complement this tool.	15
4.	23		The methodology for carrying out energy audits on construction activities with the algorithm for calculating the energy performance of buildings (June 2014), which includes the algorithm for calculating the energy performance of buildings based on CEN standards, except in individual cases where CEN standards were not appropriate, in which case other solutions were used (e.g., the application of the roof standard, ventilation and AC). This algorithm is updated occasionally. For the purpose of primary energy calculations, a set of primary energy conversion factors was determined. The calculation used three-year average data from actual annual energy balances of Croatia in 2009-2011.	3
5.	14	Bulgaria	Requires a detailed energy audit as the basis for an EPC as an audit mirrors the habits of the occupants, recommendations should be based on building's performance with some abstraction from the occupant behaviour.	95

6.	16		The Sustainable Energy Efficiency Agency (SEEA) has introduced new software forcalculating the energy performance of buildings. The software includes advanced energy recommendations and has improved functionalities.	36
7.	14	Latvia	Usually, the EPC is viewed as an annex of energy audit (this has happened because mostly EPCs are issued only when building applies to receive an EU grant for building renovation and in this process a detailed energy audit of the building is needed).	96
8.	14	Hungary	In Hungary it is a general view among assessors that an EPC belongs to the building, regardless of its owner, and of its owner's behaviour/use of the building. An audit mirrors the habits of the owner, but it should not be the basis of the recommendations for improving the building's performance.	96
7.	32		For new buildings and major renovations, thermal comfort and minimum requirements on fresh air supply are set, but these values are not included in the calculation procedure for certification.	3
8.	32		The regulations include requirements on technical building systems elements (e.g., on balancing, control, pumps, airtightness of ventilation ducts). The rulebook does not set any direct system performance requirements; only the upper threshold of the total primary energy consumption of the building is defined.	8
9.	32		CEN standards can be applied in the final stage of the design. Nevertheless, before elaborating the final construction drawings, a building permit is to be issued on the basis of overview plans. In this stage, many details of the construction are not fully defined yet and, as a consequence of the lack of input data and due to the inevitable changes during the later stages of design and construction, the application of the CEN standards is put under question. From building permit until commissioning (which may take years), the market conditions, e.g., availability and cost of some elements, may change: this is why reliable but simplified calculation tools are and will be necessary in the early stage of design (application for building permit), when lack of input data does not facilitate the application of many standards.	14
10.	14	Romania	The information provided in the EPC is sufficient to conduct an evaluation of the energy performance of the certified building. However, the detailed technical information is often incomplete or incorrect.	97
11.	14	Sweden	The EPC includes measured individual energy and water use and an assessment of indoor climate to determine the energy performance and suggest cost-effective renovation measures. However, a detailed energy audit may be needed in order to exactly design and calculate the profitability of the suggested measures and package the measures into a deep renovation plan.	97

13.	14	Cyprus	EPCs are only based on technical building performance.	96
14.	24		Estimates in reducing energy consumption in new buildings by an estimated 50% compared to the pre-EPBD period are based on calculation models that do not consider the quality of works or any flaws that occur during operation.	9
16.	7	Portugal, regions of England and Wales	These states have undertaken considerable efforts in making the EPC more user-friendly, resulting in less and shorter technical documents that present the requested information in an easily understandable way.	3
17.	14	Greece	The calculation of the energy performance and production of the certificate is performed automatically on the 'buildingcert' platform.	18
18.	14		The adoption of CEN OAS standards and the corresponding calculation methodology are under consideration in Greece.	57
19.	14		If the EPC issuer is not the energy consultant carrying out an energy audit, the building data must be recaptured for an energy audit. This takes time and entails new costs for the building owner. The results are conditionally comparable since different boundary conditions underlie.	96
20.	14	Finland	EPCs are only based on technical building performance. The only target of comparison is the building itself, not its current occupants.	96
21.	27	Estonia	Estonia has not set minimum requirements for U-values. The building has to meet the minimum energy performance requirements as a whole. For detached and terraced houses, compliance with the minimum energy performance requirements can also be demonstrated by a simplified calculation of the specific heat loss through the building envelope. Specific conduction (average U-value of building envelope including thermal bridges) and infiltration heat loss values calculated per heated floor area.	3
22.	27		Estonia has not set minimum requirements for systems and / or building components for new buildings.	5
23.	27		In new buildings or existing buildings undergoing major renovations with more than one owner, metering equipment must be installed in the heating system to determine the use of heating energy in the different parts of the building. Intelligent metering does not factor in the energy efficiency calculations or requirements.	7
25.	11	Denmark	Denmark used the energy performance calculation model to compare the gap between actual measured data and the standardised EPC. Models with adapted key variable parameters are occupancy behaviour (number of users, use of domestic hot water and use of appliances) and temperatures (both indoor and outdoor) produced results that closely align with the measured energy consumption.	8, 9
		Belgium-Walloon	Belgium used an adapted model for additional reports based on the EPC model data.	

		Latvia	Latvia used an adapted model (calibrated against measured consumption) instead of a standardised EPC model.	
		France	France used an adapted model to study the coherence between asset and operational rating methods. Discussions highlighted a conflict between the clear benefits of improving model accuracy with the frequent lack of interest among consumers. This lack of interest can be explained partly by other issues (i.e., economy) garnering more attention, and partly by the inconsistency between standard calculations and measured energy consumption. The most important contribution for any calculation is in the value added to decision-making, but no direct benefit will be realised in practice if the consumer is not sufficiently engaged.	
27.	11	Sweden Slovak Republic Lithuania UK Denmark Hungary	The energy performance shown in most MSs' EPC is based on a standardised calculation of the primary energy demand. This, however, may not be the same as the measured energy consumption in a building and savings presented in the EPC might differ from the experienced energy savings. The EPBD does not envisage the calculation of non-standard energy consumption and hence, expected energy savings. Nevertheless, realistic estimations of energy savings are necessary in order to determine the time scale of returns on investments. In Sweden, the EPC for new buildings is based on metered energy after two years of use and energy performance calculations prior to construction must reflect the expected metered energy use. The calculated energy demand deviates from the measured consumption, primarily due to user behaviour that varies from the standard assumptions. Building data models can then be used – after modifications of the standard input parameters, i.e., internal gains and losses, usage patterns, indoor and outdoor climates – to calculate realistic energy demand and potential savings. The Slovak Republic, Lithuania, the UK, Denmark and Hungary, allow the alternative use of the EPC model for a more detailed analysis of the energy saving potential. The ownership of the EPC building data model can in some cases hinder its use for alternative calculations. This can happen, for example, when the EPC data is owned by the expert who carried out the certification and created the EPC building data model, whereas additional calculations would be carried out by a third party.	7
29.	11		The use of waste heat from industry or wastewater heat pumps is allowed in energy performance calculations by some MSs, but others do not have calculation methods to account for these.	14
30.	11		Some MSs cannot account for certain types of RES technologies (e.g., a combination of PV and solar thermal; local hydro power), due to the lack of calculation procedures, either because the procedures are not covered in the EPB Standards or because there is very little or no local use of these technologies and, therefore, no need to develop such	14

			procedures. In some MSs, there are additional procedures to deal with technologies for which there is no standard calculation defined.	
31.	12		It is possible that smart readiness assessment could be connected to energy performance calculation and EPCs (e.g., become an additional module in the existing procedures), though the calculation methodology for the indicator will have to consider impacts wider than energy or primary energy. Smart Readiness Indicator, SRI, calculations will not be limited to energy, and at this stage it is not yet clear if it will become feasible (and desirable) to combine SRI and EPC procedures.	16, 19

Data Analysis of Table 5

The data included in Table 5 delivers identified drawbacks of EPC methodologies. Delivering solutions to these drawbacks in the next generation of dynamic EPCs will ensure a holistic improvement in how EPCs impact energy savings. The drawbacks covered include omitted calculation indices, a lack of calculation tools, technical issues and tolerances of calculation models.

A general view of EPC assessors in most MSs, for example, Hungary, is that the thermal characteristics of the building envelope and technical systems installed, form the basis of evaluating the energy performance of the building [5]. Building occupant' behaviour is not regarded as a significant influencing factor on the energy consumption of the building [5]. The objective of the EPC to the user stakeholder, is to promote energy efficiency of the building by recommending cost-effective renovations and changes in occupant behaviour that save energy whilst improving well-being. In order to provide useful recommendations, the EPC must base recommendations on the building's performance with input from occupant behaviour [5].

Various combinations of IAQ indicators are used in calculation procedures in some MSs, whereas, others omit IAQ indicators entirely. Indoor quality is evaluated by indoor air quality, daylight, thermal comfort and acoustics [25]. IAQ factors including thermal comfort and fresh air minimum requirements are not mandatory for all calculation procedures. The EPBD recast does not mandate the incorporation of IAQ indices into energy performance calculations. The EPC in Hungary for new buildings and buildings that have undergone major renovation, sets minimum requirements on fresh air supply and takes thermal comfort into account, however, they are not used as input values in evaluating the energy performance for certification [15]. The inclusion of IAQ indicators is intended to incentivise the building user to follow the recommendations included in their EPC for renovations or energy management behavioural changes and at the same time increasing their indoor quality. Building user engagement is therefore a key parameter in determining what indicators, when included in calculation methodologies, produce the greatest results in energy saving and transformation of the building stock [13].

Sweden uses an operational rated EPC methodology that includes an assessment of indoor air climate. To present more cost-effective renovation measures, calculate the profitability of those measures and package them into a deep renovation plan, Sweden uses energy audits in combination with the EPC [5]. This supports the opinion that cost-effective renovation measures cannot be accurately investigated by an EPC alone, even when a measured rating methodology with IAQ indicators is used. Furthermore, new buildings' EPCs in Sweden are based on measured data following two years of occupation. The energy performance calculations before construction are expected to reflect metered energy use [13]. This safeguards against a large performance gap between calculated and metered rating. In Croatia, an energy audit is a pre-condition to the production of an EPC. The EPCs in Croatia follow an asset rated methodology. In Bulgaria, where a combination of methodologies is used, a detailed energy audit is also a pre-requisite for the issuance of an EPC [5]. The conditions around the issuance of an EPC may also affect whether it is used in combination with an energy audit or not. In Latvia, EPCs are often issued for a building when an application for EU funding to carry out renovations is lodged. For grant approval the building must undergo a detailed energy audit. For this reason, the EPC is seen as an annex of the audit report [5].

A disadvantage of EPBD calculation procedures is that they are designed around a standard energy consumption that predicts expected energy savings. In the case of non-standard consumption, an energy audit indicates representative energy savings and payback periods. Energy audits are increasingly being used to fulfil the cost-optimal level requirements of renovations and to fulfil the precondition of EU and public funded subsidies, as is the case in Hungary [15]. Overall, using the energy audit in conjunction with the EPC seems to be aimed at adding a dimension to EPCs that more closely mirrors occupant behaviour and generates cost-optimum energy efficient renovations. The feasibility of linking the smart readiness assessment, energy performance calculation and EPCs is under study. The smart readiness indicators will introduce impacts beyond primary energy to EPCs [27].

When an energy audit and an EPC are issued for the same building, they may not be carried out by the same energy expert. Building calculations and data collection procedures are often replicated due to the different boundary conditions of the two assessment methods [5]. Several drawbacks can result from this; added cost to the building owner and time required for assessment, and conflict over right of access to building data due to ownership. A building data model can be created by the EPC assessor, for example, and supplementary calculations can be performed by a third party. A building data model developed for the issuing of an EPC can be further manipulated to derive a detailed analysis of energy saving potential. This is achieved by modifying the standard input parameters, i.e., usage patterns, internal gains and losses, indoor and outdoor climates. Denmark, Hungary, Lithuania, Slovakia and the UK, have encountered hindrances to the use of building data models for such alternative calculations due to ownership of the model [13].

A drawback of the asset rating methodology is the performance gap between calculated and measured energy performance. The gap often arises due to non-standard building use which is unaccounted for in the asset rating methodology or malfunctioning energy systems. To investigate the gap, an energy performance calculation model adapts key variable factors of indoor and outdoor temperature, and occupancy behaviour; specifically, the number of occupants, domestic hot water and electric appliance use, to align primary energy demand more closely to the measured energy consumption [13]. A study carried out by Concerted Action EPBD, documented how MSs are applying corrective measures to performance gaps [13]. Denmark's calculation model compares the gap between measured data and the standardised EPC. France, on the other hand, uses a different approach by using an adapted model to analyse the coherence between the two methodologies. Latvia uses a model calibrated against measured consumption to investigate performance gaps, rather than using a standardised EPC model. In Belgium, the adapted model constructs additional information from EPC model data. 3 out of 4 of the above countries use a combination of asset and measured rating. Belgium as a whole, uses both asset and measured rating methodologies, however, they are used separately, distinct for different regions. Improving model accuracy is inhibited by consumer interest. To a larger extent, consumer interest is inhibited by the costs that out-weigh the benefits and to a lesser extent, by performance gaps. Consumer engagement is seen as a major drawback to the development of calculation procedures [13].

Energy calculation tools are used to fulfil minimum energy performance requirements. MSs states can develop national or regional calculation tools and software to improve functionality and develop advanced energy recommendations [26]. Croatia's national calculation tool covers the typical combinations of RES used in the country, and combined heat and power systems. The need for a comprehensive calculation tool to address more complex calculation procedures has been cited [23]. Calculation procedures in most MSs, account for technologies that are typically used locally, where the EPB has not provided any standards. Complex combinations of RES that are not covered by EPB standards, may not be included in any calculation procedures in all MSs. For example, a combination of photovoltaics and solar thermal, or local hydro power may be excluded from a calculation methodology if there is little use of such technologies in the concerned countries or there has been no need to develop procedures previously [13]. Energy derived from industrial waste heat or the use of wastewater heat pumps is accounted for in calculations of some but not all MSs [13]. There is a growing need for calculation tools that cover more complex combinations of RES, the use of innovative technologies and EPCs issued earlier stages of construction.

Smart meters are increasingly being used in households and buildings throughout the MSs. This is often pioneered by utility companies meeting their obligation to provide dynamic energy and gas consumption meter readings that are easily accessible and understandable by the consumer. Gas and electricity metering requirements are laid out in the 2009 Gas Directive, Directive 2009/73/EC and the 2009 Electricity Directive, Directive 2009/73/EC [14]. Despite this, smart metering and real time data are not utilized in the calculation procedures of the EPC in many MSs. In new or deep renovated buildings, owned by multiple persons, the distribution of heating in the different parts of the building is monitored by metering equipment in Estonia. Despite the availability of valuable dynamic metered data, it is not used in calculation procedures [9].

In various MSs, the EPC assessment is based on technical building performance. This is the case for Cyprus and Finland, for example. Resultant EPCs can be used to compare buildings but no comparison can be made between building occupants [5]. In Romania, the information resulting from the asset rated methodology is adequate to evaluate building performance. A drawback is that, the technical information provided is usually incomplete or erroneous. This is particularly the case for existing buildings and buildings built without abiding to any environmental codes. Detailed input data for technical systems may not be available readily or at all. Default values can substitute real values. These default values must be controlled to match real input values as much as possible.

MSs can define minimum performance requirements for system and building components, as well as the upper thresholds of total primary energy consumption of the entire building for EPC issuance. Alternatively, only system performance requirements are set or the entire building must meet the minimum energy requirement for the EPC. It is most ideal when pre-requisites for both system elements and the entire building are set as this ensures a comprehensive safety measure to optimize the final efficiency of the building. Defining minimum energy efficiency requirements for individual elements is a scalable approach to realising a building with a high energy efficiency performance. The drawbacks of setting an upper limit of total primary energy consumption to be met by the building is that inefficient building systems can be used when more efficient systems would be more appropriate. In Hungary, detailed requirements of technical building system elements including control, balancing, pumps and airtightness of ventilation ducts are outlined in a national rulebook. The rulebook, however, does not set the corresponding minimum element energy requirements, for existing buildings, as they are seen as being more beneficial in the construction sector [15]. For new and existing buildings, Estonia requires only that the entire building meets the threshold of specific yearly primary energy consumption. In existing buildings, new technical building system installations, such as boilers, must meet the primary energy performance requirements [10]. There is a trend in most MSs, to move towards defining ambitious system performance requirements for elements and the building envelope in new buildings to meet targets for NZEB.

The calculation models followed by various MSs often do not factor in the quality of work of assessors or operational flaws. This is the case in Cyprus [7]. Asset rated methodologies inherently cannot take into account the malfunctioning of equipment and reflect it in the EPC. A lack of allowances for individual assessors' competencies and precision in the calculation procedures are yet another drawback of EPC methodology [7].

3.3 Data Collection

Table 6 What are the input data collection procedures for EPC calculations? What data collection tools exist and how are collection procedures regulated?

A/A	No. rep.	Country	Comment	Page
1.	n/a	Germany	Onsite visit not mandatory, full project documentation is satisfactory to evaluate energy performance [2].	24
2.	14		Guidance on default values for input data are unavailable.	34
3.	21	Belgium-Walloon	For existing residential buildings, a dedicated, stand-alone software called PACE is used by assessors to input the building data collected, after which the server generates the EPC. The PACE software includes built-in validation rules which prevent incomplete EPCs from being sent to the database and flags or prohibitions on input value to prevent mistakes.	14
4.	21		For public buildings visited by the public, a web software called ECUS was created to input the collected building data. The certificate indicates the energy class of the building according to its type based on the operational rating being converted into primary energy per m^2. The certificate also contains a graph showing the real consumption of electricity and combustible fuel for the last three (3) years and other specific indicators. Statistics determining the number of buildings will be done in the future.	18

5.	n/a	Belgium-Brussels, Walloon.	The certification process of new buildings requires proof of compliance with energy efficiency requirements; in such cases, the qualified expert may be involved during the on-site work and have direct access to the building and systems data [2].	24
6.	n/a	Austria	Onsite visit not mandatory, full project documentation is satisfactory to evaluate energy performance [2].	24
7.	14		Default input values are available from prescribed standards. In addition, an online public database, called baubook that provides characteristics of construction products, such as walls, floors, roofs, and of some building systems, such as wood heating appliances, heat pumps, ventilation fans, ducts and pipes is available.	33
8.	n/a	Czech Republic	Onsite visit not mandatory, full project documentation is satisfactory to evaluate energy performance [2].	24
9.	14		The Czech standard CSN 730331-1 provides the default values and general input data required for calculation in the national calculation tool.	34
10.	n/a	Estonia	Onsite visit not mandatory, full project documentation is satisfactory to evaluate energy performance [2].	24
11.	14		Default values for some input parameters are available in the regulation "Methodology for calculating the energy performance of the building."	34
12.	n/a	Italy	Onsite visit not mandatory, full project documentation is satisfactory to evaluate energy performance [2].	24
13.	14		Default values for input parameters are available under Annexes of the national standards UNI/TS 11300 2014 (parts 1 to 4).	35
14.	34		Conventional electric meters have been replaced by digital meters that report through the power line. This conversion provided for a more detailed bill, with summaries of monthly consumption and hourly data accessible online to users with demand exceeding 50 kW. A roll-out of gas smart meters is expected to achieve 60% in 2018.	12
15.	34		Better quality is achieved through a mandatory visit of the unit/building before issuing the EPC,	15
16.	n/a	Poland	Onsite visit not mandatory, full project documentation is satisfactory to evaluate energy performance [2].	24
17.	n/a	Bulgaria	The certification process of new buildings requires proof of compliance with energy efficiency requirements; in such cases, the qualified expert may be involved during the on-site work and have direct access to the building and systems data [2].	24
18.	14		Default input data for the different climate zones are integrated in the EPC software.	33

19.	n/a	Finland	The certification process of new buildings requires proof of compliance with energy efficiency requirements; in such cases, the qualified expert may be involved during the on-site work and have direct access to the building and systems data [2].	24
20.	28		97-98% of energy metering (electricity) points are metered hourly and read remotely (automatic meter reading). In district heating 90-95% of heat sales are read remotely and 80-85% are metered hourly. By law, it has been mandatory to install individual meters for cold and warm water in new buildings since 2011. It is not mandatory to use the readings as a basis for billing. The same applies to the renovation of buildings. Intelligent metering enables the collection of more useful data that can be shown in EPCs.	8
21.	n/a	France	The certification process of new buildings requires proof of compliance with energy efficiency requirements; in such cases, the qualified expert may be involved during the on-site work and have direct access to the building and systems data [2].	24
22.	14		Default values for typical input data as well as guidance for on-site inspection are provided in guidebooks dedicated for each topic.	34
23.	n/a	Portugal	The certification process of new buildings requires proof of compliance with energy efficiency requirements; in such cases, the qualified expert may be involved during the on-site work and have direct access to the building and systems data [2].	24
24.	n/a	Slovenia	The certification process of new buildings requires proof of compliance with energy efficiency requirements; in such cases, the qualified expert may be involved during the on-site work and have direct access to the building and systems data [2].	24
25.	14		Default input values are available.	36
26.	n/a	Spain	The certification process of new buildings requires proof of compliance with energy efficiency requirements; in such cases, the qualified expert may be involved during the on-site work and have direct access to the building and systems data [2].	24
27.	14		Commercially available software provides a default value as an input parameter.	36
28.	14	Denmark	A Hand-book for Energy Consultants, HB2019, is used as a reference guide for obtaining input information for EPC labelling of new and existing buildings. In addition, indicative default values for heat transmission values for building elements are provided in a HB2019 dedicated website.	34
29.	14		On-site inspection is required only for few categories of buildings, such as detached single-family houses, row houses.	41
30.	14	Greece	Default input values are available as a part of the reference building standards. EPC calculation software also provides default input	34, 42

			values for climatic data of the various climate zones. On-site inspection is required for all buildings.	
31.	14	Cyprus	Private software includes default values for input data such as construction elements.	34
32.	14	Hungary	Practical default values for input data are available. On-site inspection and inclusion of photographs is mandatory.	35, 42
33.	14	Latvia	In the beginning of March 2020, national annexes to around 40 different ISO standards about building energy efficiency containing default values for input data were published. It is officially not mandatory, but common for EPC assessors to perform a site visit.	35, 42
34.	14	Lithuania	A Technical Regulation provides default input values.	35
35.	32		On-site visit mandatory.	
36.	14	Malta	Guidance on default values for input data are available.	35
37.	14		On-site inspection is required for all buildings	42
38.	14	Romania	Default values are available in the regulation MC 001-2006.	36
39.	14		On-site visit mandatory.	42
40.	14	Slovakia	Default input values are available for various fields, such as climate, thermal transmittance values.	36
41.	14		EPCs can be issued online. An on-site inspection is not necessary. An on-site inspection is possible, voluntarily, but more expensive.	42
42.	14	UK	Calculation methodology and default values for various input data are available in SAP, RdSAP and NCM.	36
43.	14	Croatia	An on-site visit and energy audit are mandatory for the issuance of an EPC.	41
44.	23		The methodology for carrying out energy audits on construction activities with the algorithm for calculating the energy performance of buildings (June 2014), which includes the algorithm for calculating the energy performance of buildings based on CEN standards, except in individual cases where CEN standards were not appropriate, in which case other solutions were used (e.g., the application of the roof standard, ventilation and AC). This algorithm is updated occasionally. For the purpose of primary energy calculations, a set of primary energy conversion factors was determined. The calculation used three-year average data from actual annual energy balances of Croatia in 2009- 2011.	3
45.	14	The Netherlands	On-site visit is not required.	42
46.	14	Ireland	On-site inspection is required for all buildings.	42
47.	14	Sweden	Default values for data connected to user behaviour are available, for different types of buildings (domestic, office, educational) to	36

			calculate energy performance of new buildings before they are built. These values are also used to adjust the measured energy performance of existing buildings to normal use of a building. On-site visits are compulsory for all buildings.	
48.	11	n/a	A consortium was established by DG Energy to assess the usability of the draft EPB Standards published by ISO and CEN in June 2017, using example cases. The standards were examined as a package and tested for consistency between inputs and outputs. The data analysis further evaluated the degree of competence required to gather the input data as well as quality, accuracy and error rate. In addition, the usability analysis also considered the ease of use and the time and effort required. The drawbacks of such a detailed approach are: • many input data need to be specified (500-700 for a typical building) • many details are not relevant for simple assessment situations, but choices still need to be made for every input, which negatively impacts the usability of the standards without adding value to the assessment. •Furthermore, the approach does not guarantee easy incorporation of new building/system configurations and can even impede it, e.g., for uncommon systems that are excluded from the calculation methodology described in the standards. •The modular set-up of the EPB calculation can minimise some drawbacks but assuring consistency in the set-up and proper exchange of data is more difficult. •The use of default values could solve some of the problems, but it would be necessary to ensure that default values are realistic. • The current energy performance calculation system could be converted into a user-friendly integrated energy performance calculation core that includes standard input data. • A more systematic approach for the management of primary building input data is needed. • The use of a reference building in the calculation can reduce the significance of systematic errors. It seems that the complexity of the standards is overwhelming in some cases, e.g., in existing buildings, due to the considerable input data required in combination with the lack of detailed information for these buildings. DG Energy is encouraged to support the development of a common calculation core to ease implementation of the new set of standards in MSs.	4
49.	n/a	n/a	On-site inspection may spot additional buildings' problems that could not be identified remotely and therefore provides better reliability of the EPC issued and allows for more effective tailor-made recommendations. This is not the case for the EPCs issued on the basis of information provided by the building's owner through mail, though the cost of the EPC may be lower in this case [33].	7

Data Analysis for Table 6

Data in Table 6 refers to the different collection methods of input data stipulated in EPC schemes. Data collection strategies involving mandatory onsite inspection seem to provide more transparency to the EPC scheme and more reliable raw data for use in calculations.

19 MSs require an onsite visit to be carried out by an assessor to gather the technical information of the building and systems for energy performance evaluation and certification. Hungary further defines additional data to be included for the issuance of an EPC after a site visit. These are photographs of the building that are required and are used to verify correspondence between input data on the EPC and the building itself [8], [33]. Proof of compliance can also be extended to new buildings where an assessor's onsite inspection may cover the construction site. This is the case in 9 countries. 9 MSs accept input data from full project documentation for EPC assessment. In Latvia, onsite inspections are not officially compulsory but are commonly carried out [5]. Onsite visits or full project documentation can be used either for new buildings or existing buildings and even for specific building types. In Denmark, for example, onsite evaluation is obligatory for a few categories of buildings such as row and detached single family houses [5]. Onsite inspection generally produces more reliable EPCs because problems in the building not mentioned in the full project documentation can be spotted. Additionally, recommendations provided by the expert will be more accurately tailored to the specific building and occupants, compared to recommendations issued based on input data generated online, or delivered by mail, or communicated over the phone during consultation with the building owner [33]. Italy has achieved better quality EPCs because of conducting onsite visits before issuing an EPC [6]. Latvia presents the gradual transition from an EPC procedure without mandatory onsite visits to assessors carrying out voluntary onsite inspections for issuing the EPC. Voluntary onsite visits can also be carried out in Slovakia; however, they are more expensive than those issued by an online form [5]. The expense of onsite visits seem to inhibit the compulsory requirement of onsite visits.

