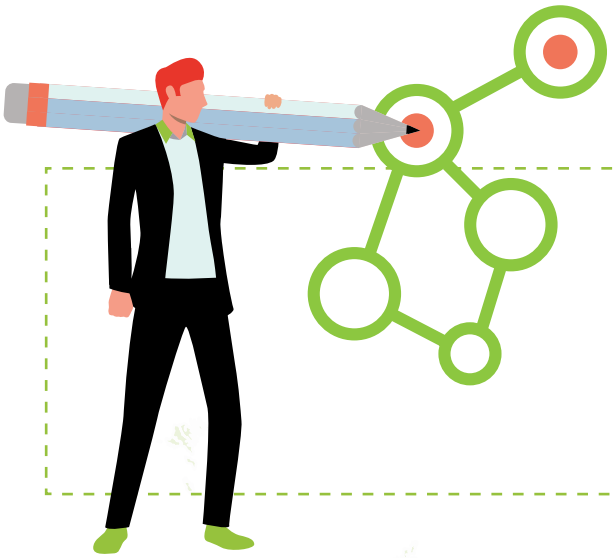
X-tendo



FEATURE 6:

EPC DATABASES

Implementation guidelines and replicability potential of the innovative features for the next generation EPCs

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 845958.

BPIE

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CONTENTS

EXECUTIVE SUMMARY

Energy performance certificate (EPC) schemes have not evolved much since their first introduction in the Member States to meet the mandatory requirements set out under the Energy Performance of Buildings Directive (EPBD). With the recent revision proposal of the *EPBD* it has become more important to focus on EPCs critically and increase their usability for stakeholders. Stakeholders have questioned their reliability but at the same time, they have been useful for the real estate industry. All the Member States have legislation in place and existing infrastructure or systems to run EPC schemes. These schemes must evolve with the changing needs of the built environment and consider elements such as enhanced indoor comfort, reducing air pollution and financing options. This should occur alongside energy consumption analysis giving impetus to renovation rates of Member States towards achieving EU 2050 decarbonisation goals for the building sector set out under the *European Green Deal.* Public authorities view EPCs as potential instruments to improve the performance of existing building stock and deeper renovation. Extending the functionalities of existing EPC systems will create several pathways to update and manage next-generation EPCs.

This report presents the implementation guidelines and replicability potential of ten innovative features proposed within X-tendo: (i) smart readiness, (ii) comfort, (iii) outdoor air pollution, (iv) real energy consumption, (v) district energy, (vi) *EPC databases*, (vii) *building logbook*, (viii) *enhanced recommendations*, (ix) *financing options*, and (x) *one-stop-shops*. The outcome of this report is a critical presentation of the barriers and drivers for each feature's wide uptake, their impact if implemented by Member States and the necessary next steps in order to implement the innovative features in certification schemes around Europe. The developed features were tested in nine countries: Austria (AT), UK-Scotland (UK), Italy (IT), Denmark (DK), Estonia (EE), Romania (RO), Portugal (PT), Poland (PL) and Greece (GR). Then the experts who tested them provided deeper insights, appropriate directions and policy perspectives which provided a realistic estimation for its implementation and replicability across different Member States. The replicability potential is mainly analysed based on qualitative information collected from previous investigations in the project and extensive focus groups within project implementing countries. However, an estimation of the quantitative effects of the implementation of innovative features into the EPC schemes is also performed for X-tendo countries based on the results of the testing activities together with use of a building stock model.

Some general conclusions derived for all features include:

- New or revised EPCs must not be burdened with a lot of new information for the end-user. Information on the first page must be prioritised for the end-user application. Thus, which information is presented on the EPC (on paper) and which on the digital EPC or digital building logbook (DBL) should be considered.

- Automation and simplification of procedures is necessary in overcoming major issues regarding interoperability and data exchange.

- User-friendliness of features is highlighted as one of the most important drivers during tests of all features and more research is needed in this regard, because so far, the features were tested with experts, not with end users.

- EPCs must be coherently linked to other instruments such as DBL and building renovation passports to increase their impact.

- Training is required for some features to upskill and improve the competence of the workforce responsible for delivering EPCs. Some features do not require training at all, while others have either simple or complex methods that require different training needs.

- All the features are compatible for different building typologies. For some features, X-tendo developed two calculation methods, one is more simple and requires low effort, while the other is complex and more reliable. Each method can fit different building typologies (e.g. a detailed SRI is needed for large commercial buildings whereas CARP and CORP can be used for school, office and residential buildings).

X-tendo features were developed from this perspective to empower the end-user with more information and help them take necessary actions for renovation. All the features have been found to have relevance in the test countries with differences in needs and application. The X-tendo project has identified a series of recommendations for policy uptake and formulation that would be beneficial in the implementation of new features:

- Establish simplified procedures at MS level to update the EPC with new features followed by individual and detailed studies at national level.

- Recognise the strengths of existing EPC best practices and provide necessary resources for the transfer of knowledge from front runner countries. Use this process to adapt new features for EPCs.

- Conduct detailed assessments of existing EPC input data and prioritise new features with significant overlap of data input with EPCs. In addition, prioritise outputs relevant to the end-user on the EPC. Information relevant for public authorities can be made available on the attachment or DBL.

- Promote the implementation of new features using market and non-market mechanisms to raise awareness among the public and other relevant stakeholders.

- Conduct cost-benefit analyses at a national level to determine the feasibility of features and their economic impact to build trust in markets.

- Carry out selective implementation and independent pilot studies in national contexts to support MS individual policy goals.

- Set up more ambitious and rigorous quality check mechanisms in EPCs, the EPC database and check consistencies within and between databases.

- Require businesses to work on creating an environment and enabling conditions to support job creation and increase investments in renovation with features such as DBL and OSS.

1 INTRODUCTION

This report brings together the outputs of the evaluation of the test projects (T5.2) alongside the insight from end-users and stakeholders gathered in WP6 (Communication and Dissemination) and from end-users in WP2 (Exploring the principles of next-generation EPCs), and include estimations of:

1. The barriers and drivers for the wide uptake of each of the 10 features.
2. The effects (in quantitative and qualitative terms) of the wider implementation of the developed innovative features of EPCs in Europe.
3. The necessary next steps in order to implement the innovative features in the certification schemes around Europe, in particular assessing staff and training needs.

The replication potential is mainly analysed based on qualitative information collected from previous activities in the project and extensive focus groups within project implementing countries. However, we have also estimated the quantitative effects of the implementation of innovative features into the EPC schemes, based on the results of testing activities in the previous task (T5.1 and T5.2) together with the use of a building stock model. An assessment has been carried out on the potential future number of EPCs with the innovative features developed throughout the course of this project. It forms the basis for the identification of the capacity-building implications for delivery bodies, particularly staff and training needs.

Table 1 provides an overview of the 10 innovative features developed in the project X-tendo and tested by partners with relevant expertise in 9 countries: Austria (AT), UK-Scotland (UK), Italy (IT), Denmark (DK), Estonia (EE), Romania (RO), Portugal (PT), Poland (PL) and Greece (GR).

Based on the methodologies of the developed features, three different test categories were used:

- **In-building testing:** In existing buildings this involved testing the new features in use by assessing the time required and viability to collect new data points as part of, or in addition to, a conventional EPC assessment. This process also involved the systematic collection of qualitative data from EPC assessors and building owners/managers on their view of the new process/indicator.
- **Systems testing:** This involved development work with EPC database operators or public authorities to assess the technical and practical viability of the new features. It considered time and cost implications, integration with existing systems, access to data and data privacy issues.
- **User testing:** Surveys were carried out with specific end users or stakeholder groups to understand the usability of the new features.

Table 1 - Overview of features and implementing partners

Feature number	Innovative feature	Feature lead	Implementing countries
1	Smart readiness	VITO	AT (IB), EE (IB/expert), GR (IB), RO(IB)
2	Comfort	BPIE	AT(IB), GR (IB/expert), PT(IB), RO(IB)
3	Outdoor air pollution	NAPE	PL (IB expert)
4	Real energy consumption	VITO	AT(IB), EE(IB), IT(IB), RO (IB/expert)
5	District energy	E-think	DK (expert), IT(IB), PL(IB), RO(IB)
6	EPC databases	TU Wien	DK (S), GR (S), IT(S), UK (expert)
7	Building logbook	BPIE	EE (U/S) , GR(U/S) , PT (expert)
8	Enhanced recommendations	TU Wien	AT (expert), DK (IB), PL (IB/S), UK (IB)
9	Financing options	ADENE	DK (U/S), PL (expert), PT (U), RO (U/S)
10	One-Stop-Shops	ADENE	DK (U/S), PT(U/S/expert), RO (U) , UK (U)

IB: In-building test; S: System test; U: User test, expert: supporting partner with existing expertise