EPC software often includes default input values used to guide assessors or provide standard values when they cannot be attained otherwise. EPC calculation software or digital platforms are required to conduct plausibility checks on input values, thereby, minimizing human error and optimizing financial resources [33]. MSs that use EPC calculation software to ensure valid and accurate input values, as well as compulsory onsite visits produce EPCs that allow for quality checks at different stages of processing. The aim of defining default input values is to provide input values where there is lack of detailed building and system information, such as in existing buildings. The aim is achieved to a larger extent when default values are realistic and systematic error is reduced [13]. Onsite inspection also assists in achieving this aim by allowing real measurement to be made and a confirmation of reported data. Input values can also be made available online or in guidebooks dedicated to technical systems and the building envelope. EPCs generated electronically consume less time and, therefore, cost less to the property owner.

Default input values are available as a part of the reference building standards in Greece and contain climatic data of the various climate zones [16]. Slovakia provides default input values of thermal transmittance values [5]. In Belgium-Walloon region, two separate software tools are used for old residential buildings and public buildings open to the public. The former generates an EPC from input data collected by the assessor. The software dedicated to public buildings is used to input collected building data and display energy class, graphs of electricity consumption and combustible fuel over three years and other specific indicators [23]. Dedicating separate software to different building types allows EPCs to be produced following exact requirements coded into the software. Human error occurs less frequently by assessors who specialize in particular building types.

Smart metering facilitates the recording of valuable measurements for EPCs [21]. In Finland, 97-98% of electrical energy metering points are read hourly and 90-95% of district heat sales are read remotely and 80-85% are measured per hour0 [21]. According to the report, it seems that this data is not used in the calculation procedures of EPCs. This would allow for more accurate EPCs that reflect user behaviour. Updates to the EPC can then be made through the database to convey real-time or up to date information. In Italy, digital meters in direct communication with the electricity power line have facilitated more detailed bills with summaries of consumption per month and hourly figures. Online access is granted to consumers whose demand is in excess of 50 kW [6]. It was estimated that a roll-out of gas smart meters in 2018 would achieve 60% energy savings [6]. Smart metering solutions provide dynamic input data for use in EPC calculations and also a means for users to follow EPC recommendations whilst being able to track their progress.

An operational rating methodology requires regulated input values that accurately reflect occupant behaviour. In Sweden, new domestic, educational, and office, buildings have default input values associated with user behaviour to calculate their energy performance before construction. These default values are additionally used in the adjustment of the energy performance of existing buildings, based operational rating, to normal building use [5].

Table 7 What protocols are part of quality assurance of EPCs, EPC assessors and EPC databases in MSs?

A/A	No. rep.	Country	Comment	Page
1.	14	Belgium	Separate training and exams for assessors are conducted for different building typologies such as type A certification for residential buildings and type C certification for public buildings. Annual training has been mandatory since 2017 in order to retain recognition as a type A energy expert.	61
2.	21	Belgium-Walloon	EPC accreditation involves training and passing an examination. Previously accredited experts could attempt the exam without extra training until 2016 for a smooth transition. As of April 2017, there has been continuous training for qualified experts in preparation for the 2021 building regulation, which includes the NZEB requirements.	2
3.	21		A control, web application is used to automatically screen all the EPCs submitted to the database by flagging inconsistent data or values and selecting a statistically representative number of EPCs to be humanly controlled. This random selection of EPCs ensures that each qualified expert gets regularly controlled. Control documents related to each assessor are archived. Sanctions can be imposed on assessors depending on the frequency, type and impact of errors exposed by control procedures.	17
4.	21		Systematized compliance checks with Energy Performance of Buildings (EPB) procedures and requirements.	21
5.	21		An initial EPB statement requires a complete energy performance calculation and a final EPB statement demonstrates compliance with the energy performance requirements. Both are uploaded to a central EPB database. The EPC is then issued based on information provided in the final EPB statement.	2
6.	20		In addition, the Flemish Energy Agency also handles complaints regarding the quality. In case of a complaint, the quality is investigated on the spot (site visit).	19
7.	19	Belgium-Brussels	Despite communication around frequently made mistakes and modifications carried out on the software, there was no dramatic enhancement to EPC quality.	8
8.	14	Luxembourg	Experts who are not architects or consulting engineers, whose profession is regulated by the law of 13 December 1989, are approved to issue EPCs after mandatory training.	62
9.	n/a	Ireland	Qualified experts need to pass a mandatory exam every 2 years [2].	19
10.	14		Each BER assessor can expect to receive at least one data review per year, at least one desk review or documentation and practice audit per year and additional auditing on a frequency reflecting the numbers of BER published, risk profiling, complaints or other indicators. Penalties	72, 82

			include suspension or termination from registration on the basis of the seriousness of their impact on the integrity of the scheme.	
11.	33		The selection of EPCs for audit is carried out on both a targeted and random basis with due consideration of risks associated with the EPC assessment processes. SEAI randomly selects a statistically significant percentage of all the EPCs issued annually and subject those certificates to verification. Routine follow up audits identify if findings from previous audits have been adequately resolved. In addition, SEAI may, under its Quality Assurance System and Disciplinary Procedures, require EPC Assessors to participate in mentoring visits arranged by its auditors to facilitate further training.	12
12.	n/a	Bulgaria	Qualified experts need to pass a mandatory exam every 3 years [2].	19
13.	22		The verification of energy audits is performed by the SEDA through systematic or random sampling of the audited buildings. Control over the activity of the inspectors is undertaken by means of checks.	9,12
14.	n/a	Lithuania	Qualified experts need 20 hours of additional training and to pass a mandatory exam every 5 years [2].	19
15.	14		All EPCs are automatically checked by software. About 0.5% of all issued EPCs are controlled via a detailed audit. A detailed audit of an EPC is performed following client complaints.	72, 70
16.	14	Latvia	It is mandatory to work under (train) for 2 years under the guidance of a certified EPC assessor to be able to take the exam for becoming an energy auditor, after which, periodic training is not necessary.	62
17.	35		Documents of independent experts are periodically selected for random testing purposes. According to the regulation, the control office also designates an appropriate certification authority to inspect the selected documents.	10
18.	n/a	Czech Republic	Mandatory training of qualified experts is required every 3 years [2].	19
19.	25		The State Energy Inspection is annually required to check at least one in twenty EPCs issued in the previous calendar year.	
20.	14	The Netherlands	A qualifying examination is required for EPC assessors.	63
21.	n/a	France	Mandatory training of qualified experts is required every 5 years [2].	19
22.	14		The certificate is renewed upon satisfactory clearance of a documentary exam and a practical exam.	67
23.	14 28		The focus of control lies on EPC assessors. New EPC assessors are checked 4 times during the first year and 4 more times in the following 4 years. Following this first cycle of certification, experts are checked 4 times every 5 years. In 2013 this led to a check of about 11,600 EPCs. If several invalid EPCs have been issued, EPC assessor can be sanctioned with a fine or loss of certification.	70, 81, 10

24.	n/a	Croatia	Mandatory training of qualified experts is required annually [2].	19
25.	14		0.3% of EPCs are controlled in the quality assessment scheme.	71
26.	23		Detailed quality control is carried out on EPCs that are randomly selected and/or based on complaints. An EPC is declared invalid only if it contains calculation results, input data or proposed measures with significant (more than 30%) deviation and if the result causes a change of one or more energy classes. Authorised persons shall be sanctioned by means of a fine or by annulment of authorisation in the case of 3 or more invalid EPCs.	11
27.	14	Estonia	A mandatory number of academic points has to be collected during a period of five years.	62
28.	27		The Estonian Technical Regulatory Authority makes random checks on EPCs and deals with complaints.	9
29.	14	Slovenia	One-week training with a written and oral exam is needed for expert certification.	63
30.	14		If necessary, the EPC assessor has to correct the EPC as well as issue and store a new one in the register.	82
31.	n/a	Romania	Proof of experience, e.g., number of EPCs issued, is required for a qualified expert's licence renewal [2].	19
32.	14		An initial mandatory training in short-term courses of 80 hours or master classes in 1 to 2-year programmes on energy efficiency or the energy performance of buildings and an examination are required. EPC certification is awarded for a period of 5 years.	63
33.	14		10% of issued EPCs have to be checked for compliance each year as a quality control measure.	72
34.	n/a	England, Wales	10 or 5 hours of continuous professional development per year depending on the energy assessor's accreditation [2].	19
35.	14	UK	Regarding public buildings in England, the random size should be at least 2%.	72
36.	14	Portugal	Mandatory training courses must be undertaken to become an EPC assessor.	63
37.	52		There are monthly or annual targets of EPCs quality assessment numbers to reach, based on: typology (residential/non-residential), type of certificate (new/existing), energy experts covering and other criteria. The levels of quality control range from simple to detailed quality checks, automatic input validation and mandatory training of experts. In simple checks 5% to 6% of certificates are cross-referenced against documents uploaded by the expert. In detailed quality checks, 0.5% of certificates, the quality assessor consults with the energy expert and replicates the work performed by the expert. Irregularities may require re-issuing of certificates. A 5% error in the ratio of primary	60, 61, 62

			energy needs and its limit that causes a change of the energy label leads to a fine. The overall quality of the EPC in terms of contents, lack of recommendations and recurrent incorrect procedures or calculations is also checked. The technical mistakes and additional aspects identified must be registered in the central database, on the individual record of the quality assurance. These mistakes are evaluated to identify the best performing quality fluctuation error (QE) and the most common mistakes to provide clarification to energy experts, adapt training schemes, reshape scope of work and monitor improvement over time.	
38.	n/a	Austria	The state government checks energy certificates on a random basis. In Tirol the state government entrusts specific quality control tasks to suitable bodies for a maximum of 3 years with possibility of renewal. The entrustment must be revoked if there are significant deficiencies in the performance of the control tasks or instructions from the state government are repeatedly or not completely followed [3].	23
39.	14	Spain	In all the 17 regions, 100% of the certificates are automatically controlled by computer mechanisms that evaluate all the certificate data, and generate automatic notices about certificates that do not correspond with reasonable average parameters. Additionally, a document control is carried out on nearly 50% of the certificates using complementary information. There is also specific inspection mechanism that reaches 0.5% of the certificates in terms of information review and improvement measures, and a deep inspection system with a visit to the building which occurs 0.05% of the time.	23
40.	14	Greece	The law requires on-desk check of a randomly selected sample of 5%.	72
41.	52		The Departments of Energy Inspection are responsible for carrying out random EPC control checks and checks on specific EPCs after complaints. The checks include: a. control of the data inserted in the electronic database used for the EPC calculations; b. on-site inspection of the building in order to verify the data used for the EPC. • The quality check procedure utilises a tolerance of 5% from the total primary energy consumption of the existing building or a variation of more than one energy class. Penalties to energy auditors are calculated according to a A penalty point system developed algorithm from the Departments of Energy Inspection of the YPEN, and covers all types of issued penalties.	61
42.	14	Cyprus	EPC assessors are required to pass a qualifying examination under the categories for residential, non-residential buildings or both. Training is not mandatory.	61

43.	24		Samples for checking purposes are drawn from four categories: new residential buildings, existing residential buildings, new non-residential buildings and existing non-residential buildings. Ten (10) specific input parameters are checked, most notably U-values, efficiencies of heating and cooling systems, and window size. If the input parameters alter the energy class of the building, the EPC is cancelled. In that case the qualified expert has to issue a new, corrected EPC by a specific deadline. If the EPC is not issued then the building permit authority is notified in order to take measures within its jurisdiction, such as the cancellation of the building permit.	6
44.	14	Malta	Undertaking training that is approved by the Building Regulation Board is mandatory for EPC assessors.	63
45.	14		Quality checks on a statistically significant sample of certificates including the input data, results and recommendations are carried out.	70
46.	38		On-site verification of the contents and calculations of EPCs displayed in public buildings takes place for quality purposes.	10
47.	14	Denmark	Qualified energy consultants must attend mandatory courses and meetings in accordance with the Danish Energy Agency's decision. All energy consultants must pass a refresher course no later than every 3 years. BedreBolig is a training course on deep renovation that is offered regularly. In case of substantial errors, EPC assessors may receive a warning being displayed in the online register of experts. As a last resort, the EPC assessor can lose their licence.	62, 67, 68, 81
48.	14		An electronic analysis is carried out for all EPCs. A technical revision must be carried out for 0.25% of all EPCs. Quality assurances of EPCs are also carried out in the case of a complaint.	72, 74
49.	26		Denmark is currently implementing a seven-step quality control plan that entails: 1. tightening supervision and quarantine and requiring consultants who make serious and/or repeated errors to take new exams; 2. shortening the time from error to learning, with a focus on case-handling time; 3. initiating further dialogue with stakeholders regarding quality efforts; 4. revising the regulatory framework; 5. developing educational standards with stricter requirements; 6. applying a user-friendly energy labelling scheme; 7. implementing a user satisfaction survey.	11
50.	14	Finland	There is a mandatory qualifying examination for EPC assessors valid for 7 years. Thereafter, periodic training is necessary.	62
51.	14	Slovakia	An initial qualifying examination is mandatory for EPC assessors.	63

52.	14	Italy	The national legislation requires 2% of all EPCs to be annually checked starting from best class EPC according to EPBD option c) point 1 of Annex II “full verification of the results stated in the certificate, including the recommendations made and onsite visit of the building.”	70
53.	34		There is a link between EPC databases and the heating and air-conditioning (HAC) inspection database. An EPC is valid only if the “HAC log-book” from regular inspections is attached.	15
54.	34		EPC experts have to be qualified for building design (registered at engineers/architects/other experts’ associations) or attend a training course (80 hours) undergoing final examinations.	16
55.	52	Italy - Lombardy	The quality of EPCs is controlled regularly on a statistical basis.	49
56.	14 16	Hungary	2.5% of EPCs are checked, of which 0.5% (i.e., 20% of the total sample size) should have total inspection with on-site visit. If faults are detected, assessors are required to correct them. When the energy class is determined wrongly and the difference is 2 classes or more, the assessor license is withdrawn for 3 years.	19, 72, 39
57.	14	Sweden	Recertification of energy experts is necessary after 5 years by passing a new theoretical test. EPC assessor needs to report number of performed assignments and any updating of skills and send in assessed EPCs to the national certification body once a year.	27, 67
58.	14		1% of certificates are checked annually for quality assurance.	70

Data analysis of Table 7

The quality assessment procedures of EPCs, assessor accreditation and EPC registries are described in Table 7. Comparisons of quality assurance procedures between MS are made in order to identity the potential for improvements.

Training schemes can be targeted at different types of energy assessors, thereby, delivering tailored and relevant educational material. Energy assessors are sometimes restricted to evaluating specific building typologies based on their qualifications. Belgium also uses this scheme to control the quality of work of experts who specialize in type A residential buildings by imposing mandatory annual training [5]. To ensure the quality of EPCs for new buildings, countries such as France and Belgium-Walloon region, rely on the use of an initial and final EPB statement that demonstrates compliance with energy performance requirements to issue an EPC [31]. Assessor targeted training schemes may simplify the regulation of continuous professional development especially for assessors who consult for complex building types.

Continuous professional development may entail regular mandatory training and examinations. To ensure a smooth transition due to changes in the certification of assessors, previously accredited experts in Belgium, Walloon region were exempt from mandatory training before taking an exam. Furthermore, annual training has since been focused around developing quality assessors to uphold the 2021 building regulation [31]. Such a training structure enables adjustments for increasingly ambitious energy performance regulations, such as NZEB requirements to be made, keeping newly assessed EPCs up to date with available technologies and current standards. In lieu of mandatory training and exams for certificate renewal, Romania requires proof of experience, such as the number of EPCs issued and a lack of malpractice [2]. This method harmonises the quality of EPCs produced with a quality assurance system that focuses on controlling individual assessors. Resources used in independent quality control practices of the EPC scheme as a whole are also optimized.

To ensure that EPC assessors have comprehensive knowledge, not only of EPC schemes, but also of building and technical elements, pre-requisite qualifications may be required. Many MSs require assessors to hold a formal qualification from a higher educational institution in architecture, engineering, or similar fields, prior to undergoing mandatory training or sitting a qualifying exam. In Latvia, however, a 2year apprenticeship with a certified EPC assessor will entitle the candidate to take the qualifying exam, without further training required in the future [5].

Short term training courses or master classes with a duration of 1 year or more may be adopted in MS's EPC training schemes for qualification or recertification. In Slovenia, expert certification is awarded after successful completion of a 1week training program with a written and oral exam. A choice of an 80hour course or 1-2year program on energy performance of buildings are offered in order to qualify for examination in Romania [5]. Italy also requires successful completion of an 80hour training course and an examination [6]. A determining factor for training methods employed may depend on the number of certified EPC assessors practicing in a MS. A low number of assessors, unable to satisfy the demand for EPCs may substantiate the implementation of short-term courses.

The EPBD requires the automatic screening of EPCs in a database that flags unusual values and other inconsistencies. The EPBD requires systematic compliance checks of EPCs based on EPB procedures and requirements. Many MS's EPCs are controlled automatically during EPC upload to a digital registry. The Walloon region of Belgium uses a control web application to achieve this and to randomly select a statistically significant number of EPCs to be humanly controlled. A random selection of statistically representative EPCs facilitate the regular control of each EPC assessor [31]. EPC quality assessments can be based on building typology and new or existing certificates among others, and be carried out at different time intervals. For public buildings in England, a random sample size must constitute at least 2% of EPCs [5]. In Croatia, 0.3% of EPCs constitute a statistically significant percent and in Romania this figure is 10% [5]. Ireland carries out extra routine follow-up audits to ascertain if irregularities discovered in prior audits have been resolved [34].

The data revealed that quality assurance systems in some MSs set a predefined number of EPCs for controls. Often the number of controlled EPCs increases after each assessment period. The Czech Republic controls a minimum of 1 in 20 EPCs from the preceding calendar year [17]. The data may imply that countries with a relatively small EPC database predefine a relatively small number of EPCs for quality checks.

Software is used to select percentages of EPCs for different levels of control. Levels can include desk or document control, information review and deep inspections with onsite visits for parallel analysis of the certified building. Lithuania allocates a detailed audit for 0.5% of their EPCs [5]. Portugal assigns the same percentage of EPCs for detailed control involving the replication of an assessors work during a consultation [24]. In Spain, 50% of EPCs undergo document checks, 0.5% are reviewed in according to data and improvement recommendations, and 0.05% are checked in detail with an onsite visit. In Italy, the annual check of 2% of EPCs prioritises checks of EPCs starting from the best class [5]. Detailed audits of EPC certificates are carried out much less than desk audits. Increasing the percentage or rate of detailed audits may result in an EPC quality that aligns with the strategic plans of each MS to improve their building stock. As stated in [35], Denmark's seven-step quality control plan focuses on:

1. tightening supervision;
2. reducing case-handling time where errors occur;
3. initiating extensive dialogue with stakeholders on quality efforts;
4. amending regulatory framework;
5. training programs with stricter conditions;
6. developing an energy labelling scheme that is user-friendly;
7. applying a user satisfaction survey.

Consulting a user satisfaction survey may allow the compounding of survey results with complaints received about EPCs or EPC assessors in order to make more beneficial improvements to quality control systems.

A targeted selection of EPCs can be made on the grounds of a filed complaint. A targeted selection can dictate the quality assurance protocol followed. The Flemish Energy agency in Belgium carries out on the spot site visits in the case of a complaint [30]. EPC control can be targeted at assessors based on risk profiling; experience, recurring mistakes, complaints etc. In Ireland, each EPC assessor has an annual review consisting of at least a desk review or documentation and a practice audit. France focuses control on newly accredited assessors, checking issued EPCs at 4 instances in the first year, and thereafter 4 times over 4 years. After licence renewal every 5 years, assessors are checked 4 times. Swedish national certification body requires that assessors annually report the number of performed assignments, additional training or skills attained and EPCs issued [5].

An EPC can be declared invalid if it exceeds set tolerances for calculation results, input data or proposed measures. If errors result in a change of energy class or label, this can also warrant the EPCs invalidity. In Croatia, an EPC is invalid if there is a significant deviation, exceeding 30%, in calculation results, input data or proposed measures that cause a change in 1 or more energy classes [23]. Portugal has a more lenient control measure. A 5% error in the ratio of primary energy needs and its limit that causes a change of the energy label leads to a fine but does not invalidate the EPC [24]. EPC validity can also be linked to other documentation. For instance, the EPC in Italy is only valid if it is accompanied by a valid heating and cooling log-book of the certified building [6]. This entails that databases of secondary documents must also be adequately controlled.

After quality checks, the control documents of each EPC assessor are archived [31]. Information contained in these records can be used to compile a list of common errors, modify calculation tools and methods from deduced systematic errors to improve expert accreditation schemes, reshape scope of work and monitor improvement over time. Control registers are used in this way in Portugal [24]. Despite communication around recurrent errors to provide clarification to energy experts and modifications to software, the Brussels region in Belgium did not achieve a radical enhancement to EPC quality [28]. Substantial data that monitors changes in EPC quality due to quality control improvements would be beneficial in assessing the positive or negative impact of a registry of common assessor errors.

EPC quality assurance checks can be done by the organizations responsible for the management of databases or they can be delegated to competent third parties as in Latvia [18]. Tirol state in Austria delegates specific quality control tasks for a maximum period of 3 years with the possibility of renewal. This entrustment can be revoked if duties are not performed satisfactorily [3].

The data suggests there is a trend to align training schemes and continuous professional development programs with ambitious national strategic plans such as the NZEB which will be applied in some MS to new buildings by 2021 such as in Belgium, Walloon region. In this way continuous improvement in quality assurance schemes is promoted. There is room for further study in terms of the monitoring of the quality of EPCs after the implementation of corrective measures to accreditation methods, database management and calculation procedures.

3.4 Penalties and Sanctions

Table 8 What penalties or sanctions are imposed on EPC assessors based on non-compliance found during EPC controls?

A/A	No. rep.	Country	Comment	Page
1.	21	n/a	A control web application is used to automatically screen all the EPCs submitted to the database by flagging inconsistent data or values and selecting a statistically representative number of EPCs to be humanly controlled. This random selection of EPCs ensures that each qualified expert gets regularly controlled. Control documents related to each assessor are archived. Sanctions can be imposed on assessors depending on the frequency, type and impact of errors exposed by control procedures.	17
2.	14	Belgium-Flanders	Sanctions can reach from re-issuance of the EPC to penalties from 250 to 5,000 EUR.	81
3.	14	Ireland	Each BER assessor can expect to receive at least one data review per year, at least one desk review or documentation and practice audit per year and additional auditing on a frequency reflecting the numbers of BER published, risk profiling, complaints or other indicators. Penalties include suspension or termination from registration on the basis of the seriousness of their impact on the integrity of the scheme.	72, 82
4.	33		Penalties include a fine of up to 5,000 €, or up to three months in prison, or both.	4
5.	33		The selection of EPCs for audit is carried out on both a targeted and random basis with due consideration of risks associated with the EPC assessment processes. SEAI randomly selects a statistically significant percentage of all the EPCs issued annually and subject those certificates to verification. Routine follow up audits identify if findings from previous audits have been adequately resolved. In addition, SEAI may, under its Quality Assurance System and Disciplinary Procedures, require EPC Assessors to participate in mentoring visits arranged by its auditors to facilitate further training.	12
6.	14	Latvia	A penalty point system is implemented. With 10 penalty points, the EPC assessor certificate is withdrawn. 5 points can be given only if deliberate violations of the laws and regulations in the field of the assessment of energy performance of buildings are made. In other cases, a maximum of 3 points can be given for errors in EPCs.	82
7.	14	The Netherlands	By repeated non-compliance, the EPC assessor can lose their license and be excluded from activities related to EPCs.	82

8.	14	Poland	Expulsion/disqualification is the only form of sanction available, except for minor errors made by EPC assessors.	82
9.	14	Germany	EPC issuers may receive fines based on non-compliance found during random EPC controls.	82
10.	14 28	France	The focus of control lies on EPC assessors. New EPC assessors are checked 4 times during the first year and 4 more times in the following 4 years. Following this first cycle of certification, experts are checked 4 times every 5 years. In 2013 this led to a check of about 11,600 EPCs. If several invalid EPCs have been issued, EPC assessor can be sanctioned with a fine or loss of certification.	70, 81, 10
11.	23	Croatia	Detailed quality control is carried out on EPCs that are randomly selected and/or based on complaints. An EPC is declared invalid only if it contains calculation results, input data or proposed measures with significant (more than 30%) deviation and if the result causes a change of one or more energy classes. Authorised persons shall be sanctioned by means of a fine or by annulment of authorisation in the case of 3 or more invalid EPCs.	11
12.	14	Estonia	Usually, EPC assessors are asked to correct their mistakes. In case this is not done, penalties of 64,000 EUR for companies or 6,400 EUR for individuals can be imposed.	82
13.	14	Slovenia	Penalties depend on the severity of the assessor's mistake. If necessary, the EPC assessor has to correct the EPC as well as issue and store a new one in the register.	83
14.	n/a	Romania	Proof of experience, e.g., number of EPCs issued, is required for a qualified expert's licence renewal [2].	19
15.	52	Portugal	There are monthly or annual targets of EPCs quality assessment numbers to reach, based on: typology (residential/non-residential), type of certificate (new/existing), energy experts covering and other criteria. The levels of quality control range from simple to detailed quality checks, automatic input validation and mandatory training of experts. In simple checks 5% to 6% of certificates are cross-referenced against documents uploaded by the expert. In detailed quality checks, 0.5% of certificates, the quality assessor consults with the energy expert and replicates the work performed by the expert. Irregularities may require re-issuing of certificates. A 5% error in the ratio of primary energy needs and its limit that causes a change of the energy label leads to a fine. The overall quality of the EPC in terms of contents, lack of recommendations and recurrent incorrect procedures or calculations is also checked. The technical mistakes and additional aspects identified must be registered in the central database, on the individual record of the quality assurance. These mistakes are evaluated to identify the best performing quality fluctuation error (QE) and the most common mistakes to provide clarification to energy	60, 61, 62

			experts, adapt training schemes, reshape scope of work and monitor improvement over time.	
16.	14		Penalties are in place, up to the (limited) suspension of the EPC assessor from the national list.	82
17.	n/a	Austria	The state government checks energy certificates on a random basis. In Tirol the state government entrusts specific quality control tasks to suitable bodies for a maximum of 3 years with possibility of renewal. The entrustment must be revoked if there are significant deficiencies in the performance of the control tasks or instructions from the state government are repeatedly or not completely followed [3].	23
18.	14	Greece	Identification of errors or faulty procedures is performed on the platform and automatic warning or written notification is sent to the assessor, the common mistakes/errors are not yet aggregated to be used in statistics or in future training. However, the issue is under consideration. Temporary license suspension (1-3 years) or permanently is foreseen, depending on the gravity of mistakes. Monetary fines ranging from 500 to 20,000€ are also foreseen depending on the impact of mistakes or fraud.	80, 82
19.	14	Cyprus	Initially, warnings are issued, if EPC data is found incorrect. If the mistakes are not corrected in time bound manner or repeated, then the license may be suspended. The time of suspension depends on the assessor's ability to prove that they can perform correct calculations.	81
20.	24		Samples for checking purposes are drawn from four categories: new residential buildings, existing residential buildings, new non-residential buildings and existing non-residential buildings. Ten (10) specific input parameters are checked, most notably U-values, efficiencies of heating and cooling systems, and window size. If the input parameters alter the energy class of the building, the EPC is cancelled. In that case the qualified expert has to issue a new, corrected EPC by a specific deadline. If the EPC is not issued then the building permit authority is notified in order to take measures within its jurisdiction, such as the cancellation of the building permit.	6
21.	14	Malta	EPC assessors are obligated to rectify incorrect EPCs in stipulated time, pending which their certification may be suspended.	82
22.	14	Denmark	Qualified energy consultants must attend mandatory courses and meetings in accordance with the Danish Energy Agency's decision. All energy consultants must pass a refresher course no later than every 3 years. BedreBolig is a training course on deep renovation that is offered regularly. In case of substantial errors, EPC assessors may receive a warning being displayed in the online register of experts. As a last resort, the EPC assessor can lose their license.	62, 67, 68, 81
23.	14	Finland	Criminal liability provisions can be applied for EPC assessors. [2020]	82

24.	28		Enforcement measures are administrative, not penal, and include requests, warnings, orders, conditional fines, and suspension of the qualified expert. [2016]	13
25.	14	Italy	Penalties in the regions range from 300 € to a maximum of 10,000 €, according to the breach of the rules. Penal consequences may be awarded in case of fraud.	82
26.	14 16	Hungary	2.5% of EPCs are checked, of which 0.5% (i.e., 20% of the total sample size) should have total inspection with on-site visit. If faults are detected, assessors are required to correct them. When the energy class is determined wrongly and the difference is 2 classes or more, the assessor license is withdrawn for 3 years.	19, 72, 39
27.	14	Sweden	If the EPC assessor fails in its independence or has issued incorrect declarations, the certification body may be notified which may withdraw the certification.	83

Data Analysis of Table 8

Where quality assurance measures result in disciplinary action for the EPC assessor, it often depends on the severity of the error. Error type, frequency and impact on the integrity of the EPC scheme can be used as criteria to categorize levels of severity. Enforcement measures may include requests, cautions, conditional fines, suspension and expulsion of the assessor [21]. In the disciplinary procedures of the BER in Ireland, EPC assessors must take part in arranged mentoring visits that provide an opportunity for further training [34]. Errors that are easily reconciled are generally regarded as minor and may require re-issuance of the EPC, or a monetary fine.