2

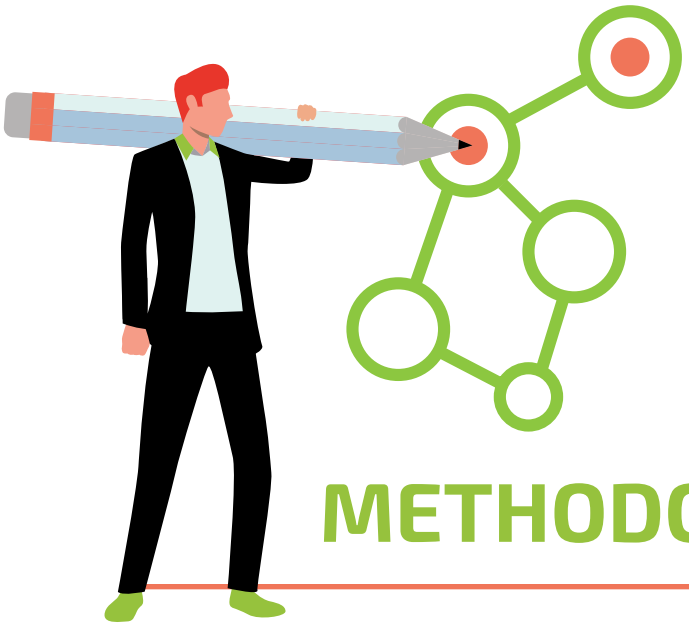
OBJECTIVE OF THE REPORT

This report on the implementation guidelines and replicability potential of the 10 innovative features has been prepared to consolidate useful information to guide public authorities, energy agencies and other relevant stakeholders in the enhancement of EPCs. The report supports the project results' replicability and implementation in different Member States of the EU.

Therefore, the objective of the report is twofold:

1. Provide implementation guidelines for public authorities for the 10 X-tendo features.
2. Estimate the replicability potential in quantitative and qualitative terms.

The implementation guidelines are mainly structured as barriers and drivers for each feature. The identification of the replicability potential is based on qualitative information and quantitative estimations of the potential number of EPCs that will – in future – incorporate the innovative features. Finally, we identify the necessary next steps to implement the innovative features in certification schemes across Europe.



3 METHODOLOGY

Implementation guidelines and replicability potential in this report were prepared through an iterative process of filtering and refining the information and data collected through different project activities. This includes findings from the viewpoints of all relevant stakeholders.

These are briefly described below:

1. **Methodologies and concepts for all features:** Approaches and methods used for the development of the ten features in the X-tendo project [1][2].

2. **End-users needs and perspectives:** A stakeholder survey comprising homeowners, buyers, tenants, sellers and landlords was conducted in 5 European countries (Poland, Portugal, Greece, Romania and Denmark) with 2,563 participants to investigate their needs and identify the relevance of the new features [3]. Interviews and focus groups were also conducted with relevant stakeholder groups for some features to collect their preferences during testing.

3. **Cross-cutting criteria:** The principles used to guide the development and testing of the features for next-generation energy performance certification ensure (i) Quality and reliability, (ii) User-friendliness, (iii) Economic feasibility, and (iv) Consistency with ISO/EN standards [4].

4. **Introductory reports for 10 innovative EPC features:** Brief reports describing the basic concepts, highlight existing cases or best practices, and outline the first steps for implementation [5]–[14].

5. **Evaluation and documentation of test projects:** Monitoring and results reports to assess the practical viability and impact of the ten features. This includes detailed evaluations of the features after testing conducted in nine test countries [15]–[24].

6. **Experience sharing web-calls:** Views gathered from stakeholder representatives within the consortium and from the advisory board.

7. **Workshops and webinars at EU level:** Stakeholder engagements conducted by the test countries with local and national stakeholders to evaluate and receive feedback on the features during their development at EU level.

8. **Online meetings between partners for each feature:** Review of evidence and data collected in the project relevant to each feature with extensive discussion on the replicability potential of each feature.

9. **Estimation of quantitative impact for wider implementation:** Analysis using a building stock model to study the impact on renovation rates of the ten features in Member States. A detailed methodology is described further in this section.

The inputs were analysed to identify drivers and barriers that impact the uptake of each feature. The effects (in quantitative and qualitative terms) of the wider implementation were also analysed for the developed features of EPCs in Europe. Based on these, the necessary next steps were outlined in order to enable their implementation in certification schemes around Europe. To ensure an impartial assessment for replicability, the findings for each feature were triangulated using feedback from testing partners, feature developers and stakeholders.

Methodology for estimation of quantitative impact due to wider implementation

To estimate the quantitative impact of a wider implementation of the 10 features an assessment was conducted for the 10 X-tendo countries using the building stock model. To estimate the impact several trigger points were identified when EPCs can or need to be issued in the X-tendo countries. These trigger points are:

- New building construction
- Major building renovation
- Building sales (if no valid EPC available)
- Renting out (if no valid EPC available)
- Other (e.g. the interest of the building owner in improving the energy performance of the building)

The reference for the above trigger points is drawn from Art 12/1 of the EPBD (2018/844) [25] which states that 'Member States shall ensure that an energy performance certificate is issued for: (a) buildings or building units which are constructed, sold or rented out to a new tenant; and (b) large public buildings'. In Art 17 of the proposed recast EPBD, this is extended to "building units which are constructed, have undergone a major renovation, are sold or rented out to a new tenant or for which a rental contract is renewed".

The different EPC features developed in the X-tendo project will have a different response to the identified trigger points in each Member State. This is due to factors such as public acceptance, real estate needs, market interests, investments, existing state of EPC system etc. The relevance of each trigger point for each feature mentioned above are presented in detail in Table 13 of Annex 1. These trigger points are used to calculate the number of annually issued EPCs until 2030 using historical data of issued EPCs (2014-2019) in the 10 X-tendo countries. The number of EPC end-users potentially interested in a certain feature was determined by estimating the share of interested end-users per trigger point and feature. For the 2030 projection, it was assumed that the number of tenants, real estate transactions and new building constructions follow the same linear trends as in the past 10 years.

More details on calculation method are presented in *Annex 1*.

FEATURE 6: EPC DATABASES

4.1 Overview

EPC databases store all EPCs and underlying data. They are an important tool for public authorities to source building stock information and check compliance with the national assessment methodology. Quality assurance processes and data verification are key to ensure the reliability and accuracy of the information stored in the database.

EPC databases have, so far, been voluntary for Member States. Most Member States have now set up databases, but the approaches vary from country to country. While some countries only collect the input data about the building (in part extracted from an XML file, for example), others go further and perform the EPC calculation within the registry. Some Member States store the detailed input data required to generate the EPC, while others collect a PDF copy of the certificate but no data. In all cases, it is highly relevant to store all EPC data and, preferably, to provide authorised stakeholders with easy access to relevant information. The database has different potential uses, such as data mining for country/sector reports, interoperability with other databases and publication of market-relevant information to different stakeholders: building owners, construction companies, real estate actors, public authorities, etc. The database can become a powerful instrument for public authorities, if used to identify and target homes where renovation support is most urgently needed, as in the case of Scotland.

In this direction, the proposed EPC database methodology focuses on the development and implementation of routines, which are able to identify outliers and to validate EPC data. This consists of a four-step approach, starting right after the EPC is logged in the database:

1. First check: "gross" threshold value check.
2. Second check: "narrow" threshold value check.
3. EPC flagging: indication of inconsistencies per EPC.
4. Feedback loop to energy auditor: identify and indicate commonly made mistakes and communicate to energy auditor training courses.

The first action required for the successful implementation of the EPC database methodology is programming the code that will perform the verification checks. An automatised interface between the national EPC database and the core code is developed, allowing the extraction of the EPC data; this interface and the data format will be country specific.

4.2 Key insights from testing

Table 7 - Test projects summary in implementing countries for EPC databases

Country	DENMARK	ITALY	GREECE
Type of Testing	System testing	System Testing	System Testing
Number of testing cases	138 EPC data	Approximately 2 million of EPCs in the Italian National EPC Database	Number of checks: 460,000
Tool	Risk based testing	Software code developed in X-tendo	Data mining software & software code developed in X-tendo
Testing Period	01/01/2019 - 31/12/2019	01 2021 - 03/2022	06/2021 - 12/2021

The system testing was conducted on Danish, Italian and Greek EPC data.

The test in Denmark on EPC data from 2019 indicated the benefits of a risk-based control scheme regarding successful hits, outcomes, resources etc. and provides possibilities of using the results in the EPC scheme. The purpose of the control is to identify EPCs with errors in the input parameters, or EPCs showing indications of possible errors in the input parameters. The risk-based control showed a total of 319 errors on input parameters across all 138 EPCs chosen for a manual check from a total of 8233 EPCs. The risk-based control was applied on parameters over ventilation, air tightness and windows/doors. Four directions could be considered to establish a complete feedback loop in the EPC scheme for enhancing the EPC data:

- Increase the information on the role of the EPC consultants in performing EPCs for new and existing buildings e.g. through webinars or technical newsletters.
- Regular evaluation of education of EPC consultants and upskilling opportunities.
- More validation checks of data to avoid errors and mistakes (e.g. digital and automatic control of input parameters).