Cyprus, Denmark and Estonia, for example, give warnings as an initial measure with conditions to correct errors in a time bound manner and non-repetition of mistakes. Corrections not made in the stipulated time may result in revocation of building permits and further disciplinary action. Denmark has made rigorous amendments to its quality control plan in how consultants who commit serious or repeat errors are supervised and quarantined, adding requirements for re-examination [35]. An EPC assessor can lose authority to certify buildings if they produce 3 or more invalid EPCs in Croatia [23]. If several invalid EPCs have been issued, the EPC assessor can be sanctioned with a fine or loss of certification in France [10].

Some MSs take penal disciplinary action against assessors where fraud is discovered. The most severe penalties in Ireland involve payment of up to €5,000 and/or three months imprisonment [34]. Earlier reports site that enforcement measures were administrative and not penal in Finland [21], however, the 2020 report indicates the applicability of criminal liability to assessors [5]. Penal consequences are reserved for fraudulent conduct in Italy [5]. Penalty point systems are in place in Greece and Latvia, with Greece using a specially formulated algorithm to calculate points. The algorithm is based on a tolerance of 5% of the building's total primary energy consumption or a change of more than 1 energy class [24]. 5 points are imposed against assessors in Latvia who deliberately violate the laws and regulations of their profession, 10 points result in licence withdrawal [5].

After licence withdrawal in the Netherlands, the assessor is further banned from participation in any activities related to EPCs. In Poland, licence withdrawal is the only disciplinary action imposed for non-compliance, except for minor errors [5]. In Portugal, temporary removal of the assessor from the national list is part of disciplinary action [24]. A deviation of 2 energy classes or more in a controlled EPC results in a 3year licence suspension for assessors in Hungary [26]. Such penalties that exclude assessors from certifying buildings for extended periods of time may have detrimental effects to the quality of work produced when a licence to practice is restored even after re-assessment. The length of licence suspension in Cyprus is determined by the assessor's ability to prove they are capable of performing correct calculations [5]. An analysis into EPC quality when the weight of penalties is determined by the assessors proved effort to successfully comply with all the regulations of the EPC scheme and not solely on pre-established penalties may allow MSs to make adjustments for penalty schemes with better outcomes.

3.5 Link to other Databases and Policies

Table 9 What data is included in EPC databases of MSs and how are indicators used to create linkages to other databases and inform policy?

A/A	No. rep.	Country	Comment	Page
1.	52	Belgium-Flanders	There is a central EPB (EPC for new buildings) database and a central EPC (EPC for building stock) database. In general, the data is being used to evaluate the building stock, the default values in the EPC and the impact on the regulation and subsidy programmes.	19, 20
2.	16		The EPC database is also used for the automatic attribution of subsidies and discounts for energy efficient buildings.	35
3.	01	Austria	Regional EPC databases are available; Upper Austria, Lower Austria and Tirol do not have their own EPC databases, Statistiks Austria database is used. The EPC databases also contain information from on-site home energy consultation and energy accounting. The EPC database is linked to relevant data from the address, building and apartment register (AGWR). Zeus is the EPC registry for Styria, Carinthia, Salzburg and Burgenland. ZEUS offers an energy accounting module for manual recording of energy consumption and a Smart Meter API for the daily delivery of meter data. In this way, private individuals, municipalities	36

			and property developers can record and evaluate their energy consumption data.	
4.	52		The Austrian Energy Agency combines data from several existing databases to monitor actual refurbishments.	45
5.	14		Databases are linked to the building standard, the Klimaaktiv standard, which meets NZEB requirements.	93
6.	52		Many research projects, infrastructure planning, subsidy programmes as well as statistical evaluations have been undertaken using the information of the EPC database system. The data is uploaded from energy experts.	19
7.	52	Greece	A central, national EPC database is used on a web-based platform. A statistical analysis of these EPCs takes place approximately every 12 months, the results of which are available to the public. The information provided – such as yearly distribution of EPCs, number of EPCs distributed in decades, distribution of EPCs according to the type of building and energy consumption (kWh/m^2) according to the climatic zone and type of building. The recommendations of the EPCs regarding retrofitting activities are used to partially cover the needs of article 4 of the Energy Efficiency Directive 2012/27/EU that requires member states to establish a long-term strategy for renovation of the building stock - and will be further elaborated in the next NEEAP. The EPC database is being used in the development of the new "National Strategic Reference Framework" (ESPA), a programme that subsidises, among others, many energy efficiency related projects. Data from EPC is linked to the Tax Authority platform and other databases. For example, it is a requirement to show the EPC in the national assets website for those properties that are rented. The data from EPCs has been extensively used in the database of the "Energy Efficiency of Household Buildings" programme. EPC data will be part of the "Electronic Identity of Buildings" website and database that are being developed. They are also used in the programme of the Technical Chamber of Greece regarding compensation for illegal construction in Greece. Currently CRES is looking at further ways to exploit the EPC data by exploring the calculated energy consumption of the building compared to the real energy consumption using data from energy bills.	20, 21, 22, 23
8.	14		Updates of EPCs are generated when the legislation and regulations for the EPC scheme (e.g. the labelling scale) are changed automatically online with the help of a central database. This is useful for comparability and improving the usefulness of EPCs in building markets.	57
9.	52	Italy	EPCs are registered on 12 regional databases. EPCs are directly uploaded by energy experts using the regional software. A national EPC information system – gathering data from regional registers – is being shaped.	23
10.	52		The Italian National Agency for New Technologies, Energy and Sustainable Economic Development develops a model methodology for harmonising EPC data analysis and monitoring building retrofit.	45

11.	52		The transfer of good practices about the different EPC databases systems between regions and dialogue with the central government is well developed. Some regions are starting using the database for policy development and evaluation of energy efficiency of the building stock.	26
12.	34		Better knowledge of the technical building system is achieved through a link between EPC databases and the heating and air-conditioning (HAC) inspection database. An EPC is valid only if the "HAC log-book" from regular inspections is attached.	12
13.	34		Interoperability with the existing regional database systems is guaranteed, taking into account specificities of regional EPC and technical building systems inspection databases. Compatibility with the building cadastre and other databases (census, national renovation incentives) is being studied.	19
14.	52	Italy - Lombardy	Many municipalities in Lombardy have been able to estimate potential impact of actions on buildings stock in their territories by relying also on EPC data, including public buildings.	51
15.	52		Within the Request2Action project, Lombardy and Sustainable Economic Development Agency will develop a model methodology for monitoring building retrofit by analysing and integrating the CENED EPC database with other significant data. Feasibility of collecting evidence from the regional EPC database CENED in a centralised information system will be analysed and validated within the same pilot project.	52
16.	01	Denmark	EPCs are registered in a central database.	36
17.	52		The EU-funded EPISCOPE pilot project of the municipality of Sønderborg in Denmark aims to examine how the energy savings mentioned in EPCs issued before and after refurbishment activities can be validated against energy consumption measurements	64
18.	26		Analyses of the EPC database have been used as part of the foundation for the Danish strategy for energy performance upgrading of the existing building stock. A new analysis has just been conducted based on the available data showing that data of the existing building stock and energy conditions can be used for many useful analyses and is essential to form future national energy strategies. The purpose was to analyse the extent to which it is necessary to include RES in the energy performance calculation, in order to compensate for the fact that some buildings may have higher energy needs than the average building due to architectural requirements or limitations from local plans. How and to what extent RES are used as a buffer in such cases is investigated.	14
19.	01	Ireland	EPCs are stored in a central database.	36
20.	52		The information available in the database is being used for strategic energy planning; EPC data showing the age and number of buildings in a district in Dublin has been geo-coded and aggregated to small areas (50-200 dwellings) in the Episcope Mapping project.	49
21.	14		The SEAI homepage includes the EPC database, detailed information on how to get an EPC, building renovation, databases, links to installers, grants etc.	100

22.	33		The national database of EPC is essential for collecting statistical insights in the energy performance of the existing building stock. The database is used to inform renovation strategies and to enable stakeholders in the supply chain to better understand the market for their products.	154
23.	01	Poland	EPCs are stored in a central electronic database.	36
24.	14 16	Romania	A central EPC register exists. The energy expert is required to transmit an electronic version of the EPC to the central database. Since there is no standardised template defined for the EPC, there is a great diversity in the formats received.	91, 42
25.	16	Lithuania	All EPCs are collected in the national central database and register.	40
26.	14		All EPC data are transferred to the Real Property Register and Cadastre of Lithuania.	93
27.	14	Slovenia	The EPC register should be connected with cadastre database as well with spatial online portal, enabling wider data accessibility and transparency.	93
28.	27	Estonia	Estonia has one central public building register, named “Register of Construction Works,” through which experts issue EPCs. All the EPCs issued, including related data, calculations and other information available, are compiled into this database,	8
29.	14 27		An Energy efficient upgrade of housing scheme is strongly linked to the EPC system. For example, a 15% grant can be applied when EPC Class E (minor renovation) will be achieved after the completion of renovation works. Grant applications and calculated energy performance certificates show that over 90% of those renovations should meet the energy efficiency requirements of new apartment buildings. The execution of the renovation work grant schemes in Estonia has shown that extensive integrated renovation is possible in situations in which buildings are managed by apartment associations, where apartment owners have to agree on the extent and budget of the renovation work. New innovative solutions can be implemented and it seems that apartment owners are willing to invest in order to renovate their apartment and building.	98 12
30.	14	Luxembourg	The EPC database is linked with Lëtzebuerger Nohaltegkeets certification (LENOZ), a voluntary sustainability assessment of residential buildings adapted to Luxembourg conditions.	93
31.	14	Spain	The 17 regional governments control and manage a registry of EPCs. EPC data includes Primary energy consumption covered by RES (kWh/m^2/yr).	21
32.	14		Data from EPC registries is used to match the energy certification before and after performing the action on the building envelope. The demand decrease for heating and cooling must be at least 30% to obtain public assistance (State Urban Regeneration and Renovation Plan 2013-2017). Green mortgage is a service that aims to apply interest rates linked to several parameters, one of which is the energy rating. The interest rates are lower the more efficient the building is. It applies to the acquisition / construction / renovation of residential buildings.	25

33.	52	Portugal	EPCs are stored in a central database that is connected to the national census database and GIS online database.	63
34.	52		The evaluation of data from EPCs has been used to verify the effectiveness of some NEEAP measures such as: • Verification of the Energy Efficiency Fund (part of NEEAP) measures implemented for solar thermal installations, windows, insulation (an energy certificate is issued before and after the retrofit works is requested). • To measure energy performance of public buildings and improvement measures (ECO-AP Project). • Monitoring of issued Energy Certificates; tools for energy efficiency through the improvement measures. The documentation and implementation of retrofit activities for other policy making purposes have been done based on the following approaches: • The EPC database was used to define the baseline of building performance. This baseline was used to establish energy policies and strategies by the Ministry of Environment Urban Planning and Energy. The information from the EPC database helped the government in terms of designing funding schemes for building refurbishment. • This baseline was also used as instrument for implementation of some financing instruments, such as National Strategic Reference Framework, concerning energy efficiency investments. • The data was also used to map energy efficiency measures based on target typologies and measures, costs and savings. The information stored in the EPC database is connected to other databases or sources of official or market information including: • Housing Energy Efficiency used the EPC data together with the data from the National Statistics Census to establish a picture of the national building stock and its distribution, providing the basis for studies of energy efficiency measures' impact (energetic, economic and environmental). • Statistics institutes compare the value of the house with the associated energy class based on unique building normalized ID. • Electricity utility is cross checked against the certificated building/dwelling's location with the energy meters locations through associating with unique building ID. • Building registry and notaries have started to use the EPC database systems. Municipalities are able to base their retrofit strategies and priority intervention areas on evidence obtained by having access to the EPC database. They use the database to calculate the tax exemption for Class	28, 29, 30

			A+/A. The real estate market association produces a market study catalogue and a Web service for label advertising with credible data. Statistics institutes have used the data to verify the impact of the energy label and its impact on the sales /rent market prices.	
35.	52		The Portuguese Energy Agency carries out a market research to identify and test different retrofit monitoring methods (website, e-mails, letters, phone, incentive gifts).	45
36.	52	Slovakia	There is a national EPC database system where qualified experts upload EPCs. The data collected is partly used for NEEAP, but is also used in combination with information from other sources, e.g., the monitoring system for efficiency in energy use and serves as basis for decisions. The combination of EPC data with other instruments is important, for example, in energy audits of public buildings by SIEA. It helps to decide which of those buildings should be refurbished earlier and which at later stages according to their energy consumption.	30, 31
37.	52	The Netherlands	Data is uploaded by energy experts to a national digital EPC database system.	31
38.	52		Every quarter, researchers evaluate the information on the EPC database for indicators on the energy label performance within the owner-occupied property market, such as the share of transactions that took place with an energy label and the impact of a green energy label on selling price.	57
39.	52		The Dutch Energy Label Atlas informs home owners on the energy efficiency of their dwelling and provides a list of potential contractors to realise improvements and necessary information on relevant subsidies. The information is based on the registered data in the energy label database. For the dwellings without a registered energy label, an estimated energy label is shown based on the known characteristics like building year and floor area.	58
40.	52		Data is also presented on the commercial House broker website Funda, which shows the full range of residential buildings for sale. Every house for sale on the website also shows the information of the energy label. Funda can provide this information by using the generic web service, which provides the information from the energy label database. Besides location, for example, specific energy class can also be used to search for a house.	59
41.	52		The Netherlands Enterprise Agency carries out a study for comparing the calculated energy demand of the EPC and the real energy consumption.	45
42.	5		The EPC database, in conjunction with sales transaction data from the database of the Dutch Association of Realtors, was used to show that properties with different ratings (A-C compared to D-G) increase sale price by 3.6% and affect selling time.	32
43.	52	United Kingdom	There are 3 EPC registries for England and Wales, Northern Ireland and Scotland. The EPC databases for England/Wales and Scotland also store records of Green Deal assessments with adjusted asset rating to reflect the lifestyle and actual number of people in the home.	33

44.	12		The EPC database is being used for a research project on the national stock of air-conditioning systems where 500 inspection reports and EPCs for the same buildings are analysed.	8
45.	52	Scotland	The Scottish Government funds the Energy Saving Trust, EST, to provide a data service to every local authority in Scotland through the Home Energy Efficiency Database version 3, HEED3, and Home Analytics. HEED3 contains datasets on aggregated EPC data, HEED; a record of installations carried out under energy supplier-funded energy efficiency programmes and Home Energy Check (HEC) records; a record of home energy self-assessment forms completed by visitors of the EST website. Each of these datasets is made available to the local authority to view at census output area level; an administrative level corresponding to approximately 125 homes. The data is made available through a web-portal so that local authorities can look at all three datasets blended together or just one of the datasets. HEED3 provides data exclusively to local authorities on the number of homes in the sub-districts in their area which have certain energy-related features using GIS. Using a combination of indicators from these datasets, EST has also developed a dedicated fuel poverty indicator for local authorities showing the likelihood of fuel poverty in each area. EST has also developed the Home Analytics address-level model of home energy efficiency features. This creates a modelled picture of each Scottish home's likelihood to have key energy efficiency features based on the following datasets: • Aggregated data from EPCs about homes in the same area. • HEED data • HEC data • Scotia Gas records - which indicate which homes are off the gas network (and therefore have to use more expensive heating fuels) • Scottish House Condition Survey – the national housing survey • Data on the installation of boilers and windows, for the purposes of compliance with building standards and safety regulations.	55, 56 57
46.	52	Poland	It is obligatory for all EPCs to be uploaded to the central database.	43
47.	14		The potential of using EPCs in financial support systems instead of energy audits for single family houses has been noticed.	98
48.	52	France	The database operator, ADEME, uses the national EPC database as a source of statistical information in the implementation of public policies in the areas of environment, energy and sustainable development. It operates under joint supervision of the Ministry of Ecology, Sustainable Development and Energy and the Ministry of National Education, Higher Education and Research. It therefore is able to provide significant input to the policy making process on the highest levels of government. Valuable statistical information collected in the EPC databases feeds into at least four major periodical ADEME publications: The Chiffres Clés,	54

			the BBC Observatoire, the OPEN campaign and the barometer of 10,000 households. • The Chiffres Clés, or Key Figures, comprises results of various studies realized following the initiative of ADEME. The main purpose of this publication is to annually measure trends and developments in the energy use in the building environment. • The BBC Observatory has as its purpose to build on and strengthen the effect of efficient operations in the energy sector, promote best practices and provide input to the development and evaluation of public policies. • OPEN or Permanent Observatory of energy improved housing, is a techno-economic tool used to describe the state of the market for energy renovation of housing. Since its creation in 2006, results are produced that include an assessment of energy policies in place for home renovation; OPEN performs an assessment of housing renovated annually and reports on the impact of incentive schemes: tax credit, eco-interest loan, Booklet for Sustainable Development (LDD), Energy Performance Certificates, reduced VAT etc. • The barometer of 10,000 households was launched for the first time by ADEME in 1986 and since then this survey is conducted annually and has two main objectives. The first is to measure the level of awareness in energy efficiency of French households and monitor their behaviour. The second is to assess the effect of energy policies in the housing sector through the examination of energy efficiency improvements.	
49.	14	Latvia	Asset rating EPCs are mandatory before and after renovation for financial incentive/financing schemes. Usually, the length of mandatory monitoring period is 5 years.	98
50.	16		With an aim to digitalize the documentation of the entire construction process, Latvia has introduced the BIS that also offer public access to the Register of Independent Experts in the Field of Energy Performance of Buildings and the Register of Certificates of Energy Performance of Buildings.	39
51.	16		The EPC has a mandatory annex with calculation of energy efficiency measures.	16
52.	5	Cyprus	There is a central register for all EPCs issued. EPC data includes primary energy consumption covered by RES (kWh/m^2/yr).	2
53.	14	Sweden	The energy certificate includes information about radon content if it has been measured for a building and if ventilation control is approved if the building is subject to mandatory ventilation control. Regulations for normalisation of energy performance to a standard year and standard users BEN 3, require that values are displayed as a mix of metered and calculated data.	27
54.	14	Croatia	The electronic central EPC database includes information on a simple payback period.	44

55.	14	Bulgaria	There is a National Energy Efficiency Information System for certified buildings.	91
56.	14	Germany	No central database exists.	91
57.	16	Hungary	Hungary uses a national electronic registration system for its EPC database.	38
58.	28	Finland	All EPCs are produced and electronically signed through the national database.	13
59.	25	Czech Republic	The energy specialist is obliged to register all issued EPCs in ENEX, the national electronic database maintained by the Ministry. In case the EPC is processed by an expert from a different Member State, the building owner is obliged to inform and present the licence of the expert to the Ministry.	8
60.	52	n/a	The European Energy Performance of Properties Analysis proposes a new database that would be a repository of all EPCs produced across Europe, building first from openly available databases. The tool would provide: • An index of all available EPCs in Europe. • Measurement and analysis of the energy performance of property portfolios. • A comparative tool for cities and regions to benchmark the efficiency of their building stock. • A multi-lingual platform that will be accessible to all European nations. • Means to identify retrofit opportunities across Europe. • A database showing best practice renovation opportunities based on real projects.	45
61.	52	n/a	The EPC databases proved to be useful for transposition of the EU legislation (EPBD and EED) to the national legislation. In all Member States, the database (when available) is used to support implementation of the Article 18 of EPBD on the independent control system of the energy performance certificates.	63
62.	52	n/a	The Energy Efficiency Performance of Properties Analysis is an initiative launched to create a voluntary pan-European EPC database. Its primary goal is to support real-estate managers in targeting inefficient properties and benchmark the energy efficiency of their building.	63
63.	5	n/a	Information from EPC databases is used to study the effect of improved energy efficiency on a property's value, whether this is affected by the age of the rating and whether purchasers who do not know the exact rating factor in energy efficiency into their price in order to develop an econometric model.	54
64.	14	n/a	One-stop-shops for deep renovation linked to EPCs may be available on national, regional or local level. In many countries one-stop-shops for building renovation exist, however, only some of them target "deep renovation." A comprehensive information platform at national level is available in Ireland and the UK. One-stop-shops for deep renovation linked to EPCs include administrative support, energy advice, financial and supply-side information to building owners with active marketing of	99

			deep renovation and EPC, and coordinating supply-side actors and supporting their marketing, training and quality.	
65.	15	n/a	A multi-criteria assessment method was proposed and developed as the underlying methodology for calculating the smart readiness indicator. The methodology is flexible with regard to the choice of assessment method, e.g., through on site-inspections by external SRI assessors, self-assessment by building owners, a blend of checklists and self-reporting by intelligent equipment, etc. EPC data could potentially be used to inform aspects of the SRI calculation. Focusing on energy-related impact criteria, there is strong support for using existing energy performance certificates to derive weighting factors. This approach solves the need to differentiate for different climate zones and different building types, as the relative importance of each domain would already be reflected in the EPC energy balance. The study team added that it could only be applied to buildings that already have an EPC or which undergo an EPC and SRI assessment at the same time. It is currently envisioned that the SRI is applicable to all buildings. The study team therefore suggests a mixed approach, where default weighting factors are defined using statistical data from the national building stock, but EPC weightings may/must be used when available.	5, 111

Data Analysis of Table 9

Most MSs have a national EPC database and those with regional databases are making efforts to combine them into a central database. This trend has enabled countries, previously without EP registries, to develop them following best practice examples from MSs with experience. Poland used this strategy to develop its national database [24]. Countries that allow state governments to develop independent EPC schemes, may in turn have state-controlled EPC databases. In Belgium, Flanders, EPCs for new buildings are stored in a central EPB database and a separate, central EPC database exists for the rest of the building stock. The EPC registry is used to evaluate the building stock in the region [24]. Flanders' separation of EPC databases for new and existing buildings could imply that analyses of EPC data for the two building types is made easier. Regional databases in Austria are used to store EPCs from several regions. The ZEUS database differs from the Statistiks Austria database in that it offers an energy accounting module for manual recording of energy consumption and a Smart Meter API for the daily delivery of meter data to municipalities, property developers and individuals [2]. Regional databases may be bound by different regulations related to data access according to state laws and thus give rise to a variance in information available on the databases. A varied range of access to energy consumption data that can influence occupant behaviour and energy efficient renovations could make it difficult to compare the national building stock against the EPC scheme alone. The Austrian Energy agency organizes data from various EPC registries in order to monitor actual refurbishments [24].

Italy is developing an EPC information system combining the country's 12 regional databases. Additionally, the feasibility of collecting evidence from a regional database in a centralized information system is also being examined using Lombardy's registry. A model methodology is used to harmonize EPC data analysis and monitor building renovations of the 12 databases. An enabling factor for coordination between the regional databases is well established dialogue with the central government and transfer of successful practices between regions. A common regulation between all 12 databases is linkage with the heating and air-conditioning inspection database. The link is used to promote a more comprehensive understanding of the technical building system. Compatibility between databases and the building cadastre, census and national renovation incentives registries is being studied for similar interoperability. The Lombardy region is undertaking a project to develop a model methodology to monitor building renovations by linking its EPC registry with other significant data sources such as tax databases [6].

In Estonia, EPCs are issued through an existing public building database, the Register of Construction Works [9]. The use of an EPC database lacking a standard template results in energy experts uploading EPCs in various formats, as is the case in Romania's central EPC register [26]. This may affect comparability of the building stock without recourse to additional resources. Occupants of buildings without EPCs may still benefit from energy efficiency improvement recommendations through the Dutch Energy Label Atlas. A projected energy label is assigned to the building based on EPC characteristics from similar neighbouring buildings or characteristics particular to the building such as building year [24]. EPCs issued after renovations are not distinguished in most databases, as such in Belgium, Walloon, therefore, it cannot be ascertained how many EPCs are made for renovated buildings [31]. The inclusion of an input parameter in the database describing renovation works may be advantageous for monitoring building stock.

The facilitation of cross comparability between EPCs of different MSs is a driving force for the development of a voluntary pan-European database. The need for an openly accessible EPC registry of all EPCs in Europe is being addressed by the European Energy Performance of Properties Analysis. The proposed database would provide a comparative tool for regions to benchmark the efficiency of their building stock and show renovation strategies based on real projects [24]. EPCs can also be issued by energy experts from other MSs. The Czech Republic makes allowances for this by requiring the building owner to submit the expert's EPC licence to relevant authorities [17].

Information from EPC databases are generally used as follows:

Informing policy:

- Datasets on aggregated EPC data are used to develop a fuel poverty indicator for local authorities in Scotland showing the likelihood of fuel poverty at census output area level; an administrative level corresponding to approximately 125 houses [24].

Informing renovation strategies (in compliance with EED 2012/27/EU) [24]

- Public funded grant schemes may use EPC data such as change of class and heating and cooling demand due to renovation works to approve applications. The baseline of building performance is defined data in the EPC registry [24]. EPC data used in Estonia's Energy Efficient Upgrade of Housing Scheme has revealed that extensive integrated renovation can be achieved, for example, in cases where apartment associations and apartment owners decide on the magnitude and budget of the retrofit measures. Ultimately, it was proved that innovative solutions can be applied and owners are prepared to invest in apartments and building renovations [9]. Similar analyses by other MSs would allow comparisons to be made in order to validate findings even further.
- Poland has observed the potential of employing EPCs in financial support systems instead of energy audits for single family houses [5].
- Data from the EPC registry allows supply chain-stakeholders to better understand the building market in Ireland [34].
- Mapping energy efficiency based on building typologies, costs and savings can assist in allocating priority schedule for retrofit strategies [24].
- One-stop-shops for deep renovation linked to EPCs provide supply-side information to building owners with active marketing of deep renovation and coordination with supply-side stakeholder's [5].