The test in Greece showed that a considerable percentage (about 13%) of the 460,000 EPCs were not useful for this kind of detailed analysis, due to incompatibilities between the various EPC processing software applications used by energy experts.

Therefore, as first learnings from the testing activity, it is as an absolute priority to develop standards based, machine-readable definitions of the XML format used by the national EPC calculation. From the remaining XML files, a small percentage (about 6%) was found to violate elementary data quality rules (1st level check). A statistical analysis was performed on the same sample of EPCs, yielding parameter values to identify EPC outliers (2nd level check) with regards to similar buildings and about 12% of the sample were found to be outliers in at least one parameter. It is proposed by Greek experts that an EPC failing a 1st level check should lead to an error, while failing a 2nd level check should lead to a warning message to the EPC expert when uploading the XML file in the EPC registry. The EPC assessor can then decide if any action should be taken. Moreover, the second level checks can be used to identify faulty EPCs for further check by the EPC registry administrators.

In Italy, the National Italian EPC Database was tested on a "test environment" database containing nearly 2 million EPCs. The software code was used to perform two levels of checks: (i) 1st level checks, which control the presence and the correct data typology of 46 chosen parameters (i.e. global energy performance for renewable and not renewable energy, energy label, etc.), and (ii) 2nd level checks, which control that the values of 11 parameters (i.e. global energy performance for renewable and not renewable energy, etc.) are within a range defined by a certain percentile value, calculated by ENEA considering the EPCs present in the database. This level of checks aims to identify possible significant differences from the bulk of the EPCs stored in the database.

- The major challenge in Italy is the high execution time of the code. With the actual code execution time, it is possible to run it on the whole database only a few times in a year.

- Special attention must be paid to the definition of the rules. When defining 1st level rules, it is very important to avoid interdependencies with involved "critical" parameters.

- Through post-processing of the output provided by the code, it is possible to identify the faulty EPCs, the riskiest building clusters, and the parameters presenting the highest number of non-compliant EPCs.

4.3 Drivers and barriers for a wide uptake of the feature

4.3.1 Calculation method and quality assurance

The implementation and improvement of EPC databases include aspects such as how to set up an EPC database, how to gather the data, how to establish the interoperability of different databases, and how to use data and extract relevant insights from it. Finally, ensuring the reliability and accuracy of the information stored in the database through quality assurance processes and data verification remains a key requirement common to all EPC schemes. The EPC database feature in X-tendo focuses on defining and establishing routines and analyses for quality control of EPCs in the EPC Databases. One of the main drivers is that the methodology can be applied to any EPC database, national or regional and is replicable to other countries. However, the main condition is that the EPC data is automatically updated through an appropriate file format (for example, XML). EPCs in a PDF format do not allow the data to be automatically read. Also, the method is replicable to other countries but country-specific adaptations, such as the choice of parameters to be checked, are necessary. The modular interface between the core code and the EPC database allows for the code structure to be easily adapted to specific countries.

Some of the identified barriers include:

- Manually controlling and correcting (if necessary) the EPC is not part of the scope of this methodology. This can be overcome by creating override mechanisms that are more controlled in databases. The outcome of this methodology can help to select the EPC, that will be manually verified, based on a riskiness of the EPC (and not randomly, as done in many Member States.

- Possible fault categories for the final EPC score are defined with different levels of their gravity: very serious, serious or less serious faults. These definitions need more explicit details based on Member States databases.

In Denmark, data is automatically transferred to the national EPC database. It has already tested and implemented the concept of an automatised EPC database analysis, and the results were also used to provide feedback on how to improve education programs for energy auditors and other professionals responsible for issuing EPCs. This learning from Danish experts supported the development of the EPC database feature. Greece and Italy implemented and tested the new EPC database feature for the first and second level verification checks that were used to flag EPCs.

In Italy, both in the national and in the regional databases, EPCs are stored as machine readable data. In the national EPC database, only data present on the certificate is stored. At a regional level, it depends on the region/autonomous province: in some regions a wider set of data is stored in the regional database, whereas in other regions only the data present on the certificate is stored. The databases are not currently interoperable and the official level for EPCs control is regional.