Real estate market and financing instruments:

- Interest rates, under the Green mortgage service in Spain, are lower the more energy efficient the building is. The lower interest rates apply to residential building's construction, acquisition and renovation [5].
- Real estate advertisements contain credible EPC data obtained from databases. The impact of energy labels are used to verify transaction prices of property. The Dutch Association of

Realtors recorded results that show that properties with an energy rating A-C had an increase in sale price by 3.6% and a faster selling time than properties with an energy rating of D-G [24].

- An econometric model shows the correlation between property value and age of energy rating, and whether buyers factor in energy efficiency into their price even when they are unaware of the exact rating [24].

EU-Funded projects:

- Municipal pilot Episcope projects examining and validating energy consumption before and after refurbishment activities as in Denmark [24].
- Episcope Mapping project in Ireland; strategic energy planning using 50-200 geo-coded dwellings aggregated to small areas [24].

Innovations:

- EPC data has the potential to inform SRI calculation in energy-related impact criteria for all buildings. Weighting factors for different climate zones and building types can be derived from existing EPCs and default weighting factors from statistical data [11].

3.6 Database Access

Table 10 How is access to databases by various stakeholders managed whilst observing GDPR and promoting EPC use?

A/A	No. rep.	Country	Comment	Page
1.	21	Belgium-Walloon	For certification of apartments, if systems are collective (e.g., heating or cooling system, centralised ventilation, and/or RES), an assessor performs an initial report regarding the systems, and data are collected and inputted into a database in order for certificates for each connected apartment to be issued.	14
2.	21		In the EPC registry it is not possible to know how many EPCs have been issued for renovated buildings, since it is not an input data necessary for completing an EPC.	16
3.	52	Belgium-Flanders	The raw data is not publicly available, but the host generates statistics and trends for research purposes or general information. Only qualified experts can view their own files/EPCs due to privacy issues.	19
4.	14	Bulgaria	There is a National Energy Efficiency Information System for certified buildings that is publicly available.	91

5.	14	Czech Republic	There is no public access to the central EPC register.	91
6.	14	Denmark	All EPCs are registered in a central database that is publicly available on the website.	91
7.	14	Estonia	Public database (protecting privacy) of EPC ratings is available.	91
8.	14	Finland	The database is not accessible by the public.	91
9.	14	France	The database has limited access. Professionals (in charge of the certifications, accredited auditors as well as public organizations) have a privileged access to this database. For the general public, it allows either to search for a specific DPE using a reference number or to obtain statistics on EPCs per type of building, construction year or type of heaters.	91
10.	14	Latvia	Public database (protecting privacy) of EPC ratings is available.	91
11.	14	Lithuania	A public EPC register is available complete with building address, energy class, energy consumption etc.	91
12.	16		The database of EPCs can be used only by responsible specialists. The central register is published on www.spsc.lt and can be used by related institutions, specialists and private persons.	40
13.	14	Malta	Public database of EPC ratings is not available. One can check the validity of the EPC by entering the EPC number.	91
14.	14	Romania	A central register exists; however, no public access is available.	91
15.	14	Slovenia	The serial number of EPC, building cadastre identification code, address of the building, cadastral municipality and parcel number, name of EPC assessor and date of issuance is publicly available.	91
16.	14	Spain	There is no public access to the regional registries of EPCs.	91
17.	14	Sweden	Public database (protecting privacy) of EPC ratings is available.	91
19.	52	Austria	The information is available for the municipalities of the province as well as building facility managers. Parts of the information (for example their own EPCs) can be made available for private citizens.	19
20.	[2]		The access to ZEUS is limited to the following groups: EPC calculator, planner, developer, affected departments of the regional governments and persons who do statistical analyses of the data from EPC.	1001
21.	52	Greece	Information can be accessed, if a formal request is made to the particular ministry department (energy audits body), explaining the reasons for seeking access to these data. If the request is accepted the data are provided, but information related to personal data is not released. Energy auditors can only access their own certificates.	21, 42
22.			A monthly public report report shows: • The distribution of EPCs according to year of production.	22

			- The distribution of EPCs according to decade of construction of the building. - The distribution of EPCs according to the type of building. - The distribution of EPCs according the geographical area of the building. - The energy category of the buildings according to the geographical area, age, type of building. - The energy consumption (kWh/m2) according the climatic zone and type of building. - The percentage of energy conservation potential according to the type of building and the climatic zone. The reports only make graphs and figures publicly available rather than data files.	
23.	14		The database is not publicly accessible. Access is limited to the Ministry and the operator of the platform (CRES). It is also accessible to the assessor/issuer of the EPC as well as to the owner of the EPC, or any other physical person but only with the registration number and security number of the certificate and only for the information included in the 1st page (Energy class, administrative data of the building). Aggregated/anonymised data can be requested by institutions for research and analysis purposes and are provided by the Ministry's assigned staff.	91
24.	52	Portugal	Portuguese Energy Agency, ADENE, has direct access to the raw data and provides monthly technical, generic and specific data for different Portuguese entities on statistics, benchmarking and financial reports. There is also information sharing with municipalities on building permits and market value in terms of energy label and the size (m²) of the property. The real estate sector promotes the value of the buildings' energy class in the selling or renting market and monitors market activities by counting the issued EPCs. In this case, ADENE provides access to the database via a website that displays the information stored on EPC by using EPC unique ID number the entities get real time information. The real estate market association produces a market study catalogue and a Web service for label advertising with credible data. Database evaluation and improvement possibilities have been made available directly or indirectly for market actors such as trades people including large communication campaigns, with key stakeholders involved.	28, 29
25.	14		A searchable public database exists.	91
26.	16		Having a single EPC ID number that not only identifies the EPC (with around 150 variables per certificate) but also the building in question, allows for several public and private bodies that are not necessarily familiar with technical data to gain easy access to the relevant information.	41

27.	52	Slovakia	Certified experts have full access to the raw data (login necessary). General information such as the number of EPCs per region and per energy class is publicly available. The system also allows a search for building types (year, category, purpose and energy class) without requiring registration.	30
28.	52	The Netherlands	The data on the EPC is publicly available. 1. On an individual basis the EPC of every residential building is available on the EPC website by entering an individual address or zip code: http://www.zoekuwenergielabel.nl/ 2. Certifying bodies can obtain the information from the database for the purpose of quality control of the energy label assessors. 3. The energy label is part of the rental system for social housing, regulated by the housing regulation. Individual tenants can check their energy label on the EPC website. 4. For scientific research the information from the database is available by using the generic web service, which provides all registered energy labels in one file, based on zip code and house number. 5. Companies and organisations can make use of the information from the database by using the generic web service, which provides all registered energy labels in one batch, based on zip code and house number. 6. Several subsidy schemes and soft loans are based on improving the energy label of the building. These improvements can be checked in the energy label database. 7. Further the database is used for policy development and policy evaluation on energy efficiency of the building stock. The government has started a new campaign and has started to issue a provisional EPC for all buildings and send it to every home owner since the beginning of 2015. This provisional EPC is based on the information available by the characteristics of the national stock. This campaign is aiming to increase the energy improvement of the building stock.	32
29.	14		The letters of energy labels for buildings are registered on www.ep-online.nl and are retrievable per address on that site. The energy labels themselves, including the underlying information to those label letters and the recommendations of energy-saving measures, in principle, are only available to building owners.	91
30.	52	United Kingdom: England and Wales	Copies of individual EPCs are made available on a certificate-by-certificate basis through a website on a fully public basis. Bulk EPC data is also made available to certain classes of organisation in the public and private sector for certain uses, on payment of an administration fee. There have been concerns raised by stakeholders about the cost of data and the CSV/excel data format which can be barriers to organisations accessing and non-specialist organisations such as local authorities processing the data. However, to protect privacy, holders of an EPC may opt-out of their certificate (or data from their certificate) being made publicly available. Certificates can be searched for on the	34

			basis of the property address or through the unique reference number (URN) on each certificate. The certificate is downloadable as a PDF. EPC data can be made available for the planning, targeting and promotion of energy efficiency programmes, for research and for policy making purposes. The data can be made available to central government departments, NGOs, local authorities and academics for these purposes. It can also be made available to private companies who are identified as a “Green Deal relevant person” or who are involved in the delivery of micro-generation (PV or renewable heat technologies) under government programmes.	
31.	52	United Kingdom: Scotland	The access to the database is regulated. Individual EPCs can be accessed by a report reference number. Data can also be made available to “authorised recipients” delivering energy efficiency and carbon reduction initiatives on behalf of the Scottish and UK Governments for statistics, strategic and infrastructural planning, subsidies and trend developments.	35
32.	52	Italy: Lombardy	The database provides open data access. Trade associations are developing a GIS to boost a wider use of the database from their members. EPC owner’s data is protected for privacy reasons. Analogous information on energy performance of nearly zero-energy buildings can be specifically called up from the database and displayed.	49
33.	14		All EPC data is published in a spread sheet that is openly available online.	91
34.	16	Italy	From 2017, regional EPC data are sent to the SIAPE; a harmonized national EPC information system. SIAPE is a multi-tier web portal that allows regions to access and analyse their own raw data, and other users (citizens, trades, local authorities) to retrieve aggregated data. The SIAPE will provide the national statistics on the number of EPCs and related controls, average costs for issuing EPCs for different typologies, EPC distribution by energy class and NZEB, and other relevant energy performance data contained in the EPCs. The aim is to facilitate policy making on sustainable building at national and regional levels.	39
35.	52	Poland	A database of the publicly available central register shows, on the basis of issued EPCs in Poland, information about these buildings; among other things, the parameters of the energy performance, the share of RES, the value of CO2 emissions. However, this is only for buildings with floor area exceeding $250m^2$ occupied by the judicial authorities, the prosecutor's office and public authorities that serve the public directly.	43
36.	52	Ireland	The SEAI launched a national BER research tool; an open platform that gives access to all data from the EPC database (excluding personal data like the address). This tool is designed primarily for researchers who can generate and download the sample of raw data per location, age band, energy class, rating type etc. The EPC and labelling information of the buildings do not fall under data privacy law of Ireland. Individuals can	47, 48

			look up an EPC online via the register website, comparing the energy performance of their property with that of similar buildings. Authorised organizations, EPC assessors, real estate agents and building owners have access to EPC bulk data or extracts from the EPC register. The statistical data is updated every night and can be seen on the EPC database website.	
37.	5	Cyprus	Access to EPC data is restricted to energy inspectors under personal data protection law. Personal data such as exact address and identification of the qualified expert is restricted.	133
38.	14	Hungary	Address of a building and energy category from the EPC database is available publicly online; however, detailed information and calculations from the system are not available.	19
39.	32		EPCs issued before 2016 have been automatically rescaled, but unfortunately owners are not automatically informed about the change because of technical barriers of the database.	9

Data Analysis of Table 10

MSs promote the transparency of the EPC scheme using methods that comply with national GDPR laws. The EPC database, the cadastre database and special online portal are linked in Slovenia, with an aim to provide transparency and enable wider data accessibility [5]. A boost in the wider use of Lombardy, Italy's EPC registry by trade associations is to be achieved by the use of a GIS tool, whilst applying privacy protection measures [24].

Due to GDPR, some MSs have resorted to displaying statistics and aggregated data instead of raw data to the public. They can be displayed as trends and graphs, presenting a potentially easier way for the general public to better understand the implications of energy consumption without having to deduce it from data files. These statistics can be viewed online or in publications as EPC data per building type, construction year, type of technical systems installed and geographical area. In Slovakia a login is necessary for certified experts to access raw data.

In the UK copies of EPCs on an individual basis are publicly available through a website and attainment of bulk EPC data is available to categories of organizations for a fee. Administrative fees for large quantities of data are a hinderance to extensive use of the data for analyses due to high costs. Certificates are downloadable as PDF files, this is a resolution to formats such as excel files that present barriers to the ease of data processing. An additional barrier encountered by professional bodies interested in evaluating EPC data in further studies is a lack of access to the complete EPC database. Building owners have the choice to restrict public access to EPCs issued for their properties [24].

MSs may grant the public access to EPC databases with privacy protection measures. RES use, energy performance parameters and $C0_2$ emission measurements are retrievable from the EPC data of Poland for only for public buildings [24]. In Malta, only the validity of the EPC is available to the public by entering a corresponding EPC number [5]. Private citizens in Austria, are only able to access their own EPCs. The Netherlands' registry does not restrict access to EPC data based on residential address to building owners and access is granted to certifying bodies to perform quality checks on assessors [24]. Access to EPC data by the assessor or physical person is further regulated in Greece by a combined use of registration number and security number of the certificate, whereas, full access to the EPC is accorded to the responsible ministry and the database operator. On the other hand, the EPC database in Hungary provides public access to building address and energy category, but access to calculations and detailed information is prohibited [5]. Changes to EPC data due to the automatic rescaling of EPCs issued prior to 2016, are not automatically communicated to EPC owners owing to technical barriers of the database [15]. Automatic changes enable EPC comparability and effective use in building markets in a timely manner [5]. The technical structure of the EPC database can be a limiting factor in the ease and speed of processing EPC data even when access is less rigorously regulated.

To bypass the myriad of restrictions to data access and privacy protection, Ireland's BER research tool is used by authorized organisations and building owners to access bulk data or extracts from the register regarding EPC and labelling information that is not protected by the data privacy law of Ireland. Statistical data is frequently updated to the database website on an evening by evening basis [24]. The data seems to suggest that the use of a research tool modeled to data protection laws expediates the statistical evaluation of EPC data, whereas applications for aggregated datasets require more time, resources and preparation by relevant authorities before EPC data can be used. Portugal shares real time EPC data via a website with its national real estate sector. The sector uses this data to monitor market activities and count EPCs used during transactions. This symbiotic relationship between the energy and real estate industry has also opened the database to market actors such as traders [24].

Slovenia offers an extensive amount of data publicly on its databases. This data includes the serial number of EPC, building cadastre identification code, address of the building, cadastral municipality and parcel number, name of EPC assessor and date of issuance [5]. A gap in literature exists surrounding the effect of data access on the impact to energy savings and user understanding of the EPC. After the approval of formal requests to relevant authorities in Greece, research institutes receive anonymised EPC data without personal information. This enables researchers to investigate EPCs across all MSs states and carry out analyses. When access to data for research purposes is denied, studies may exclude countries from beneficial analyses and decrease the impact and accuracy of results from subjects covering the entire scope of EPCs in the EU.

EPC assessors may also only have access to EPCs they have issued themselves. This is the case in Greece [24]. This approach protects the ownership rights of the calculations and building models made by the assessor. Concerning EPCs of building units with shared technical systems, such as apartments, an initial report of the systems is carried out and uploaded into a database. Independent EPC certificates for each building unit are then issued in Belgium, Walloon [31].

4 Identification and Prioritization of Stakeholders

The Energy performance certification is an EU wide scale market. As such, it is important to define the main world entities/stakeholders involved in this market. The methodology adopted for the recognition of relevant stakeholders is specified by the Project Management Institute (PMI). According to this definition, a project stakeholder is, "an individual, group, or organization, who may affect, be affected by, or perceive itself to be affected by a decision, activity, or outcome of a project."[1]. This method applies a category approach to identify the important stakeholders based on three categories.

- **Those who affect the EPC assessment**

This category includes the stakeholders participant in the delivery of EPCs and those who determine the context of the EPC. This category mainly includes organizations/companies implementing and developing EPC software and assessments as well as the entities who set the legal framework and specific rules of the market. The legal entities have a significant impact on how national markets are structured, how flexibility service providers can access various markets, how the products are priced etc.

- **Those who are affected by the EPC assessment**

This category includes the stakeholders who are directly or indirectly affected by the EPC assessment depending on the context. This category represents mostly users/owners, General public as well as community groups and associations.

- **Those who may be interested**

The stakeholders under this category may be interested on the outcomes and methodology for EPCs mainly for research purposes, campaigns, Media or future projects under this context.

Table 11 Identification of Stakeholders

Broad category	Sub-category	Types of individuals/groups
Those who affect the EPC assessment	Those involved in delivery of the EPC	Building Industry Contractor(s), sub-contractor(s), Building Material Industries, Professional consultants (e.g. architectural, engineering and financial) Tool developers Energy service companies (ESCOs) Financial Institutions/Banks

	Those who determine the context of the EPCs	State/Governmental Departments – Public Bodies EU legislative instruments Standardization Bodies
Those who are affected by the EPC assessment	Directly affected by the EPC assessment	Users of the buildings, Facility managers etc. Suppliers
	May be directly or indirectly affected depending on the context	Owners/Users General Public Local community groups such as resident associations, or other community-based groups
Others who may be interested		Environmental/social campaigning organisations, Researchers/ Academics, Media Designers Potential users/clients for future projects

4.1 Stakeholder Definition

Table 12 shows the role description of identified stakeholders and the respected connection with D^2EPC project. The responsibilities and roles of each stakeholder were investigated for the definition of the prioritization with regards to project's objectives.

Table 12 Description of D^2EPC Stakeholders

Stakeholder	Description
Standardization Bodies	The main responsibility of standardization bodies is to develop and deliver the methodology and technical specifications for evaluating the energy performance of the buildings.
State/Governmental Departments – Public Bodies	Goals and policies are set by policy makers in national policy statements, national plans, executive decrees or other formal official announcements. National policies and legal framework set the scope (tasks) for regulation
EU Commission	The Energy Performance of Buildings Directive (EPBD) is the European Union's principal legislative instrument for the promotion of improvements in the energy performance of buildings within communities.
R&D sector Researchers/Academia	Researchers/Academia/R&D sector may support the development of the methodology and perform further research upon request from competent Authorities
Software tool Developers	These companies develop and sell software for the implementation of Energy performance certification based on the respective standards adopted by the National legislation. Their important buyers are mainly ESCOs, Engineer firms, Architects and professional consultants.

Energy service companies (ESCOs)	Energy service companies (ESCOs) play a significant role in the promotion of energy efficiency improvements. The Energy performance certification is among their important services offered by ESCOs
Professional Consultants (Architectural and Engineering firms)	The Professional consultants implement the Energy performance certifications to their projects according to the National legislation of their countries.
Real estate agents (Rental and sales of buildings)	The energy performance certification affects property value in the real estate business. Energy efficiency is considered an important purchasing/rental criterion for sale and rentals of buildings. Therefore, real estate owners will have a motivation to build with greater energy efficiency
Owners/users/tenants	The energy performance certificate will raise awareness of Owners/users on the energy consumption and may trigger energy-saving improvements. Especially the owners, who want to increase the property value for rental/sale.
Building services Industry	Building Services Industries affected by the legislation on energy efficiency of buildings for their future technological services
Suppliers	Suppliers affected by the legislation on the demand and their quality of their products
Building Material Industry	Building Material Industries affected by the legislation on energy efficiency of buildings for their future material development pathways
Energy Agencies	Energy agencies act as policy advisers and assist governments in improving standards. They provide advice on the development, implementation and impact assessment of efficiency policies. Through actively engaging relevant stakeholders, energy agencies could play a significant part in the successful implementation of the EPC scheme.
Environmental/social campaigning organisations, Researchers/ Academics, Media Designers Potential users/clients for future projects	The stakeholders under this category may be interested on the outcomes and methodology for EPCs for different applications according to the context

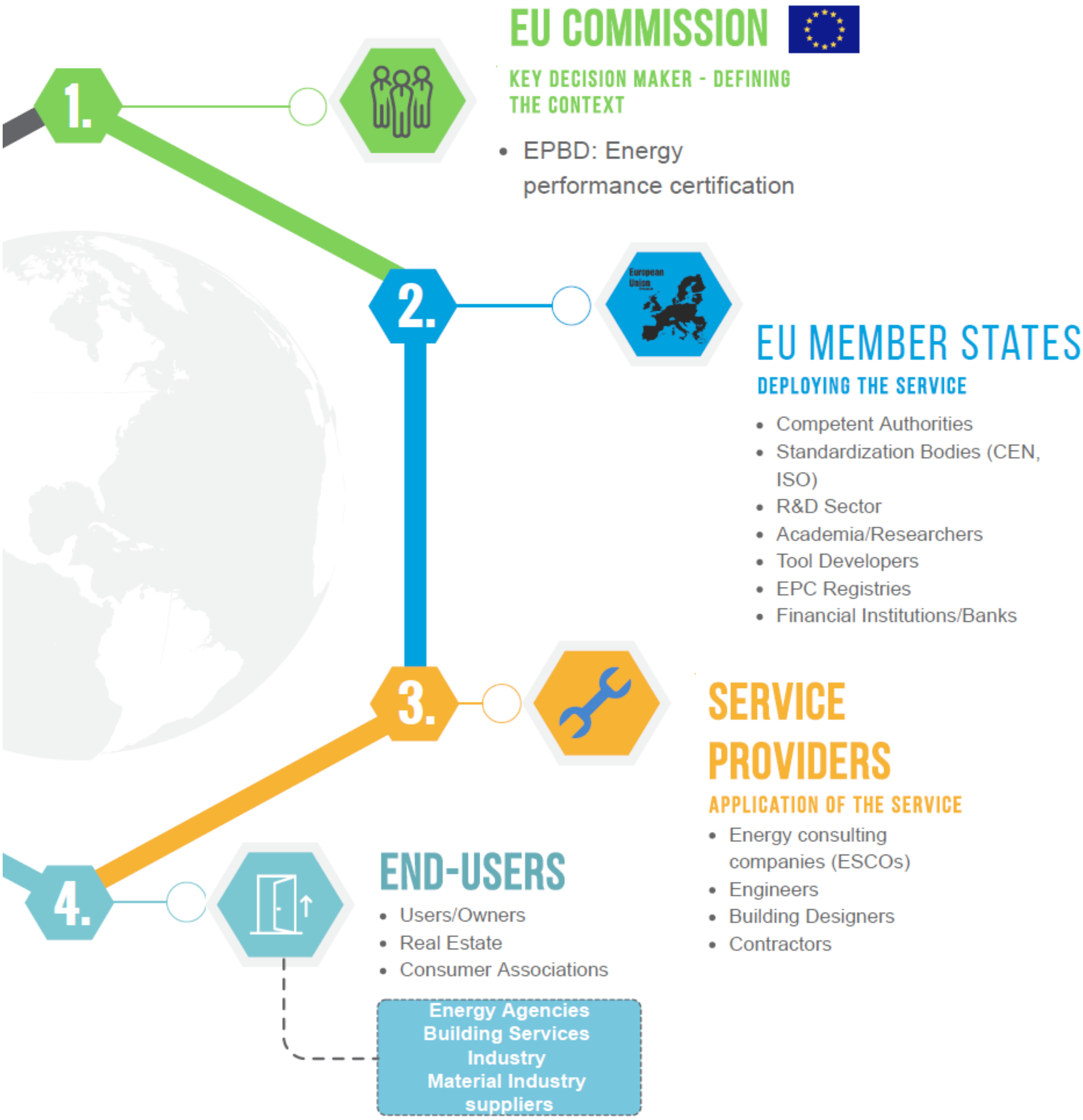

Figure 1 D^2EPC Identified Stakeholders

4.2 Prioritization of D^2EPC Stakeholders

The number of stakeholders involved in the Energy performance certification is considerable and covers a wide range of people and organizations around the EU. In order to have a holistic approach on the drawbacks and requirements of the current EPCs, it is important capture the stakeholder requirements from each stakeholder's perspective. From policy makers to end-users, all stakeholders can provide valuable feedback (e.g., technical, social, economic) depending on their role on the EPC life cycle. The number of stakeholders makes it almost impossible to process the requirements in equal rights —two conflicting requirements of stakeholders cannot be traded off effectively. To this end, Stakeholders were prioritized.

The allocation of stakeholder importance with relevance to the project is based on the PMI's *Stakeholder Circle® methodology* [1], which measures the stakeholder's rating resulting from three basic factors: power, proximity and urgency. The ratings are aggregated within the tool to form an 'index' for each stakeholder. A prioritized list of stakeholders is produced with the highest 'index' value is appropriated to the stakeholder considered to be of highest priority. The relative influence of each stakeholder is assessed by applying these weightings to the assessment of the stakeholder's Power, Proximity and Urgency/Importance to calculate a unique index value (the higher the index value, the greater the stakeholder's influence). The resulting Index is then translated into a priority (Priority 1 = the most influential). The factors considered for the production of the index are shown below.

Power

This factor measures the *degree of power of a stakeholder to formally instruct change* in the context and application of Energy performance certificate legislation. This rating is based on three sub-factors which measure the positional, professional and political power of the stakeholders.

4 High capacity to formally instruct change (e.g., can authorize stopping of the project or have the power for significant modifications)

3 Some capacity to formally instruct change (e.g., must be consulted or has to approve)

2 Significant informal capacity to cause change (e.g., a supplier with input to design)

1 Relatively low levels of power (i.e., generally incapable of causing much change)

Proximity

Proximity is an attribute which measures *how close stakeholders are involved in the execution of energy performance certificates* in processes chain. The higher the proximity the higher the level of day to day involvement with EPCs aspects.

4 Directly involved in the work (e.g., team members and contractors working during most of the project)

3 Routinely involved in the work (e.g., members of the project team working part-time, external suppliers and active sponsors)

2 Detached from the work but has regular contact with, or input to, various processes (e.g., clients and most senior managers)

1 Relatively remote from the work (i.e., has no direct involvement in the work)

Urgency / Importance (Team action required)

This attribute measures the *degree of stakeholder's claim for immediate action*. These are the stakeholders who are most likely to be affected by the outcomes and changes to the context/methodology/legislation of the EPCs.

5 Immediate action is warranted, regardless of other work obligations

4 Urgent action is warranted provided it can be accommodated within current commitments

3 Planned action is warranted on short notice

2 Planned action is warranted within the medium term

1 There is little need for action outside of routine communication

Stakeholder Influence

The last aspect of stakeholder prioritization is the stakeholder Influence/direction. The methodology classifies stakeholders according to five potential "directions of influence": These aspects define how stakeholders may influence or be influenced by the project or/and its outcomes. Directions include upwards (senior managers), downwards (the team), sideways (peers of the project manager), outwards (outside the project) and inwards (self-managing). In order to manage the expectations and win the support of each category of stakeholder, there is a need to recognize the best way to manage the relationships described by these categories. The Table 13 summarizes the directions of influence.

The data is essential to developing targeted communication in order to manage relationships with important stakeholders and must be defined.

Table 13 Stakeholder Influence/direction to the project

Direction	Stakeholder Influence
Upwards	Influencing senior and functional managers to maintain organisational commitment
Downwards	Managing the project team including contractors and workers
Sideways	Managing relationships with peers for collaboration rather than competition
Outwards	Managing suppliers, vendors, users and external stakeholders
Inwards	Managing oneself (limited relevance to the project)

The stakeholders and their respective importance are summarized on Table 14 based on the methodology described. Each role category represent a set of needs and requirements that can be extracted based on the specific perspective of each role. The following roles and potential needs and requirements are summarized:

Deployers of the service – These stakeholders represent an important source of technical and non-technical needs and requirements of the current EPCs. This category represent the technical development of the EPC service (Tool developers) as well as the methodological development (Researcher, R&D sector). As expected, this stakeholders will have a wide range of experience on possible drawbacks on the EPC methodology and its technical development.

Service provider - Implementation – This category is represented by stakeholders who provide their services and implement Energy performance certifications. Therefore, these stakeholders will play a key role on defining the drawbacks and improvement potentials given that they have the most empirical experience on the application of the service.

Directly affected parties – The stakeholders under this category represented mainly of the users/owners of Energy performance certificates. These category will give a valuable insight on the usability, user-friendliness and information impact of energy performance certificates. The project should be able to achieve acceptance of these stakeholders on the new aspects of nEPCs.

Key decision maker - Defining the context – This category is represented by stakeholders of great power but lower day to day involvement on EPCs issuance. They are the major legislative bodies who are responsible for environmental targets (EU commission/Legislative bodies). Therefore, these stakeholders have a wide experience on how EPCs are impact the EU and MS targets on energy related issues.

Table 14 Prioritization of D^2EPC Stakeholders

Name	Direction	Role	Power	Prox.	Urg.	Index	Priority
Tool developers	D	Deployment of the service	2	4	4	36.0348	1
Energy service companies (ESCOs)	D	Service provider - Implementation	2	4	3	31.0341	2
Engineers	D	Service provider - Implementation	2	4	3	31.0341	3
EPC Registries	S	Deployment of the service	2	4	3	31.0341	4
EU commission - legislative instruments	U	Key decision maker - Defining the context	4	2	2	30.0474	5
Suppliers	O	Direct on indirect affected parties	2	1	4	30.0258	6
Building Designers	D	Service provider - Implementation	2	3	3	29.0311	7
Contractors, sub-contractors	D	Service provider - Implementation	2	3	3	29.0311	8
Standardization Bodies	D	Key decision maker - Defining the context	3	3	2	28.0404	9
Researchers/Academia	D	Deployment of the service	3	3	2	28.0404	10
R&D sector	D	Deployment of the service	3	3	2	28.0404	11
State/Governmental Departments - Public bodies	U	Decision maker on National level - Service, operation & Monitoring	3	2	2	26.0374	12
consumer associations	O	Directly affected parties	2	1	3	25.0251	13
Users/Owners	O	Directly affected parties	1	1	3	21.0151	14
Real Estate agencies	O	Directly affected parties	1	1	3	21.0151	15
Building Services Industry	O	Direct on indirect affected parties	1	1	3	21.0151	16
Energy Agencies	S	Policy advisor & Monitoring	2	1	2	20.0244	17
Financial Institutions/Banks	S	Deployment of the service	2	1	2	20.0244	18
Building Material Industries	O	Direct on indirect affected parties	1	1	2	16.0144	19
Facility Managers	O	Direct on indirect affected parties	1	1	2	16.0144	20
Local community groups and associations	I	Parties that may be interested	1	1	2	16.0144	21
Environmental/social campaigning organizations	I	Parties that may be interested	1	1	2	16.0144	22

Table 15 Stakeholder Prioritization based on Roles

Priority	Role of stakeholders				
	Deployers of the service	**Service providers**	**Key decision maker - Defining the context**	**Directly affected parties**	**Parties that may be interested**
1	Tool developers	Energy service companies (ESCOs)	EU commission - legislative instruments	Suppliers	Local community groups and associations
2	EPC Registries	Engineers	Standardization Bodies	consumer associations	Environmental/social campaigning organizations
3	Researchers/Academia	Building Designers	State/Governmental Departments - Public bodies	Users/Owners	Media
4	R&D sector	Contractors, sub-contractors		Real Estate agencies	
5	Financial Institutions/Banks			Building Services Industry	
6				Building Material Industries	
7				Facility Managers	

4.3 Stakeholder Engagement

Stakeholder engagement is a key part of the stakeholder elicitation process which ensures the long-term involvement of stakeholders in the project. Effective engagement ensures the continuous monitoring of stakeholder requirements into organisational goals and creates the basis of effective strategy development. The aim of this task is to ensure effective communication with stakeholders to satisfy their needs / expectations, address concerns as they occur and build appropriate stakeholder engagement in project activities throughout the life-cycle of the project.

Communication effort is related to the prioritization of the stakeholder as well as a comparison between their actual and optimum levels of support and receptiveness.

Table 16 Stakeholder's level of Support

Rating	Receptiveness	Support
5	High: eager to receive information	Active support
4	Moderate: will agree to receive information	Passive support
3	Ambivalent	Neutral
2	Not interested	Passive opposition
1	Completely uninterested: actively refuses information	Active opposition

High power, interested people:

High degree of engagement with these stakeholders — it is assumed that higher priority stakeholders require a more pro-active communication effort.

High power, less interested people:

Focused communication needed - satisfactory communications is needed. Avoidance of over communication

Low power, interested people:

Focused communication needed – Include stakeholders that may be able to help with the details of the project.

Low power, less interested people:

Business as usual communication needed - Monitor of this stakeholders is needed - ensure updates about the project are sent, but avoid excessive communication.

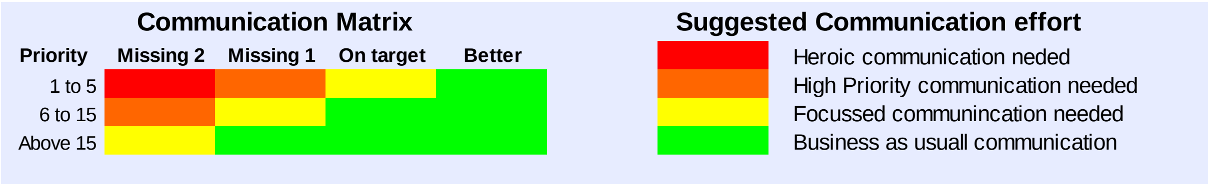

Figure 2 Stakeholder' communication Matrix

Communication effort is related to the prioritization of the stakeholder as well as a comparison between their actual and optimum levels of support and receptiveness.

- It is assumed that higher priority stakeholders require a more pro-active communication effort.
- Stakeholders that are below optimum on both the receptiveness and support dimensions also rate highest.
- Stakeholders below optimum on one-dimension rate next, followed by stakeholders that are optimal.
- Stakeholders rated better than optimal are assessed as needing 'business as usual' communication.

Table 17 Stakeholder Engagement level

				Current		Optimal		
Name	**Direction**	**Role**	**Priority**	**Receptive**	**Support**	**Receptive**	**Support**	**Level of Communication**
Tool developers	D	Deployment of the service	**1**	4	3	4	4	High Priority
Energy service companies (ESCOs)	D	Service provider - Implementation	**2**	4	4	5	4	High Priority
Engineers	D	Service provider - Implementation	**3**	4	4	4	4	Focused
EPC Registries	S	Deployment of the service	**4**	4	3	4	4	High Priority
EU commission - legislative instruments	U	Key decision maker - Defining the context	**5**	5	4	5	5	High Priority
Suppliers	O	Direct on indirect affected parties	**6**	3	3	4	3	Focused
Building Designers	D	Service provider - Implementation	**7**	4	4	5	4	Focused
Contractors, sub-contractors	D	Service provider - Implementation	**8**	3	3	4	3	Focused
Standardization Bodies	D	Key decision maker - Defining the context	**9**	4	5	5	5	Focused
Researchers/Academia	D	Deployment of the service	**10**	4	5	5	5	Focused
R&D sector	D	Deployment of the service	**11**	4	4	5	4	Focused
State/Governmental Departments - Public bodies	U	Decision maker on National level - Service, operation & Monitoring	**12**	4	4	4	5	Focused
consumer associations	O	Directly affected parties	**13**	4	3	4	4	Focused
Users/Owners	O	Directly affected parties	**14**	2	3	4	4	High Priority
Real Estate agencies	O	Directly affected parties	**15**	3	3	4	4	High Priority
Building Services Industry	O	Direct on indirect affected parties	**16**	3	3	4	3	Business As Usual
Energy Agencies	S	Policy advisor & Monitoring	**17**	4	4	4	5	Business As Usual
Financial Institutions/Banks	S	Deployment of the service	**18**	4	4	4	4	Business As Usual
Building Material Industries	O	Direct on indirect affected parties	**19**	3	3	4	3	Business As Usual
Facility Managers	O	Direct on indirect affected parties	**20**	3	3	4	3	Business As Usual

Local community groups and associations	I	Parties that may be interested	**21**	3	3	4	3	Business As Usual
Environmental/social campaigning organizations	I	Parties that may be interested	**22**	3	3	4	3	Business As Usual
Media	I	Parties that may be interested	**23**	3	3	4	3	Business As Usual

5 Stakeholders Questionnaire/Interviews – Analysis of findings

5.1 Results: - End- Users requirements and needs questionnaire

Preceding the questionnaire, respondents asked to provide their inputs to the base questions in order to ensure homogeneity of the sample. The respondent's demographics are shown in Figure 3 and Figure 4. The majority of respondents were homeowners themselves as well as tenants. The level of education varied with the majority declare to have higher education. These data was taken into consideration for the statistical analysis of the sample where specific correlations identified.

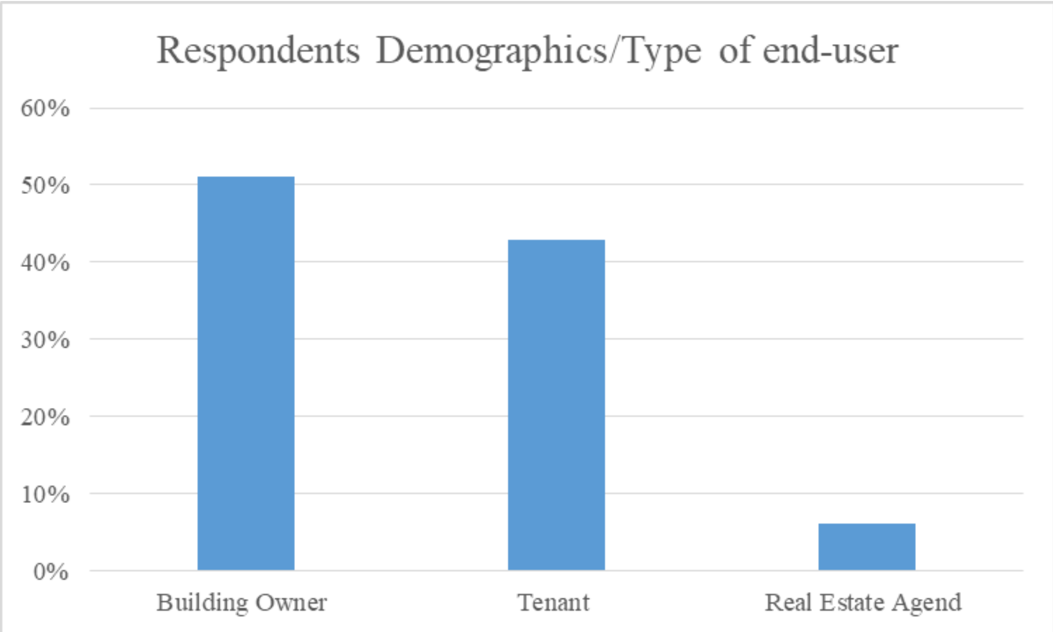

Figure 3 Respondents Demographics/Type of end-user

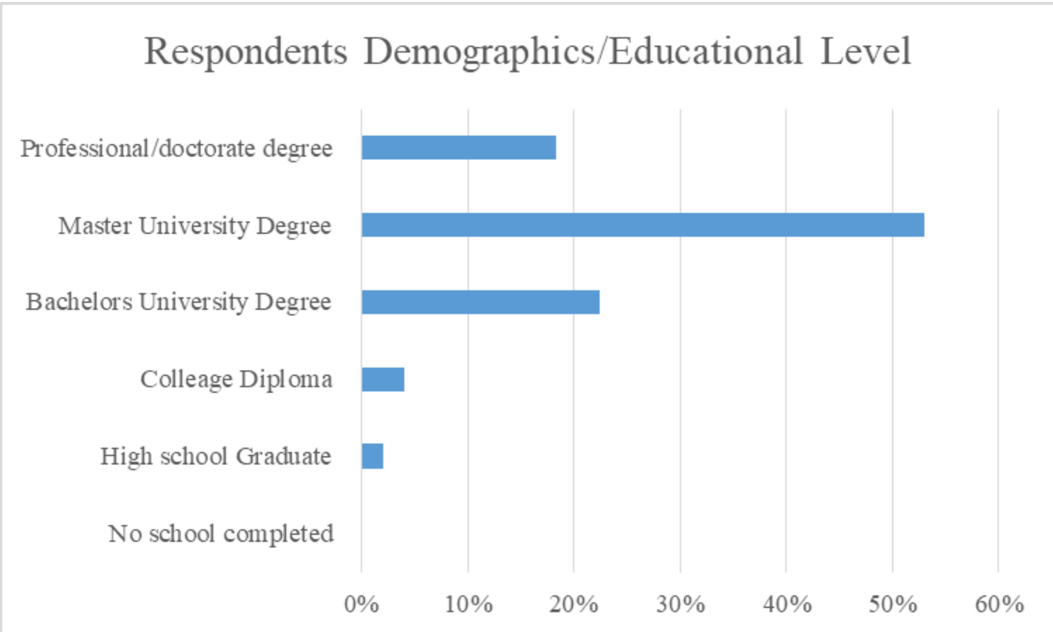

Figure 4 Respondents Demographics/Educational Level

5.1.1 Section 1: Understanding of energy performance certificates (EPC)

The first section of the End-user questionnaire investigated the respondent's current understanding of EPCs with regards to four factors: Perceived reliability of EPC data, Level of impact of EPC data, Usefulness of EPCs and importance of EPCs in rental/sales decisions.

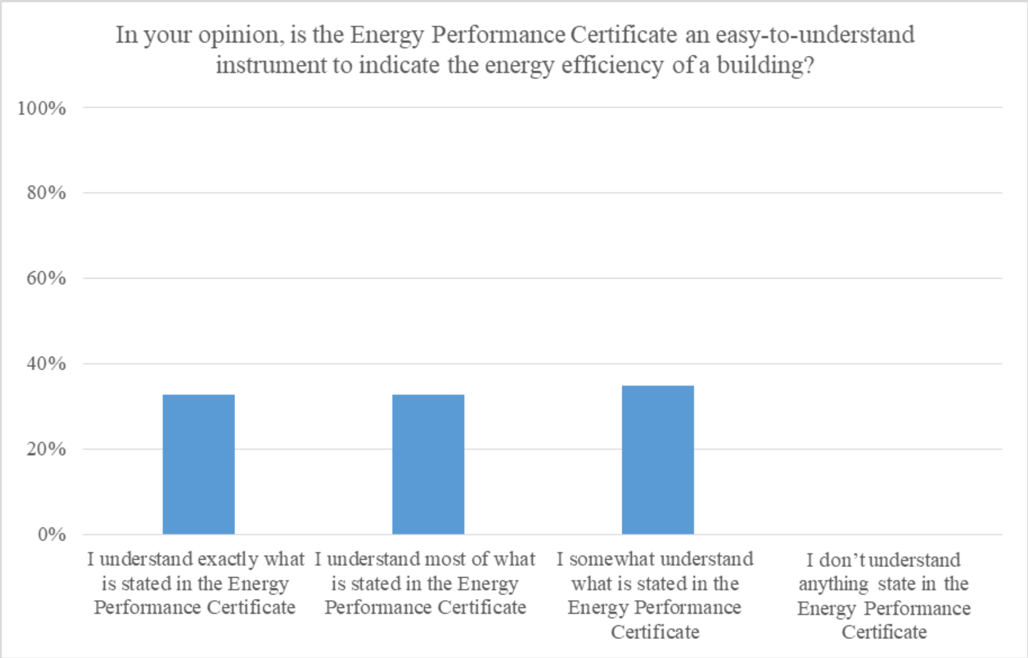

Figure 5. Understanding of the EPCs

According to Figure 5, there is at least a basic understanding of EPCs through the different age groups and professional levels. Some respondents commented on this section that they have a related professional background and therefore they have a high level of understanding what is stated on the EPC. However, users like Real Estate Agents stated that when speaking to clients mostly do not know and some do not understand even after explaining. There were also comments stated that the language used on the EPC issuance is too complicated or not easy to understand. These responds shows that there is a need to improve the user-friendliness of EPCs. .

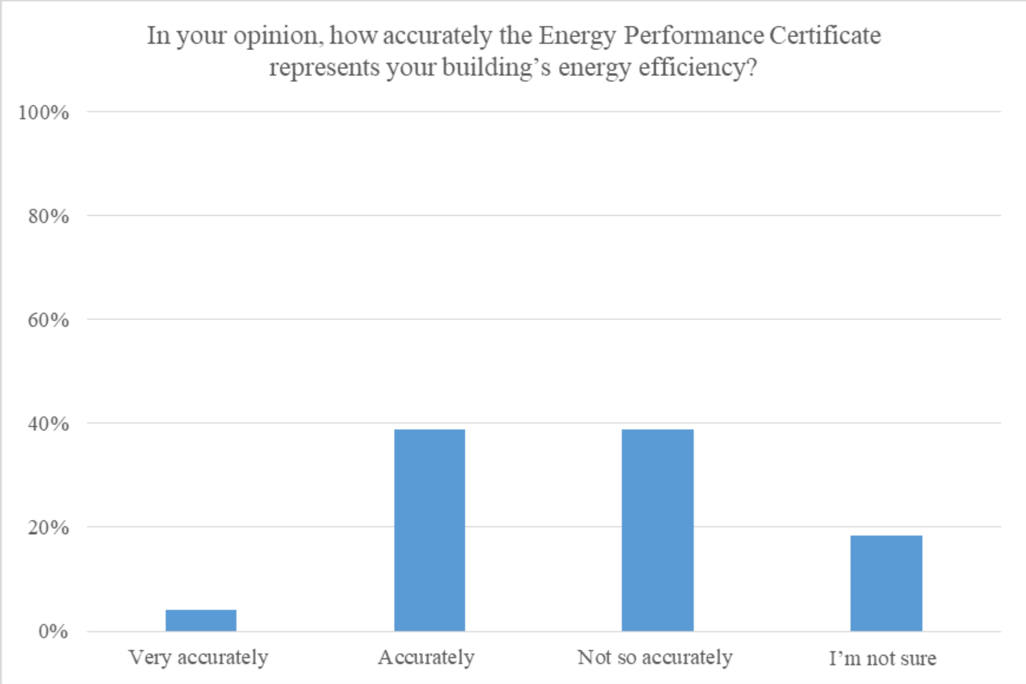

Figure 6. Perceived accuracy of EPCs

Figure 6 represents how the building users perceive the EPC accuracy on their buildings. The opinions on the accuracy of energy performance certificates are divided. The trend identified behind these responses correlates with the level of understanding of the EPCs. In particular, the respondents who rated EPCs as 'Not so accurate' are mostly the people who rated themselves to have a high understanding of EPCs in the Question 1. Furthermore, the majority of respondents who rated themselves to have somewhat understanding of EPCs rated EPCs as 'Accurate' or 'I'm not sure' option. The results of Figure 7 show the correlation of the respondent's EPC understanding with regards to the perceived accuracy of EPCs. It is evident that there is a partial tendency to question the accuracy of EPCs in respondents with high rated understanding of EPCs.

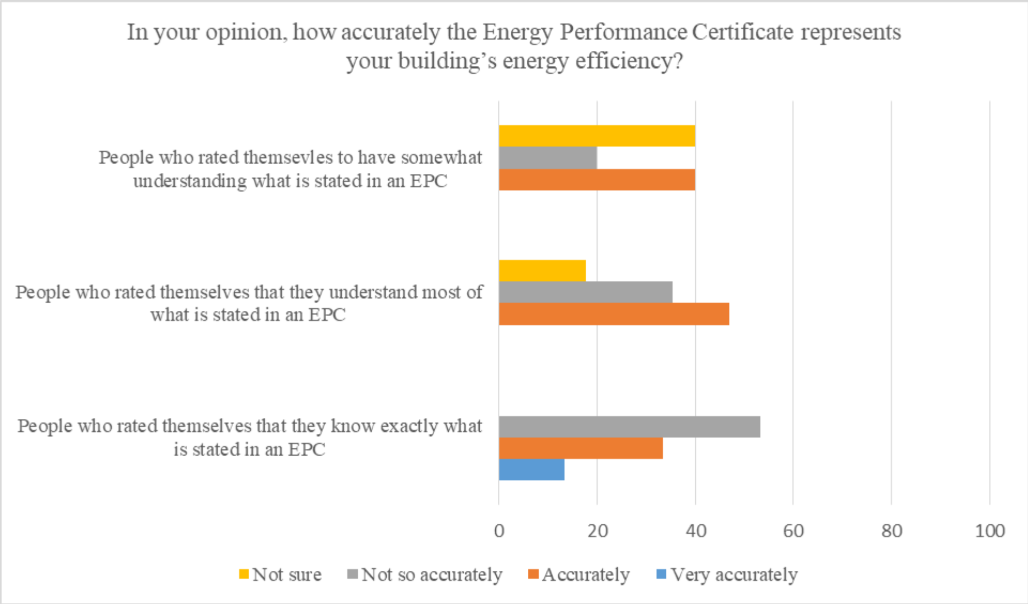

Figure 7. Correlation of EPC perceived accuracy and rated level on EPC understanding

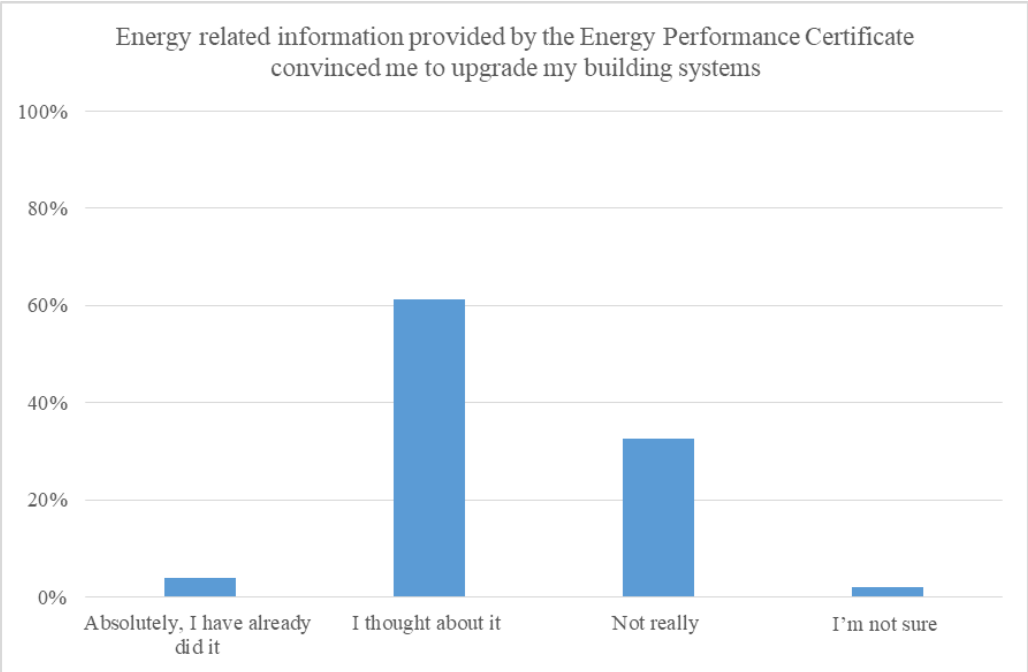

Figure 8. Level of impact of EPC information towards triggering energy renovation measures

Figure 8 shows the level of impact of the information provided by EPC towards triggering energy renovation upgrades to building users. It is evident that there is a tendency towards improving the energy behaviour of buildings, even though the most of the respondents did not implement such measures. However, even though the energy efficiency of the building is consider an important feature, to a considerable number of respondents, there is no significant impact of the EPC to their energy renovation decisions. The results show a need for a more user-friendly and informational EPC where the users will receive useful insights on the level of energy efficiency and comfort of their buildings. Such transition requires that EPCs will become an important instrument for promoting energy efficiency as well as a valuable guidance for energy renovation measures.

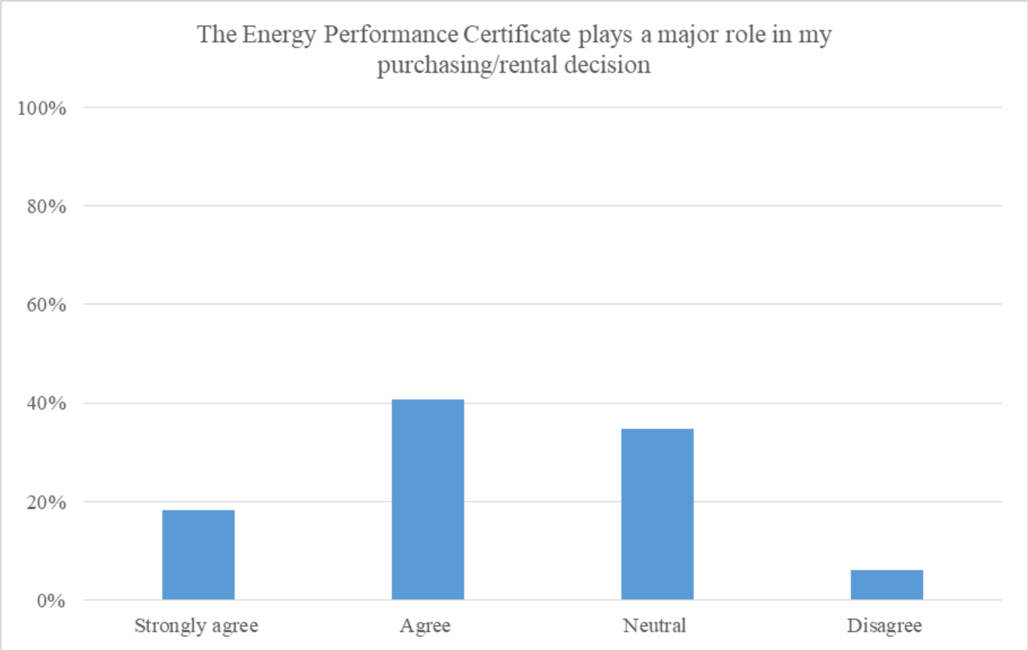

Figure 9. Impact of EPC in purchasing/rental decisions

Figure 9 shows the perceived impact of EPC on the rental/sale decisions of users. The results show that most respondents consult EPCs prior to buying or rent a property however a significant number of responds indicated EPCs as 'Neutral' in usability. This trend indicates the need to increase the impact of EPCs to the users by introducing valuable and easy to understand information of the energy performance of building.

Section 1: Conclusions

This section of End-user questionnaire shown the following trends with regards to understanding of EPCs in EU:

- There is at least a basic understanding of EPC throughout the EU and among educational levels and age groups. Some respondents commented that the language used on the EPC issuance is too complicated or not easy to understand.
- There is a trend which correlates the perceived reliability of EPC data with the respondent's level of understanding on EPCs. In general there is tendency for questioning EPC reliability in groups who rate themselves high in EPC understanding.
- There is a positive trend towards implementing energy related upgrades even though in majority, people did not implement such measures. The impact of EPC for triggering energy related investments needs to be improved.

- The energy performance of building is an important aspect to be taken into account prior rental or buy of properties. However, many respondents rate the EPC usability as 'Neutral' when it comes for buy/rental decisions.

5.1.2 Section 2: Understanding/Adoption of Smart building technologies

This section investigated the understanding of Users with regards to Smart building technologies. Given that D^2EPC will be based on Smart technologies, there is a need to identify the current perception of such technologies.

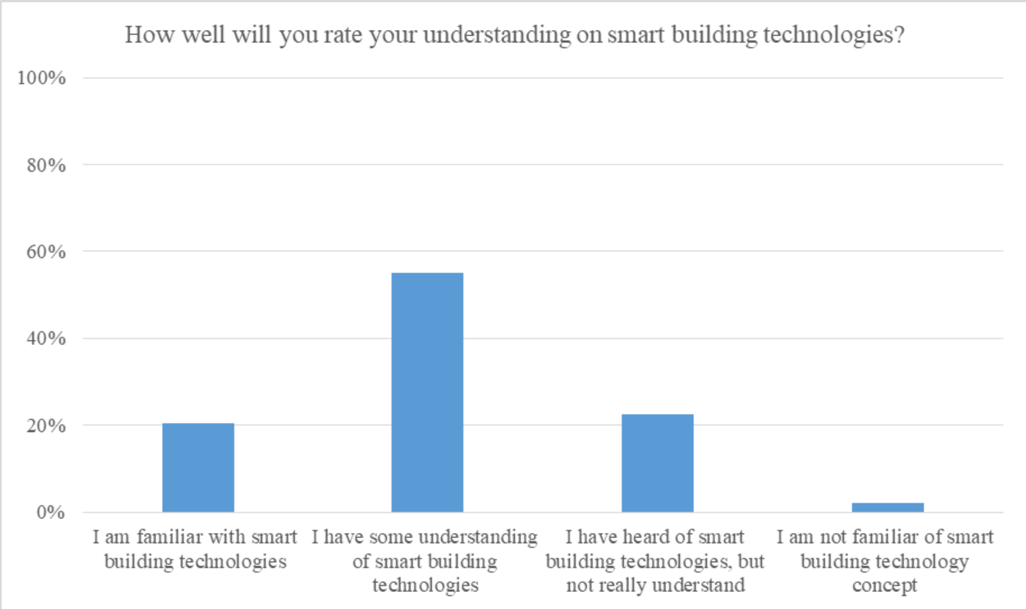

Figure 10. Self-evaluation on understanding of smart building technologies

Figure 10 shows the respondent's self-evaluation on understanding of smart building technologies. The results show that there is at least a basic understanding of these technologies among different age groups and educational levels. It found that respondents who are not familiar of smart technologies are mostly above the age of 60. The answers of this question show the penetration of technology in the lives of people regardless of country and age and profession. However, is seems that there is a need to further educate and inform people about the advantages of such technologies especially for older age groups.

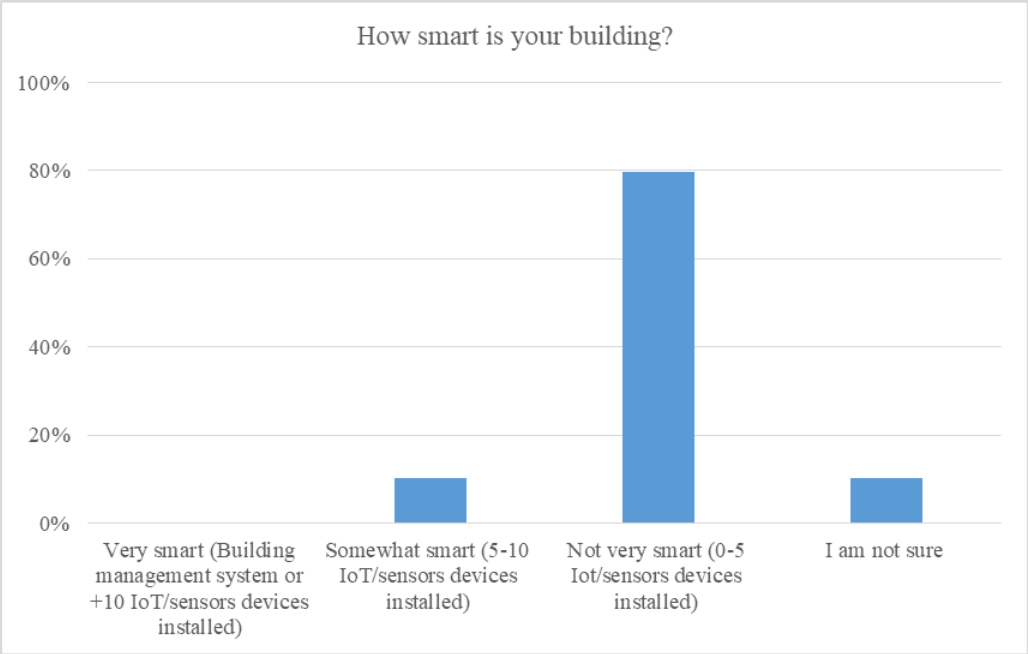

Figure 11. Current status of smart building adoption

The current status of implementation of smart building technologies investigated as shown in Figure 11 in terms of number of installed devices. It is evident that there is room for improvement for the adoption of such technologies given that the majority of the respondents ranges in the 'Not very smart' option which represent 0-5 IoT/sensors installed. There is a gap between understanding of smart technologies and actual adoption which lead to the conclusion that cost, security issues and motivation are among the most important factors for actual adoption of such technologies.

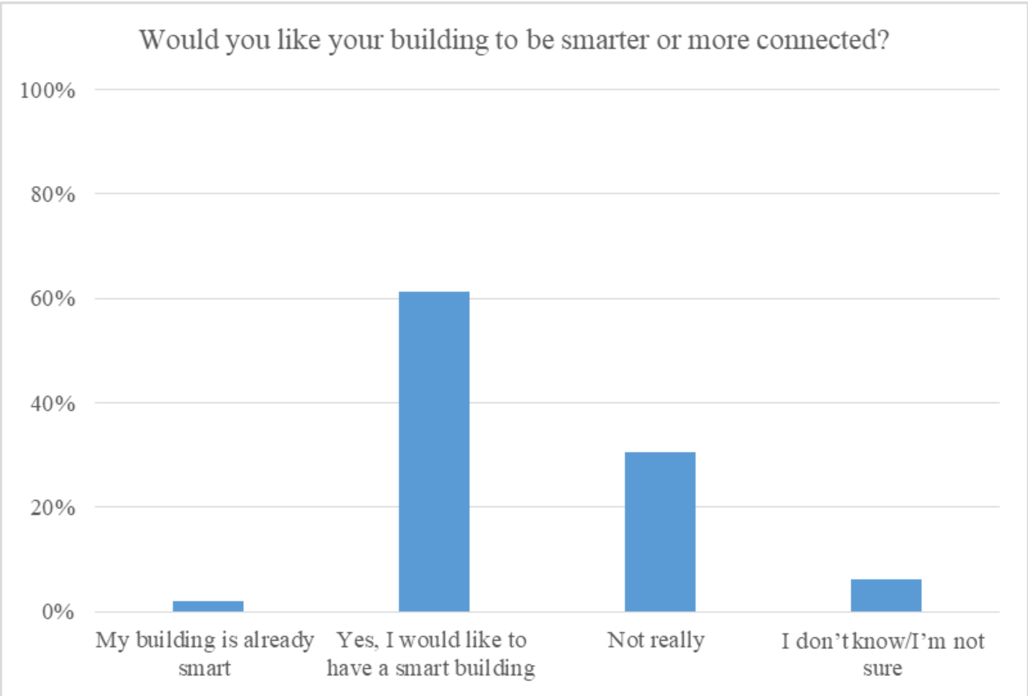

Figure 12. Willingness of users for a smarter or more connected building

This question investigated the willingness of building owners and tenants to live in a smarter building. Even though the majority of the respondents replied positive, there is a considerable number of negative responses as shown in Figure 12. Interestingly, for those who are willing to live in a smarter building, tenants have slightly more positive responses than building owners.

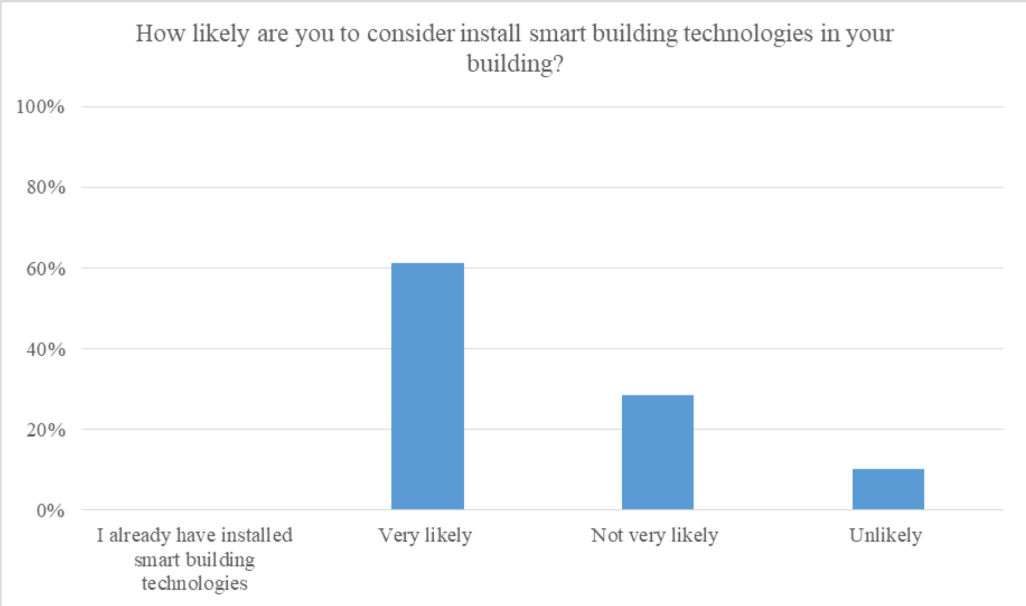

Figure 13. Likehood of installing smart building technologies

The likelihood of users towards installing smart building technologies investigated as shown in Figure 13. In general there is a positive trend with regards to the consideration of installation of smart technologies, however there is a considerable amount of negative responses. Some comments accompanied the negative responses were the incentives to do so (in case of tenants) if they are not the owners of the building. Moreover, the cost of installation and servicing was one of the most important parameters of those willing to install smart building technologies. This trend may reveal the need for incentives of housing companies and real estate to install smart building technologies given that tenants seem to value such technologies in their living environment.

Section 2: Conclusions

This section shown the following trends with regards to the adoption/understanding of smart building technologies for the Users:

- There is an overall good understanding of smart building technologies among different countries and age groups. Users who rated themselves as ‘lower understanding’ on such technologies are mostly within the age group above 60.
- There is a gap between understanding of smart technologies and the actual adoption which lead to the conclusion that other factors such: cost, security issues and motivation may determine the level of adoption.

- Even though the majority of the respondents would like to have in a smart building, there is a considerable number of negative responses. Tenants are slightly more positive compared to building owners.
- In general there is a positive attitude towards installation of smart building technologies. The negative responses where associated with the cost of installation and maintenance of such devices as well as the incentives (in case of tenants).

5.1.3 Section 3: New aspects of Energy performance certificates

This section investigated the user's perspective on the new aspects of next generation EPCs suggested by D^2EPC. These section aims to validate the major objectives of D^2EPC described on the initial phase of the proposal.

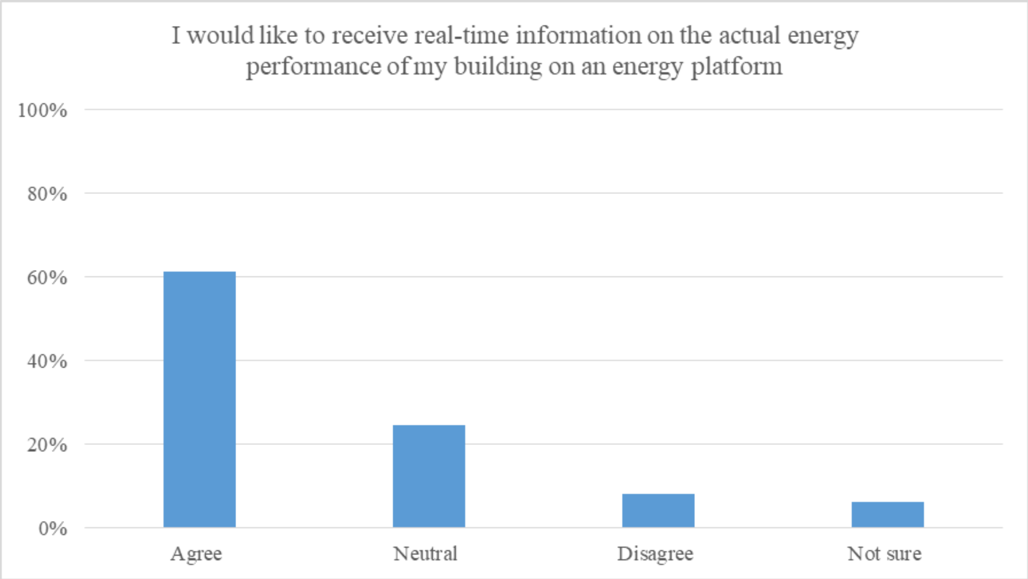

Figure 14. User's perspective on real time information of the building through an energy platform

Figure 14 investigated the user's willingness to receive information on the actual performance their buildings via a real time platform. The dynamic concept is the first objective of D^2EPC which concerns the calculation of the operational EPC on a regular basis and the potential of regular definition of the reference building. The majority of responses reveal that such information is perceived as useful and desired from the users.

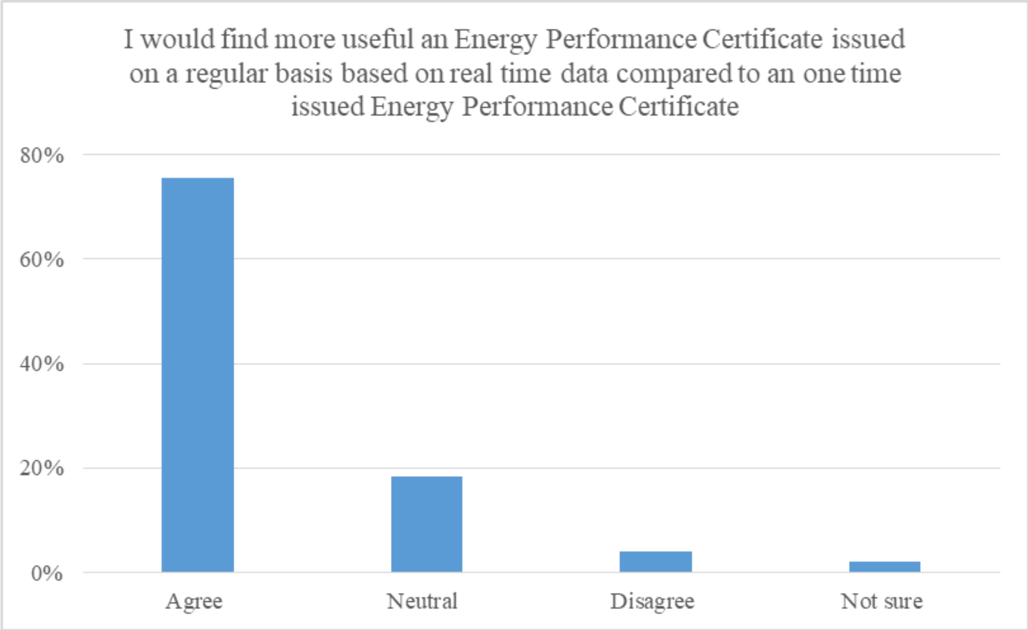

Figure 15. Preference on regular based issued EPC compared to one-time issued

Although cutting edge monitoring technologies allow the real time integration of measured data into the calculation process of EPCs, this has still not been regulated either by existing EPC tools or methodologies. D^2EPC aspires to define the required framework to empower the regular energy classification of buildings, based on their operational performance. The majority of the respondents replied positive to the question whether a regular based issued certificate is preferable compared to a one-time issued certificate.

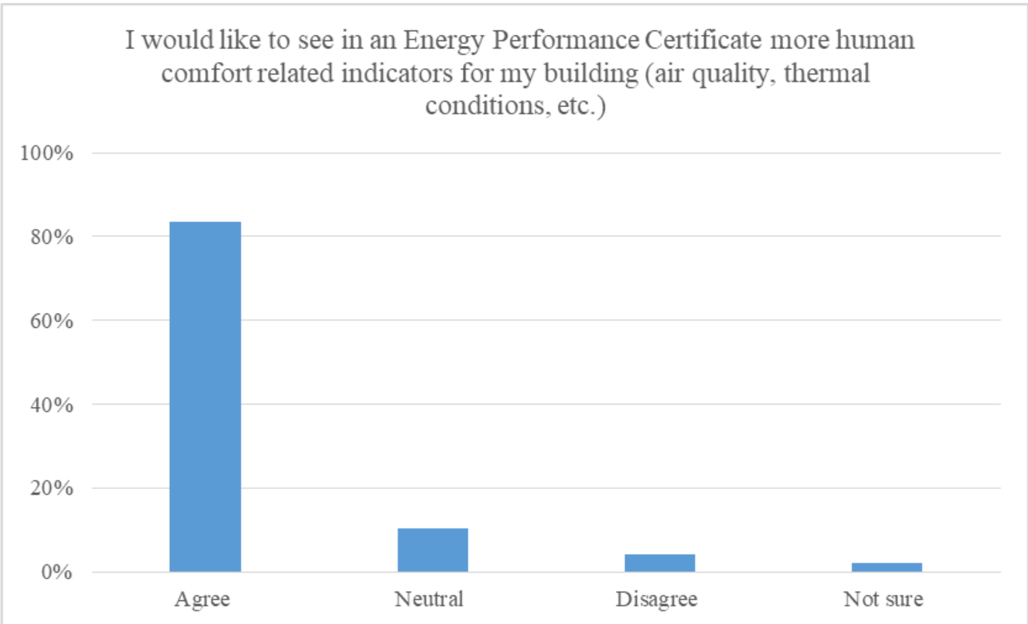

Figure 16. End-user's perspective on human comfort indicators

D^2EPC aims to establish a set of indicators which will be human-centric and foster user-friendliness and enhance human comfort conditions of the building. These indicators are currently absent from

Energy performance certificates. However, as shown from the responses of Figure 16 are highly desired by the users. The responses validate the first assumption of D^2EPC concerning the usefulness of such indicators.

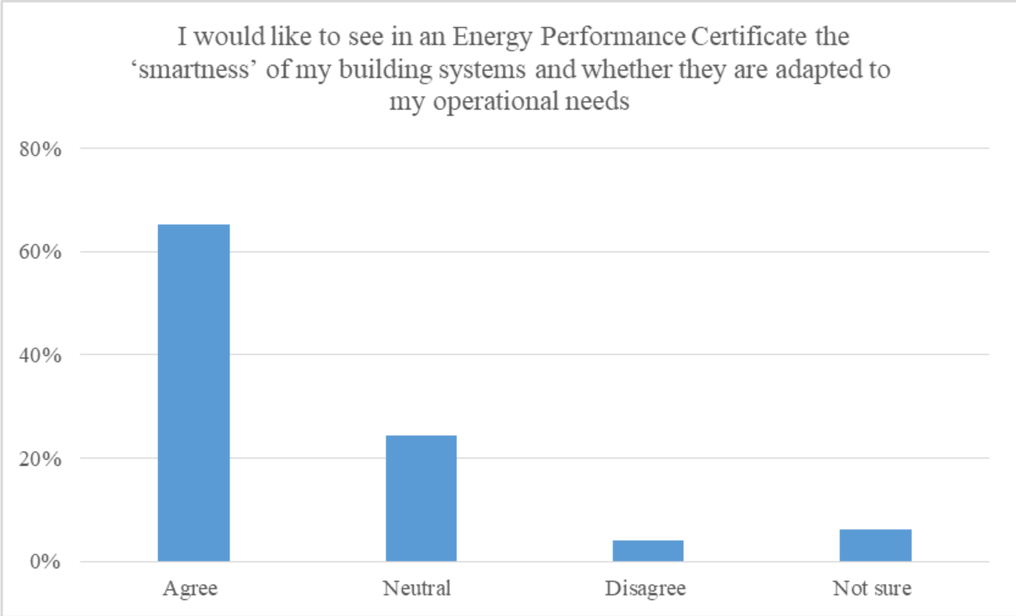

Figure 17. End-user's perspective on Smartness level of building systems

The D^2EPC scheme envisions smartly monitored and controlled buildings, involved in demand-side management strategies. Smart readiness indicator can measure the capability of buildings to process information and communication technologies and electronic systems to adjust building operation to needs of occupants and the grid, thereby, improving the energy efficiency and overall performance of buildings. The user's perspective of these indicators are perceived as useful according to the responses shown in Figure 17.

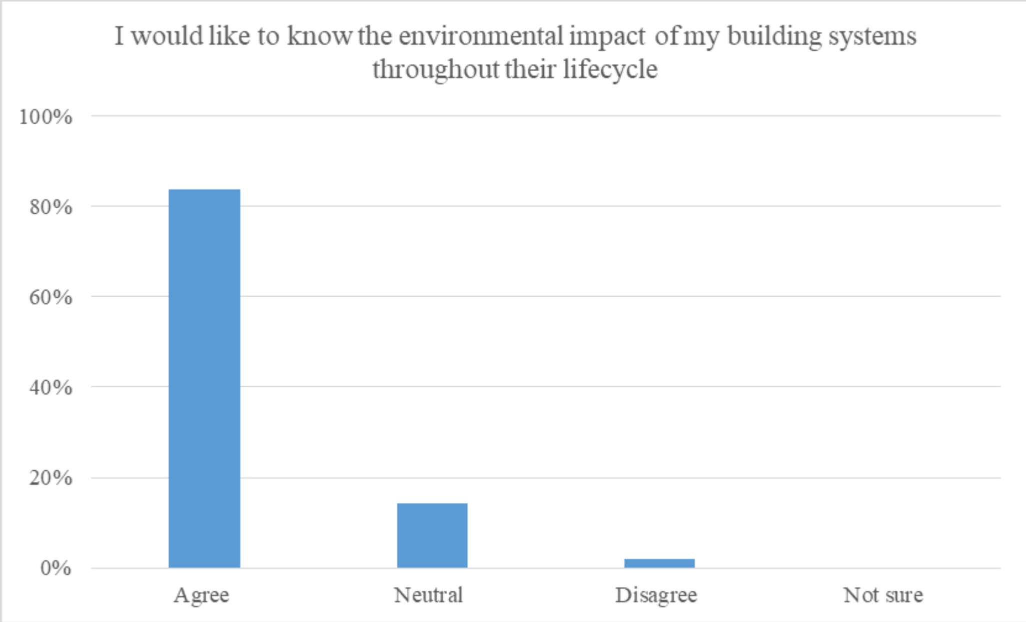

Figure 18. End-user's perspective on environmental impacts of building systems

Additionally, to human comfort indicators, D^2EPC aims to establish novel indicators which covers environmental aspects. These indicators are oriented towards the entire building life-cycle and will enable the evaluation of buildings holistically and cost-effectively across complimentary dimensions which will consider both the envelope and the system performances. The respondents show a positive approach towards including environmental indicators as shown in Figure 18.

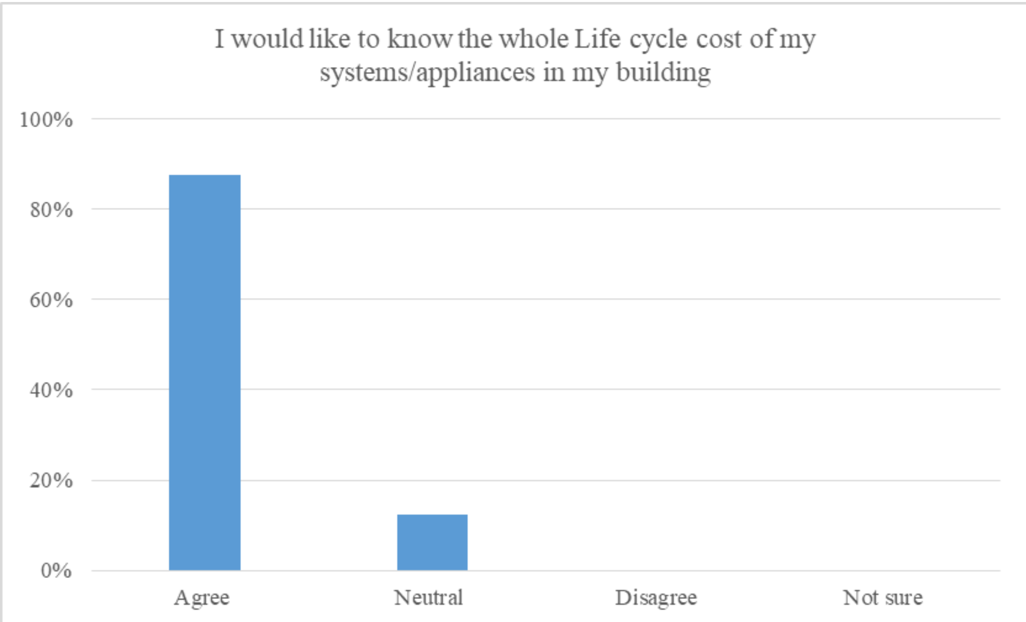

Figure 19. End-user's perspectives on life cycle costing of building systems

Life Cycle Costing (LCC) has been used in the context of building sustainability and as the methodology for the assessment of these costs. LCC is defined as the "cost of an asset or its parts throughout its life cycle, while fulfilling the performance requirements." D^2EPC will place emphasis on the development of suitable monetary indicators related to the main operations of building's energy consumption (heating, cooling, lighting, appliances) which will be developed based on the well-established principles of LCC assessment. Such indicators are highly desired by the users according to the finding of Figure 19.

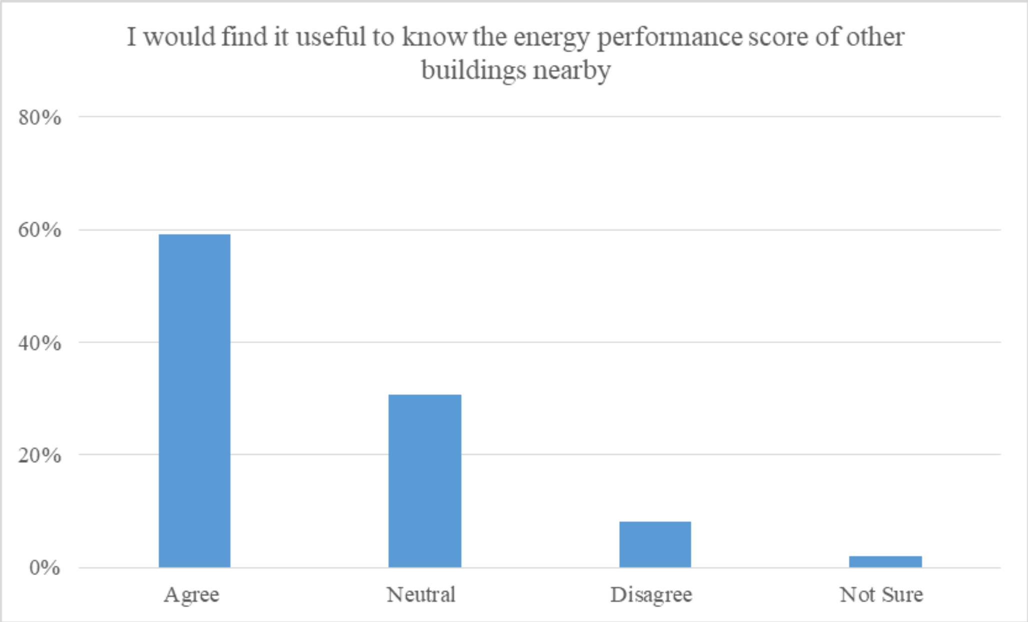

Figure 20. Users perspective of geo-location services

D^2EPC envisions the provision of applications that include comparing buildings with the performance of other buildings in more than one normalised metrics as per the SRI framework (building energy performance benchmarking) as well as verifying the credibility of the data collection and processing (performance verification and credibility tool). A D^2EPC GIS Tool will visualise generated EPCs in a GIS environment, empowering users to perform various types of spatial and attribute queries This aspect will foster the efficient implementation of the financial related policies and will strengthen the role of the next-generation EPCs. The responses of this question, revealed that the majority of users will find this aspect useful, however a considerable amount of responses remained neutral.

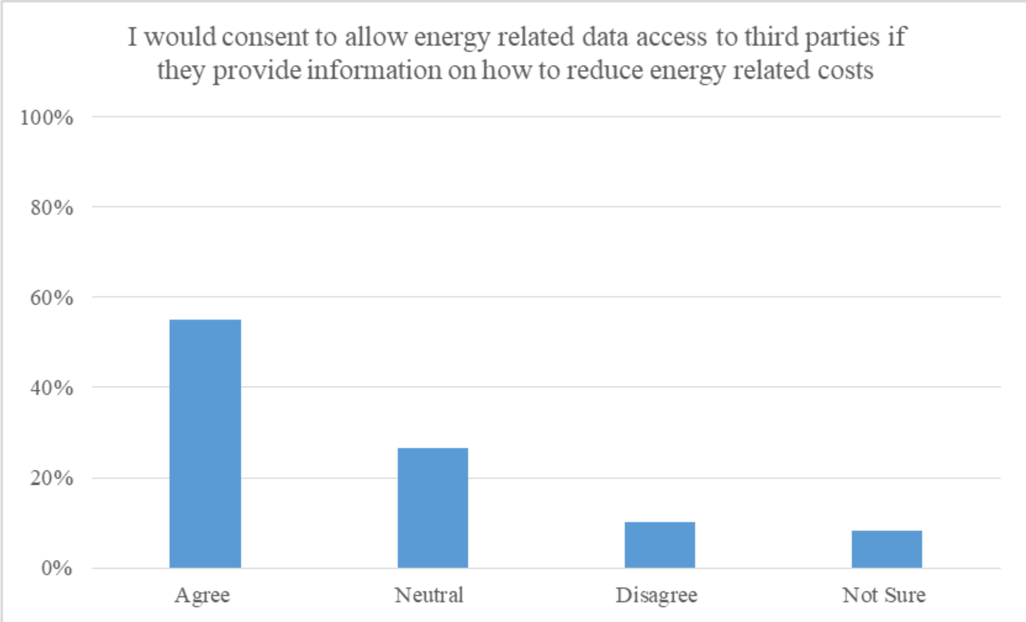

Figure 21. End-user's willingness to allow energy related data access to third parties

This question investigated the willingness of the users to allow access of energy related data of their buildings to third parties given that they will provide information to reduce their energy costs. According to Figure 21, there is a positive tendency of users to provide such data however; the neutral responses reveal that a considerable number of people may be concerned with security related issues. This trend reveals the need for protection of sensible data and the concern of people towards allowing

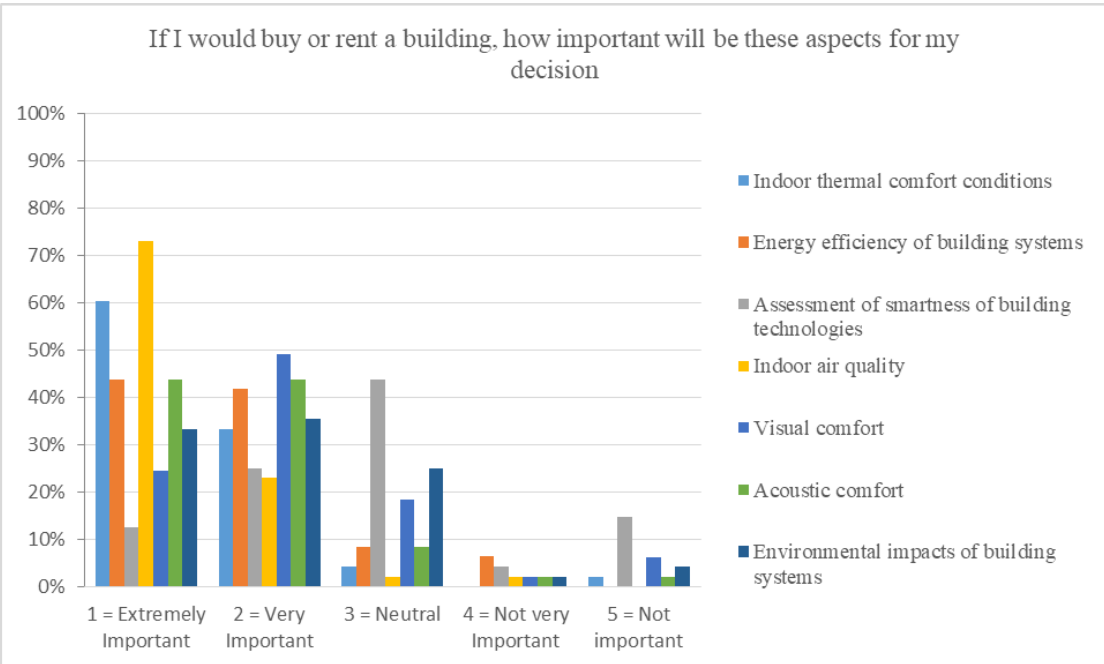

Figure 22. Rating and prioritization of building aspects according to user's perspective

The importance of different building's aspects investigated as shown in Figure 22. The top rated aspects which will have an important impact to the rental/sale decisions according to users are Indoor air quality, indoor thermal comfort conditions followed by the energy efficiency of building systems and acoustic comfort. The responses reveal that such data prior rental and sales of properties will have a positive impact towards promoting energy efficient buildings as well as offering greater control and information to the users.

Section 3: Conclusions

This section of the questionnaire revealed the following trends concerning the new aspects of next generation EPCs as described in D^2EPC

- The majority of the responses will find useful to receive real time information of their building's energy efficiency through an energy platform. Moreover, the majority of the respondents prefer a regular based issued EPCs compared to one-time issued.
- The 60 – 80% of the responses are positive for the integration of the new set of indicators (thermal comfort, smartness of building systems and environmental related indicators) suggested by D^2EPC for the next generation EPCs
- The D^2EPC GIS Tool which envision to visualize generated EPCs in a GIS environment is considered useful by the majority of the respondents.
- In general there is a positive tendency of users to allow access to energy related data however the neutral responses reveal that a considerable number of people may be concerned with security related issues.
- The majority of users have rated indoor thermal comfort conditions and air quality as the leading parameters influencing their rental or sale decisions
- Among different building aspects, the users would like to have more control of indoor thermal comfort conditions, Indoor air quality and building system's energy efficiency. There is no major preference of these options over the others.

5.1.4 Section 4: Visual aspects of next generation energy performance certificates

This section investigated which type of information and visualization type is preferred by the users. These questions target to improve user-friendliness of EPCs towards real understanding of EPC data and energy renovation options.

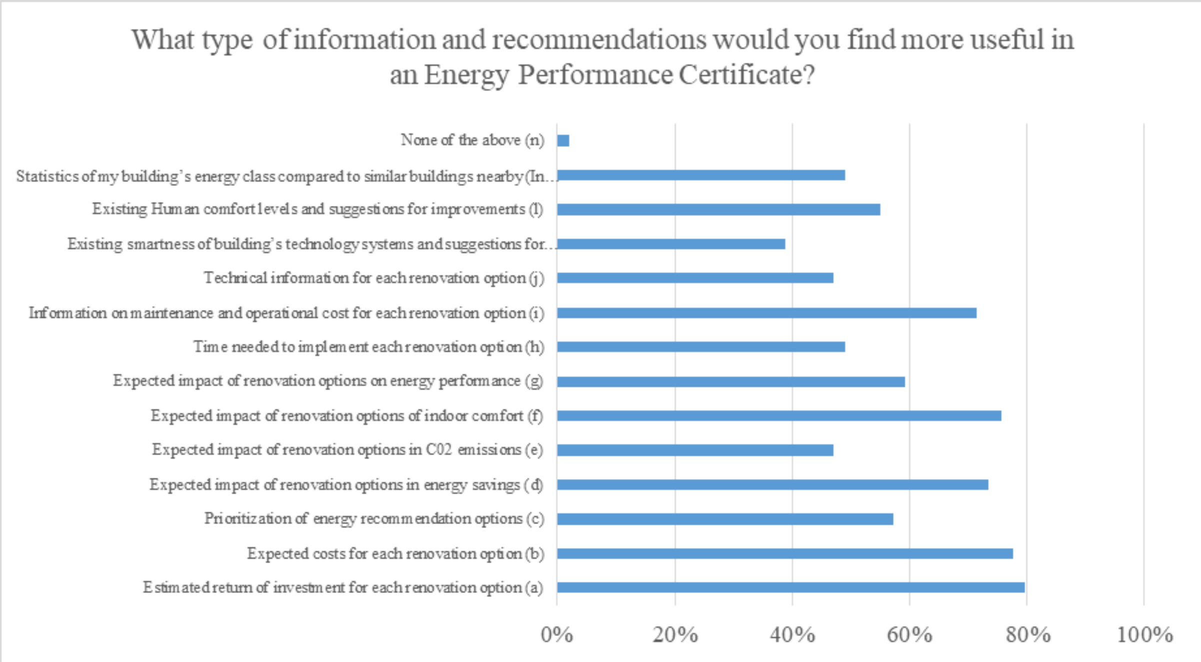

Figure 23. Perceived useful information to be presented on EPCs

This question investigated which information would be found more useful to be presented on an EPC based on the user's perspective. Even though the answers did not vary greatly, estimated return of investments and cost of renovation measures are the leading preferences according to Figure 23. The impact of renovation options on thermal comfort conditions as well as the information related to maintenance and operational cost of renovation measures are also among the most popular answers.

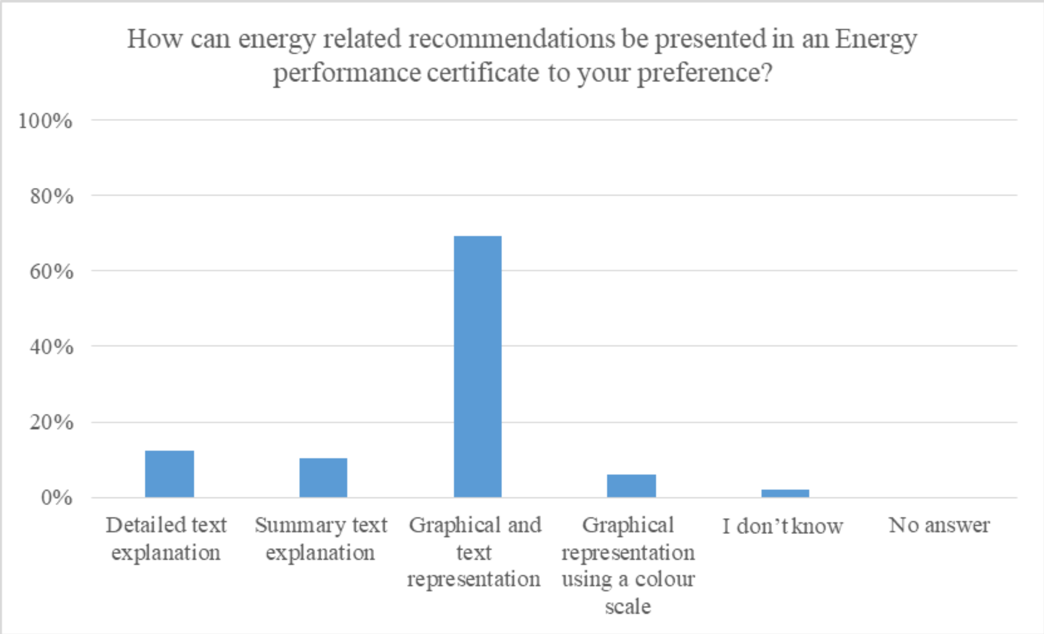

Figure 24. Presentation of energy related recommendations on EPCs

The visual representation of results in EPCs is one of the most important aspects contributing to the improvement of understanding of EPCs. This question investigated the users preference on how EPC data should be presented. For the majority of the responses, a combination of graphical and text representation is the optimal option. There is a need to take into consideration the variation of age groups as well as educational level of the users, therefore any information must be presented and explained in Layman's language.

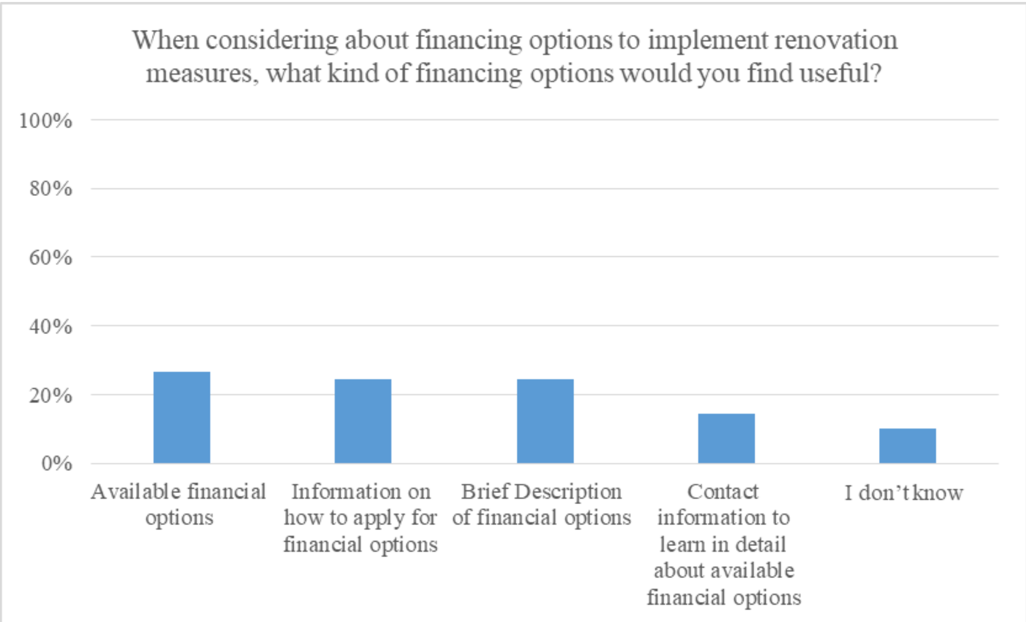

Figure 25. Preferred financing options for implementation of renovation measures on EPCs

This question investigated the preferred presentation type of financing options for implementation renovation measures. The responses did not reveal any major trend for this question however D^2EPC will investigate the possibility of introducing a combination of these options in a user friendly manner.

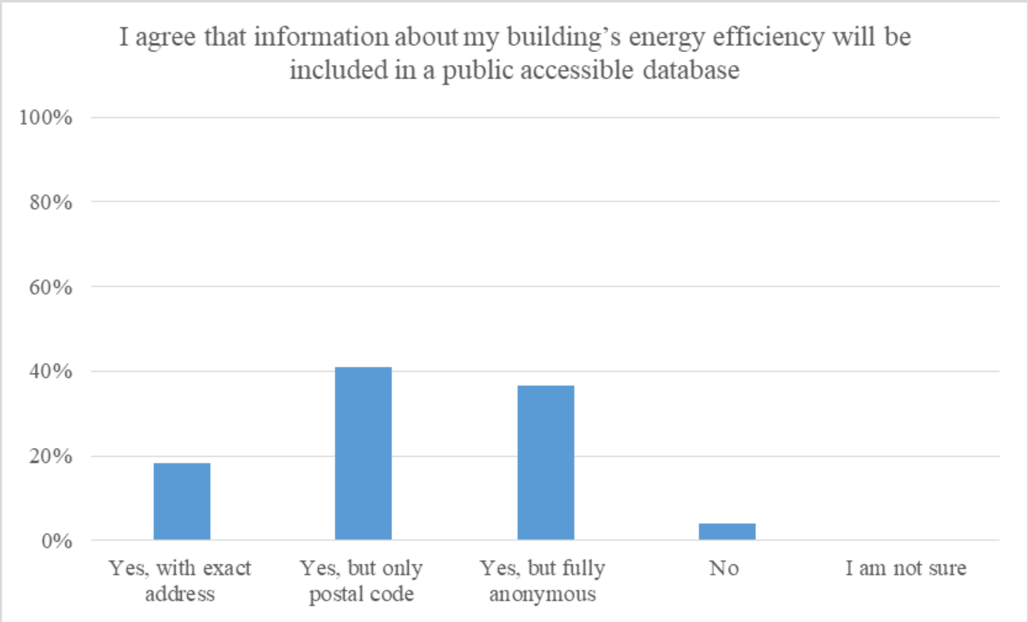

Figure 26. User's willingness to include building's energy efficiency in a public accessible database

Among the limiting factors related to interconnected smart solutions is the security related issues and data protection. Since D^2EPC envision the integration of GIS tool for the comparison of buildings energy efficiency, there is a need to examine the perception of users towards allowing access of energy related data in a public database. As show in Figure 26, the majority of responses are willing to allow access however avoiding exact location and personal data.

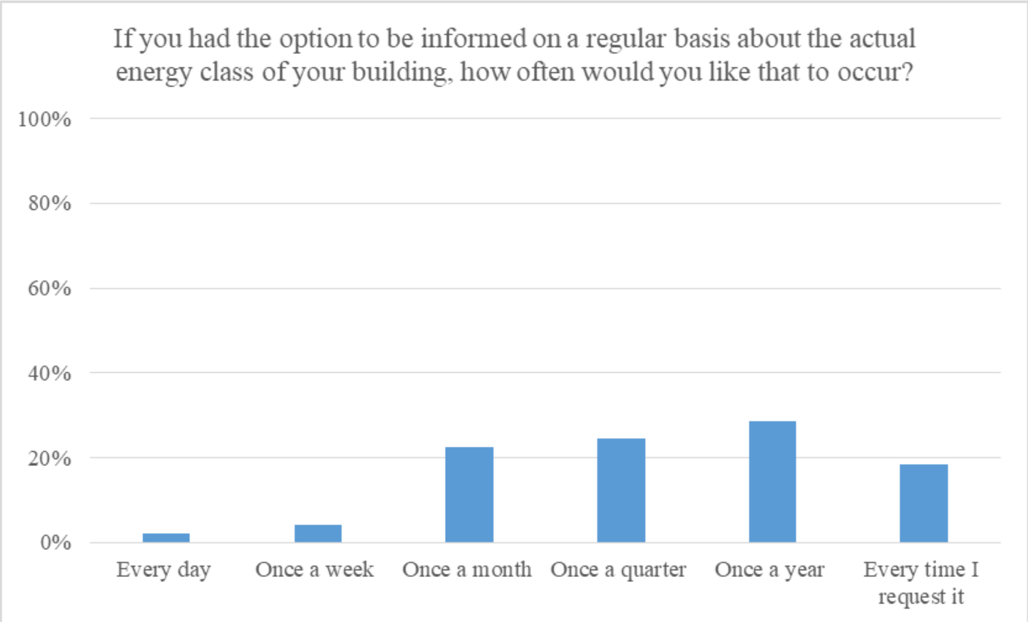

Figure 27. Preferred frequency of information on building's energy class

The dynamic concept of D^2EPC will give the opportunity to the users to be informed about the actual energy class of their buildings. This question examined the preferred frequency of information presented to the users. There are no major variations of responses however high frequency of once a day or once a week are not preferred. There is slight preference for the information to be presented once a year according to Figure 27.

Section 4: Conclusions

This section of the questionnaire shown the following trends concerning visualization aspects of new aspects of next generation EPCs as described in D^2EPC

- Concerning user's perspective on the information needed for EPC recommendations, the estimated return of investments and cost of renovation measures are the leading preferences according to Figure 21. Thermal comfort conditions as well as the information related to maintenance and operational cost of renovation measures are also among the most popular answers which are found useful be the respondents.
- The majority of responses prefer a combination of graphical and text representation of energy related recommendations in the EPCs.
- The financing options for implementing renovation measures should be presented on EPCs. The responses did not reveal any major trend for this question however D^2EPC will investigate the possibility of introducing a combination of these options in a user friendly manner.

The respondents express their willingness to provide their building energy efficiency data in a publicly available database as long as private data and exact location

5.2 Results - Technical stakeholder's questionnaire

Technical questionnaire identified the needs and requirements of technical stakeholders and policy makers concerning Energy performance certificates (EPCs). The interviewees were the stakeholders responsible for deploying the EPC service (Tool developers, EPC registries etc.) as well as service providers (ESCOs, Engineers, Building designers etc.).

5.2.1 Section 1: Accuracy of Energy Performance Certificates (EPC) Methodologies

Question 1: Do the methodologies used for the evaluation of the EPC effectively represent building's energy performance?

Opinions on the effectiveness of EPCs methodologies for the accurate representation of building's energy performance are divided. Negative responses support that EPCs represent accurately building's energy performance related to a standard use, but they are not tailored with the actual use of the building. Moreover, Simulations used in the methodologies are seen as inefficient at assessing individual apartments in multi-storey buildings. Answers justified a positive response when the methodologies are applied to buildings of a similar typology, for energy inefficient buildings where only basic technical systems are considered and if the results of an asset rated methodology are only regarded as theoretical. EPCs are considered effective for the representation of a new building's energy performance, whereas audits can be assigned to old and renovated buildings.

Question 2: Are there any drawbacks (eg omitted energy flows) in the methodology and the certified tools of the EPCs calculations?

The majority of respondents identified limitations in EPC methodology and calculation tools. The omission or use of default values for important energy consumers such as lighting systems, electrical appliances, internal gains and standardized behaviour does not reflect actual consumption. Answers describe an inability to accurately model dynamic processes due to incorrect input values of modern systems. Calculation methods for the evaluation of complex energy flows such as solar gains are considered to be ineffective, and by others, those energy flows that are omitted are considered negligible. Another drawback in the methodology is that after a building undergoes deep renovation, energy consumption modelled to building data of a new reference building may result in a lower energy rating than actual.

Question 3: What types of ratings are available in your country, asset, operational, or both? Which do you consider more effective and reliable?

This question investigated technical stakeholder's perspective on the accuracy of asset or operational methods for the issuance of EPCs according to the respondent's county of reference. Almost all responses for countries with an asset rated methodology considered the operational rated methodology to be more effective at calculating energy performance, especially for older buildings. Where asset rated methodology is used, operational methodology can be used to provide supporting evidence for certification and to indicate savings to EPC users. Where there is a lack of dynamic energy consumption databases, asset rating is seen as the most credible methodology. Operational ratings are credited with being reliable and asset ratings with being more accessible and easier to perform. Few responses considered the use of both methodologies as objective, expressing that separate ratings can be misleading.

5.2.2 Section 2: EPC Input data quality and transparency

Question 4: Do the procedures for collecting input data for EPCs result in reliable and accurate data?

Generally, current collection procedures are deemed reliable, however these procedures may subject to error by assessors based on their experience. An increased difficulty in collecting the input data of technical building components and mechanical equipment is highlighted. Moreover, the lack of architectural property drawings and other datasheets required in the full project documentation are often unavailable, incomplete or incorrect, making input data collection through desk review unfeasible. Assessors in this case, need to make a site visit in order to gather the required geometric information for the accurate design of EPC building models. In this end, assessors required time for the calculation of EPCs varies widely depending on the availability and accuracy of the available building data.

Question 5: Are there any advanced procedures for collecting data for EPCs in force? (e.g. digital logbooks, BIM documents, etc).

This question investigated the possibility of existence of advanced procedures for collecting data for EPCs. Advanced data collection procedures stated under this question include BIM and CAD, however some countries include such advanced procedures only with private market products. Emphasis is placed on the need for easy-to-use tools that recognize more building characters. A drawback to the implementation of advanced collection procedures is ever-changing building legislation that hinders the progress achieved under previous laws. Respondents highlight the necessity of achieving balance between ease of use, transparency and comparability of such advanced solutions.

Question 6: Could the transparency of EPC data enable energy efficiency improvements to the building users/owners?

EPC data applied for certification is too specific to be used by building owners to understand how their building is operating and implement energy efficiency improvements. More detailed EPC data, mandatory consulting following certification and an increased certification cost that reflects the credibility of the EPC system may have greater impact on energy efficiency improvements. The interests of both building operators and owners with regards to cost savings and energy efficiency must be reflected transparently in EPC data. General data protection laws that prevent the display of user owned consumption data hinder the further use of EPC data for energy efficiency improvements. EPC data is currently used effectively in energy efficiency renovation schemes.

5.2.3 Section 3: Quality control of energy performance certificates

Question 7: Are the independent control systems for energy performance certificates and inspection reports controls, implemented effectively?

Technical stakeholder’s perspective on the effectiveness of inspection control of EPCs are mostly limited to specific responses. The majority of responses support that independent control systems are not very effective since inspections are limited only to a small number of EPC controls. Moreover, there are less controls on site compared with controls performed electronically. Understaffed inspection directorates may be the reason for limited quality controls such as a significantly lower number of onsite inspections compared to desk reviews. Control systems that are not linked to user behavior are also regarded as ineffective at implementing comprehensive quality checks.

Question 8: Are there any novel practices in force for advanced quality control of the submitted EPCs?

There is currently a lack of novel practices for advanced quality control of EPCs. Available novel practices include automated quantitative verification. The quality controls in place are based on preliminary value ranges built on statistical data for different cases, then if a value falls out of the ranges there is a detailed check from energy experts. Advanced quality checks may be reserved for checking compliance with national funding schemes and building codes. It was highlighted that efficient quality control is sometimes overshadowed by many other priorities. There is a need for advance quality control methods which will check holistically the quality of EPCs.

5.2.4 Section 4: Scope of the EPC register

Question 9: Is the data collected in EPC registries sufficient for energy benchmarking and assessment of building stock energy performance?

There are mixed opinions about the sufficiency of EPC data for use in energy benchmarking and assessment of building stock energy performance. The data provided is regarded as suitable only for statistical purposes, whilst in some cases access to databases are not open to public or research purposes, prohibiting the assessment of building stock energy performance. Depending on the country, different types of EPC data are stored to the national/regional databases (calculation data, label data etc). Moreover, the store of data are regulated either in regional or national scale. In the cases of regional databases different type of data are gathered while the single database provides a uniform system that allows comparison.

Question 10: What additional information could have been included in the EPC registry, which would enable the improvement of the assessment of the building stock?

The data model should include additional fields such as input data, comfort evaluations, statistics of building and technical characteristics, e.g., HVAC systems; window orientation; and the fuel types used in these systems. Listing energy consumption by building age category would allow easier correlation to the applicable building performance legislation. Buildings could also be categorized by the profile and number of occupants/building users. For existing buildings, the inclusion of actual energy consumption data is recommended and for renovated buildings, the EPC could state what renovations were completed and when. Digital links to databases would improve monitoring building stock.

5.2.5 Section 5: EPC Policy Implication

Question 11: Which are the 'pollutant pay' practices in force, in case non-compliance is observed between the actual building's performance and its EPC class?

In polluter pay enforcement, the seller of a building can be sued for non-compliance due to an incorrect EPC during a transaction and an EPC assessor can incur penalties and fines. Polluter pay enforcement may be limited to non-residential buildings, and new or deeply renovated buildings where linkages to the electricity grid is prevented. Polluter pay practices are also contested with arguments about the responsibilities of both the user and the building designer, and the lack of a comparison tool to assess real consumption against the EPC. Respondents highlighted that there is no real assessment of the actual consumption in relation to the EPC.

Question 12: Are there policy programs in force that could dispense tools to the users/owners for monitoring their building energy performance?

Respondents pointed out the available policy programs in force for the monitoring of building energy performance. Where exist, consumers are eligible to apply for funding of such programs which are mainly focused on the provision of monitoring and control of technical systems. National funding schemes may support energy efficiency upgrades in residential buildings by subsidizing smart controls, BMS and automation systems. In cases that such programs are absent, consumers make use of commercial gas, heat and electricity meters.

Question 13: Should public authorities have the option to regularly monitor the actual energy performance of single buildings or of the building stock of a region or a district, are there any policies would you suggest that could be adopted and implemented?

Public authorities may monitor the energy performance of public buildings, or private buildings under request due to privacy protection. Real time sensors can be used to map microclimates and data can be obtained from energy providers. Actual energy performance must be monitored against achievable energy efficiency. A policy that registers energy data per VAT number, region and energy use may make monitoring feasible, it must also provide recommendations for reduced energy use. Economic advantages have also been cited to make monitoring feasible due to the high costs involved.

5.3 Summary of Stakeholder needs and Requirements

The following Tables present a summary of the identified needs and requirements from building users and technical stakeholders concerning nEPCs. The finding were summarized based on the findings of the stakeholder questionnaire as well as from the desk research conducted under this task.

Table 18 Summary of User Requirements

Users Requirements	Description
User-friendliness	The language used on the EPC must be simplified for easier understanding by an ordinary user.
Usability	• Information on a building's energy efficiency, comfort and cost savings, will impact the usability of EPCs as well as purchasing and rental decisions. • Valuable guidance for energy renovation measures is needed.
Security	• Security surrounding the use of IoT devices, sensors and building management systems. • Protection of sensitive data when sharing energy related data with third parties. • Exclusion of exact building location, i.e., only postcode, and personal data in a public database.
Incentives	Incentives for installing smart building technologies for housing companies, real estate agencies and users, especially those who are not owners of the building.
Real time information	Users value receiving information on the actual performance of their buildings via a real time platform.
Human-centric comfort indicators	Provision of Comfort indicators including thermal conditions, air quality, visual and acoustic comfort.
Environmental impact indicators	Provision of environmental related indicators
Understanding smart building technologies	There is a need to further educate and inform people about the advantages of smart technologies especially for older age groups.
Indication of building smartness in the EPC	Introduction of smart readiness indicators (SRI) in EPCs. Users will be informed on the ability of buildings to process information and communication technologies and electronic systems and to adjust building operation to needs of occupants and the grid.
Life Cycle Costing	Monetary indicators of the whole life cycle cost of heating, cooling, lighting and appliances.

Geo-location services	Visualization of generated EPCs in a GIS environment, empowering users to perform various types of spatial and attribute queries.
Control of building environment	User control of different building aspects especially indoor thermal comfort conditions, indoor air quality and building system's energy efficiency.
Visual Identity of EPCs	The use of a combination of graphical and text representation of information
Renovation measures	Information on estimated return of investments, cost of renovation measures, the impact of renovation options on thermal comfort conditions and information related to the maintenance and operational cost of renovation measures.
Renovation financing instruments	Available financing options presented with a brief description, application instructions or contact information, or a combination of any of these representations.
Indication of actual Energy class	The preferred frequency of building energy class indication ranges from annually, quarterly, monthly and upon request, with annually being the most preferred option.

Table 19 Technical needs and Requirements

Technical Requirements	Description
Dynamic simulation methods	Capability of assessing individual apartments in multi-storey buildings.
Defined building and system characteristics	• Defined input values for new technologies and systems. • Easy-to-use collection tools that recognize more building characters.
Reliability	Complementary energy audit for existing and renovated buildings, and to assess energy performance of non-standard building use.
Inclusion of energy consumers	Energy consumption of lighting systems, electrical appliances calculated by use of actual (non-default) values
Inclusion of energy flows	Internal gains calculated by appropriate means, e.g., solar gains.
Real time databases	• Dynamic energy consumption databases for operational rating. • Data from utility providers or public authorities.
Objectivity	Use of both asset and operational methodologies
Onsite data collection	Reduced delays by incorrect project documentation.
Conducive legislation	Legislative frameworks that advance prior regulations.
Transparency	• User-friendly EPC data, consultation with EPC owner and an increased certification cost. • Both building operators and owners informed about savings and efficiency.
Database accessibility	Authorization of further processing of user owned consumption data.
Advanced control	Prioritization of quality checks linked to user behavior and more onsite inspections.

Comparability	Through national EPC databases and a pan-European EPC database.
Database expansion	• Adaptation of data model to include input data, comfort indicators, statistics of building and technical characteristics, system fuel types, accompanying actual energy consumption and renovation dates and details where applicable. • Categorization by building profile and number of occupants.
Connection	Digital links to other databases
Responsibility	Polluter pay penalties for both user and the building designer after verification using a comparison tool to assess real consumption against the EPC.
Building monitoring	Through policy that registers energy data per VAT number, region and energy use.

6 Challenges and recommendations for next generation EPCs

6.1 Challenges and limiting factors for next generation EPCs

EPC databases represent an important source of information about the energy consumption of the built environment. However current challenges associated with EPC practices hinder the usability and credibility of these data. In order to achieve the expected impact on the building sector and be well received by the public audience, high quality of EPCs is a prerequisite. The following challenges concerning current EPCs were identified:

Quality of EPC data: EPC calculations can use default input data and building-specific data, or they can be based solely on specific building data. To this end, the performance gap ranges between estimated and actual energy performance are hindering EPCs reliability. According to the findings of the user and technical questionnaire, the perceived accuracy of EPCs vary significantly. Specifically, 40% of the end-users rated that EPC does not effectively represent their building's energy performance as shown in Figure 6. Moreover, around half of technical experts who answered the questionnaire believe that EPC calculation methodologies may result to inaccurate data. Many EPC ratings evaluate theoretical performance or design intent without measuring actual energy consumption. For example, minor systematic errors and the use of 'average sizes' for walls and rooms and other imprecise measurements, quickly add up to potentially significant variations from the actual buildings performance. The substantial irregularities between the EPC and real energy demand prohibits policymakers from planning future strategies efficiently.

A human-centric certificate: Current EPC schemes do not consider thermal and human comfort aspects related to occupant well-being in inhabited spaces. However according to the analysis of the user questionnaire, more than 80% of the responses consider human comfort indicators as highly valued and desired (Figure 16). Moreover, the revised EPBD (2018/844/EU) requires the integration of human centric elements to the energy performance calculations, which will provide to the building the ability to adapt its operation mode in response to the needs of the occupant. According to the user's perspective, Indoor air quality and thermal comfort conditions were rated as top priority for property rental/sale decisions (Figure 22). Current practices should be extended and introduce a set of additional novel indicators, which will turn the energy certificate into a more user-friendly and informative document, covering different aspects of the energy and comfort performance of buildings

Software credibility and quality: Software used for the calculation of EPCs can lead to different ratings due to the set of algorithms used or various time step for analysis. Although building digital design processes have been improved in the previous years, most of the EPC software used in EU MSs are based on simplified architecture. Moreover, in most cases, EPCs calculation is not combined with any building energy performance simulation for the design of the HVAC equipment and buildings thermal comfort, but they perform simplified calculation paths. These practices make it more difficult to ensure the quality of the EPC calculation procedure and introduce additional design steps, of questionable quality.

Limited information on the actual energy performance of buildings: Current practices follow the issuance of Energy performance certificates at the early stages of the building construction. This methodology fails to present the actual energy behaviour of the building over time. The actual energy consumption of buildings through smart meters will offer several of possibilities for integrating building management systems and digital twins into the certification process. According to the user's questionnaire, around 60% of the respondents would found useful to receive information on the actual performance their buildings via a real time platform (Figure 14). There is a clear preference on the regularly calculated EPC compared to one-time issued EPC (Figure 15).

Insufficient information to building users and limited user-friendliness: The information provided by the EPC to the building users is currently of limited use and lacks basic explanatory features. Aspects such as thermal and acoustic comfort, indoor air quality and daylight which are among the primary drivers for buildings renovation, are not considered in current EPCs. According to the user questionnaire, there is a need for enhancement of the information provided by the EPC to the building user, in terms of simply interpreted indicators. Even though there is a basic understanding of EPCs among various age groups and educational levels, some respondents commented that the language used on the EPCs is too complicated or not easy to understand (Figure 5). On the same time, the recommendations for energy upgrade are automatically generated by a standard list (e.g. increasing insulation, replacing windows etc.) and do not offer a user-friendly document which would motivate renovation.

Assessor's subjectivity during calculation procedures: EPC calculation procedures are highly depended on assessor's experience and therefore EPC delivery process can be subjective. Given that most EPC calculations rely on a range of standard inputs or default inputs, data quality can be easily influenced by the energy assessors because of the standard assumptions made in the process of producing the certificate. Moreover, according to technical stakeholder's questionnaire, usually lack of appropriate technical documents required for the full project documentation could lead to inaccurate EPC results.

EPCs as an active part of smart city concept: Smart buildings and smart cities constitute a major challenge for the construction industry for the decades to come. Energy efficiency certificates should incorporate and disclose to the users, information related to the building's intelligence. The requirement to integrate Smart Readiness Indicators (SRI) into the energy calculation procedure is also a requirement of the latest EPBD recast. More than 60% of the users would like to know the smartness level of their buildings and if their technical systems adapt to their operational needs (Figure 17). The opportunity: Industry 4.0, digitisation of cities and the increasing ubiquity of data have facilitated an intensive development of massive datasets and data streams associated with the urban environment. Digitalization of the process of EPC issuing and the integration of intelligent infrastructure in the certification process would support harmonization of EPC data collection, enable automatic upload to a central database and simplifies the statistical analysis of data from a technical perspective. Moreover, the use of advanced design models and tools such as Building Information Modelling (BIM), as well as digital twins based on cutting edge monitoring technologies would turn EPC into a tool which would enable holistic technical, economic and environmental approaches for the environmental design of sustainable buildings. Linking the design process with the calculation process by integrating BIM, can significantly speed up the EPC issuing process, reduce potential mistakes and better represent the functional and physical properties of a building. Simultaneously, the valuable data contained in EPC registries can be utilized as an information tool for profiling the energy status of the current EU building stock, induce the decision for building renovation and facilitate energy policy and decision making.

6.2 Recommendations and Guidelines for next generation EPCs

This section provides a detailed list of recommendations for the successful implementation of the project based on the specific objectives of D^2EPC. These recommendations were resulted from the detailed analysis of users and technical questionnaires as well as from the desk research conducted under this task. It is important to note that recommendation list is not exhaustive since understanding of needs and requirements are continuously growing and will be expanded throughout the duration of the project and according to the feedback from stakeholder engagement. The recommendation and guidelines targets 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 novel set of indicators covering environmental, financial, human comfort and technical aspects of new and existing buildings
- The issuance of EPCs based on real-time data and advanced BEPS tools integrated into BIM

- The integration of smart readiness indicators into the building's energy performance assessment and certification
- Intelligent operational digital platform for dynamic EPCs issuance and real-time building performance monitoring and improvement

Establishment of an operational dynamic EPC issued on a regular basis

Although 14 EU MS established operational EPCs based on real data, this method failed to take into consideration the user behaviour and how this can impact the energy class of the building. A general view of EPC assessors in most MS is that the thermal characteristics of the building envelope and technical systems installed, form the basis of evaluating the energy performance of the building. The impact of building users' behaviour on the energy consumption of the building is not regarded as significant. Moreover, technical stakeholders pointed out current EPCs omit important sources of energy consumption such as lighting systems or electrical appliances. Based on these findings, there is a need to define the required framework for a holistic approach of the regular energy classification of buildings, based on their operational performance. Trends identified though the user's questionnaire, shows a preference towards an EPC issued on a regular basis compared to a one time issued EPC as well as the willingness to receive information on the actual performance their buildings via an energy platform. The implementation of such user-centric features will foster the energy saving consciousness of buildings' users, through their regular information on the actual energy performance of their buildings. Moreover, 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 of EU MSs building stocks. In this manner a more active role of next generation EPCs into policy making will be enabled.

Establishment of EU standards on the classification requirements of buildings

Since the onset of the EPBD in 2002, numerous standards have been published and amended, aiming to simulate and predict the energy performance of the EU MSs building stock on the design stage. According to the research findings, countries in the EU are able to select EPC calculation methodologies that best suit their needs whilst adhering to current CEN and EPB standards. 14 MSs use asset rating as the energy performance methodology, to make use of operational rating, and 13 MSs, including the UK, use a combination of calculated and measured rating. The resultant EPCs produced by each member state may not be comparable in order to provide valuable information about the overall state of EU building stock, monitor progress towards energy performance goals set in the EPBD or develop energy efficiency policy. The next generation EPC scheme should be based on the relevant EU standards and the Energy Performance of Buildings Directive, in order to allow for an EU-wide deployment. There is a need for the development of a new set of standards which will enable the concept of the dynamic EPC through the integration of real time monitoring data into buildings energy performance simulation paths. One of the main objectives of D^2EPC is to conclude to a specific series of proposals and measures to be used for the update of the ISO/CEN standards developed under Commission mandate M/480.

Establishment of novel set of indicators covering environmental, financial, human comfort and technical aspects of new and existing buildings

Although EPCs should be indicator-oriented documents aiming to foster the reliability, user-friendliness and cost-effectiveness of energy certificates across Europe, current practices lack presenting such information effectively. Currently, a combination of human comfort indicators are used in calculation procedures in some MSs, whereas, others omit these indicators entirely. Based on the findings of the user questionnaire, there is a strong indication that indicators related with sustainability, smartness, comfort and finance are highly desired and valued. There is a need for the establishment of indicators which will turn the energy certificate into a more user-friendly and informative document, covering different aspects of the energy and comfort performance of buildings. Next generation EPCs should adopt indicators which cover environmental, financial, human comfort and technical aspects of new and existing buildings, aiming to simplify the understanding of buildings energy performance and to present a more comprehensive overview of the actual energy performance of buildings.

The issuance of EPCs based on real-time data and advanced BEPS tools integrated into BIM

Current EPCs are issued based on public or private software and in accordance on the legislation and requirements of the EU MSs. Although the effectiveness of available software cannot be questioned, there is a need for harmonization of state of the art practices of Industry 4.0 digital tools with the EPC issuance procedures. Industry 4.0 advancements offer cutting edge monitoring technologies which can be exploited to allow real time integration of measured data into the calculation process of EPCs such as BIM and IoT/smart meters. Next generation EPCs should bridge the technological gap and enable the realization of digital twin practices in the calculation processes, making use of available and increasing number of building energy related data from sensors, smart meters and connected devices. The use of advanced digital construction design tools will contribute to the improvement of the effectiveness of certificates, by demonstrating how these could be strengthened, modernised and best linked to the user needs and requirements.

The integration of smart readiness indicators into the building's energy performance assessment and certification

Smart readiness indicator (SRI) introduced by the 2018/844 directive, as a part of demand-side management strategies in an effort to raise awareness among users for the adoption of building automation and monitoring for building technical systems. SRI was designed to measure the capability of buildings to process information and communication technologies and electronic systems to adjust building operation to needs of occupants and the grid, thereby, improving the energy efficiency and overall performance of buildings. Next generation EPCs should establish the required framework for the calculation of 'Smart readiness' based on a list of building smartness level parameters which will allow comparable, good quality EPCs, in order to instil trust in the market and incite investments in energy efficient buildings. The assessment criteria of 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.

Intelligent operational digital platform for dynamic EPCs issuance and real-time building performance monitoring and improvement

The potential of EPCs to develop user awareness on sustainability depends on the build of trust as a reliable energy information tool. Current EPC schemes are based on a cradle to site rationale, completing their mission after the delivery of the certificate to the building user, while energy upgrade recommendations are automatically generated by a standard list and do not offer a user-friendly document which would motivate renovation. There is a need to extend EPCs applications and usability while providing a valuable tool to the users which will motivate renovation. Next generation EPCs should include provision of customised recommendations for energy performance upgrade as well as provision of performance forecasting tools in order to coordinate the operation of building's assets in the optimal comfort and efficient way. Further to that, next generation EPCs should offer extended applications that include comparing buildings with the performance of other buildings in more than one normalised metrics as per user request.

All of the extracted challenges, limitations and recommendations are also taken into account when delivering the D^2EPC scheme in the context of activities performed in T1.3. Finding from this report will also act as drivers for the architectural design of the D^2EPC framework within activities of T1.4, with a more complete list of requirements being documented in D1.4.

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ANNEX A: User and Technical stakeholder questionnaires

End-User's Questionnaire

Base questions: all respondents

BQ1 Pleased provide your Country

BQ2 Please provide your gender

BQ3 Please provide your age

BQ4 Please provide your level of education

BQ5 Type of user: Building owner/tenant/real estate agent

Section 1: Understanding of current Energy Performance Certificates

Please provide your opinion on the following statements on the current Energy Performance Certificates.

Q1 In your opinion, is the Energy Performance Certificate an easy-to-understand instrument to indicate the energy efficiency of a building?

a) I understand exactly what is stated in the Energy Performance Certificate
b) I understand most of what is stated in the Energy Performance Certificate
c) I somewhat understand what is stated in the Energy Performance Certificate
d) I don't understand anything state in the Energy Performance Certificate

- **Q2 In your opinion, how accurately the Energy Performance Certificate represents your building's energy efficiency?**

a) Very accurately
b) Accurately
c) Not so accurately
d) I'm not sure

Q3 Energy related information provided by the Energy Performance Certificate convinced me to upgrade my building systems

a) Absolutely, I have already did it
b) I thought about it
c) Not really
d) I'm not sure

Q4 The Energy Performance Certificate plays a major role in my purchasing/rental decision

a) Strongly agree
b) Agree
c) Neutral
d) Disagree

Section 2: Understanding/Adoption of Smart building technologies

Q5 How well will you rate your understanding on smart building technologies?

a) I am familiar with smart building technologies
b) I have some understanding of smart building technologies
c) I have heard of smart building technologies, but not really understand
d) I am not familiar of smart building technology concept

Q6 How smart is your building?

a) Very smart (Building management system or +10 IoT/sensors devices installed)

b) Somewhat smart (5-10 IoT/sensors devices installed)
c) Not very smart (0-5 Iot/sensors devices installed)
d) I am not sure

*Smart devices are any type of IoT/sensor/measuring device which can monitor and/or optimise the building's energy or comfort related performance

Q7 would you like your building to be smarter or more connected?

a) My building is already smart
b) Yes, I would like to have a smart building
c) Not really
d) I don't know/I'm not sure

Q8 How likely are you to consider install smart building technologies in your building?

a) I already have installed smart building technologies
b) Very likely
c) Not very likely
d) Unlikely

Section 3: New aspects of Energy performance certificates

Please provide your opinion on the following questions concerning potential aspect of a new Energy performance certificate (EPC). To what extent do you agree or disagree with each of the following statements?

The dynamic concept

Q9 I would like to receive real-time information on the actual energy performance of my building on an energy platform

Not sure	Disagree	Neutral	Agree

Q10 If I implement building energy renovation measures, I would like to see the impact of such measures on the energy consumption of my building

Not sure	Disagree	Neutral	Agree

Q11 I would find more useful an Energy Performance Certificate issued on a regular basis based on real time data compared to an one time issued Energy Performance Certificate

Not sure	Disagree	Neutral	Agree

Next generation Energy Performance Certificate indicators and geolocation services

Please provide in which extent you would like to see the following indicators in an Energy Performance Certificate.

Q12 I would like to see in an Energy Performance Certificate more human comfort related indicators for my building (air quality, thermal conditions, etc.)

Not sure	Disagree	Neutral	Agree

Q13 I would like to see in an Energy Performance Certificate the 'smartness' of my building systems and whether they are adapted to my operational needs

Not sure	Disagree	Neutral	Agree

Q14 I would like to know the environmental impact of my building systems throughout their lifecycle

Not sure	Disagree	Neutral	Agree

Q15 I would like to know the whole Life cycle cost* of my systems/appliances in my building

Not sure	Disagree	Neutral	Agree

*Life cycle cost (LCC) is an approach that assesses the total cost of an asset over its life cycle including initial capital costs, maintenance costs, operating costs and the asset's residual value at the end of its life.

Q16 I would find it useful to know the energy performance score of other buildings nearby

Not sure	Disagree	Neutral	Agree

Q17 I would consent to allow energy related data access to third parties if they provide information on how to reduce energy related costs

Not sure	Disagree	Neutral	Agree

Please rank the following aspects according to your personal level of importance using the scale

1 Extremely important 2 Very Important 3 Neutral 4 Not very important 5 Not important

Q18 If I would buy or rent a building, how important will be these aspects for my decision:

Indoor thermal comfort conditions	
Energy efficiency of building systems	
Assessment of smartness of building technologies	
Indoor air quality	
Visual comfort	
Acoustic comfort	
Environmental impacts of building systems	

Q19 What areas of your building would you like to have more control of?

a) Indoor thermal comfort conditions (heating, cooling, ventilation)
b) Indoor air quality ($C0_2$ concentrations, air quality, etc.)
c) Energy efficiency of building systems (how much energy they use)
d) Acoustic comfort (noise levels)

Section 4: Visual aspects of next generation energy performance certificates

Q20 What type of information and recommendations would you find more useful in an Energy Performance Certificate (Multiple options available)

a) Estimated return of investment for each renovation option
b) Expected costs for each renovation option
c) Prioritization of energy recommendation options
d) Expected impact of renovation options in energy savings
e) Expected impact of renovation options in $C0_2$ emissions
f) Expected impact of renovation options of indoor comfort
g) Expected impact of renovation options on energy performance
h) Time needed to implement each renovation option
i) Information on maintenance and operational cost for each renovation option
j) Technical information for each renovation option

k) Existing smartness of building's technology systems and suggestions for improvements
l) Existing Human comfort levels and suggestions for improvements
m) Statistics of my building's energy class compared to similar buildings nearby (In a GIS map)
n) None of the above

Other:

Q21 How can energy related recommendations be presented in an Energy performance certificate to your preference?

a) Detailed text explanation
b) Summary text explanation
c) Graphical and text representation
d) Graphical representation using a colour scale
e) I don't know

Other:

Q22 When considering about financing options to implement renovation measures, what kind of financing options would you find useful?

a) Available financial options
b) Information on how to apply for financial options
c) Brief Description of financial options
d) Contact information to learn in detail about available financial options
e) I don't know

Other:

Q23 I agree that information about my building's energy efficiency will be included in a public accessible database

a) Yes, with exact address
b) Yes, but only postal code
c) Yes, but fully anonymous
d) No
e) I am not sure

Other:

Q24 If you had the option to be informed on a regular basis about the actual energy class of your building, how often would you like that to occur?

a) Every day
b) Once a week
c) Once a month
d) Once a quarter
e) Once a year
f) Every time I request it

Q25 What do you believe would be the best use of a dynamic Energy Performance Certificate?

Free text

Q26 What aspects of your business/personal life would be improved/enriched through a dynamic Energy Performance Certificate?

Free text

Technical Questionnaire

Instructions to respondents:

Please answer all 12 questions, based on the practices applied in your country/region.

Energy Performance Certificates (EPC) Methodology

The EPBD recast (Art.3) provides guidance for Member States regarding the EPC calculation methodology, in accordance with EU standards. Annex I to the EPBD states that the energy performance of buildings can be evaluated on the basis of the calculated (known as asset rating) or actual energy consumption (known as operational rating). At the same time, the rating needs to reflect the energy needs associated with a typical use.

Q1 Do the methodologies used for the evaluation of the EPC effectively represent building's energy performance?

Q2 Are there any drawbacks (eg omitted energy flows) in the methodology and the certified tools of the EPCs calculations?

Q3 What types of ratings are available in your country, asset, operational, or both? Which do you consider more effective and reliable?

EPC Input data quality and transparency

The quality of input data for the calculation process is an important determinant of the quality of the results [BPIE, 2010]. To obtain sufficient information to calculate energy performance levels (i.e. asset rating methodology), a qualified expert needs to have access to at least the full project documentation and/or conduct an on-site inspection of the buildings (when possible).

Q4 Do the procedures for collecting input data for EPCs result in reliable and accurate data?

Q5 Are there any advanced procedures for collecting data for EPCs in force? (e.g. digital logbooks, BIM documents, etc).

Q6 Could the transparency of EPC data enable energy efficiency improvements to the building users/owners?

Quality control of energy performance certificates

The control system for the energy certification scheme is one of the key aspects that have been improved with the EPBD recast (Article 18) 41. Following the Directive, Member States shall establish an independent control system and verify "a random selection of at least a statistically significant percentage of all the energy performance certificates issued annually"

Q7 Are the independent control systems for energy performance certificates and inspection reports controls, implemented effectively?

Q8 Are there any novel practices in force for advanced quality control of the submitted EPCs?

Scope of the EPC register

Although there is a lack of requirement for MS to establish EPC registries/databases, most countries developed National or/and regional operational databases. The EPC data and information gathered are uploaded and stored in these databases. The register format varies between Member States from a simple folder structure with an electronic copy of the EPC to advanced SQL databases.

Q9 Is the data collected in EPC registries sufficient for energy benchmarking and assessment of building stock energy performance?

Q10 What additional information could have been included in the EPC registry, which would enable the improvement of the assessment of the building stock?

EPC Policy Implication

EPCs can be a valuable source of information regarding energy efficiency of National building stock, but can also be an important tool to evaluate and monitor energy related policies. Energy Performance Certificates are major contributors to EU and National environmental targets on the building sector.

Q11 Which are the 'pollutant pay' practices in force, in case non-compliance is observed between the actual building's performance and its EPC class?

Q12 Are there policy programs in force that could dispense tools to the users/owners for monitoring their building energy performance?

Q13 Should public authorities have the option to regularly monitor the actual energy performance of single buildings or of the building stock of a region or a district, are there any policies would you suggest that could be adopted and implemented?