In Greece, there are no issues with data upload, but there is an issue with verifying the uploaded data and the calculation engines. There are inconsistencies which make the use of data problematic. Theoretically, the data is available, but in practice the data does not show reliable results due to the fact that data is structured in different ways with different software used.

4.3.2 Social drivers and barriers (occupants/owners' perspective)

Often EPC databases have restricted access and are not publicly available for different stakeholders. Quality assurance of the EPC databases using the developed feature can contribute significantly to improving trust in EPCs. This feature has some of the main barriers that restrict its availability in public domains:

- The GDPR is highlighted as the main barrier in giving access to end-users and other beneficiaries in most of the countries. Partial access is often a solution however, different opinions exist in the interpretation of the regulation.

- The feature is not directly relevant for end-users but more so for public authorities. There is interest in the public availability of data on areas at the municipal level.

Italian experts highlighted that not everyone in public authorities has access to the database, only permitted personnel are allowed to access it due to GDPR issues and thus testing presented no issues. In Denmark, the GDPR applies only to information that is identifying with a person. There is no issue in releasing information about the building and there is no confidential information about it. For all experts it was more feasible to test the feature without any major issues since all of them are EPC database managers. However, in Greece there are limitations regarding access to data which is not accessible to the public and special permission is needed from the Ministry. Even public authorities have restricted access to the data, like in Italy.

4.3.3 Construction sector (upskilling, construction industry, investors, developers etc.)

An EPC database has different potential uses, such as interoperability with other databases and publication of market-relevant information to different stakeholders: building owners, construction companies, real estate actors, public authorities, etc. To be able to provide these uses, EPC databases must inherently provide support to test these functionalities. Among the main drivers are the provision of automatic verification checks performed by experts with a good knowledge of IT and big-database handling and statistical analysis skills. Expert programming knowledge is essential for database management. This is required to execute the code and provide quality assurance checks.

In Italy, due to the GDPR, only permitted personnel are allowed to access the national database's microdata. At a provincial level, some aggregated data and some statistical analysis are publicly available. Similarly in Greece, the database is not easily accessible and requires special permission from the authorities to conduct any statistical analysis. However, the EPC database has been in operation for more than 10 years and stakeholders of the market (both professionals in the field and building owners are well aware of the issuance process and of the features of the database). In contrast, Denmark is quite flexible towards granting access to its public database for testing purposes.

4.3.4 Economic and market drivers and barriers

Code structure that does not entail additional investments in the update of EPC databases can be easily adapted to specific countries. With the shift in the real estate and construction industry, several stakeholders are becoming more aware of the potential use of these databases to seek opportunities in the renovation sector. Often these databases are useful in developing products and conducting feasibility analyses. Stakeholders and experts see that there are opportunities for the market to exploit these databases. However, this strongly depends on the level of information that would be available for commercial or public use once the new EPBD 2021 recast is implemented in Member States.

4.3.5 Consistency with existing policies and standards

The EPC database feature would contribute to a higher quality of EPCs in the database and would support all the other aspects in EPBD like Building Stock Observatory, building renovation passports, building logbooks, and also includes the Minimum Energy Performance Standards. All aspects are closely related to the question of quality checks which are foreseen in the EPBD. There is a further need to harmonise the quality assurance standards that should be applied in all the countries. With improved data quality, data can be better used for benchmarking or for the implementation of policies. For this purpose, the data should be more reliable and relevant to the building logbooks. To enable effective EPC databases, an interface between the national database and the developed code must be implemented. This interface would allow the inputting of EPC information into the core programming code. If needed, the code can be translated to other programming languages. However, the code may become obsolete if the necessary conditions are not met.

In some regions of Italy (e.g. Lombardia, Piemonte, Valle d'Aosta) EPCs are considered as support to plan local energy policies. While in Greece, the EPC databases are used in conjunction with other databases such as land registry, tax authority etc. Denmark considers that the quality of data is relevant for future policies, such as the building logbook. However, in their investigation with public stakeholders they identified that more data is required than the existing one in the EPCs for policy purposes. It is also important that all data collected during the issuing of the EPC is available as aggregated data. In Denmark some of the data is not made accessible in tables and this can make data extraction more complicated than necessary.

Compatibility with the EPC scheme

The principal method is replicable to any other country, but the concrete implementation is very much tailor-made. It is not possible to directly take the code as some effort is needed to tailor it to technical implementation:

- Providing an EPC quality control and assurance routine is important so that EPC data is readable for computer systems and accessible to users. Storing PDF documents is not sufficient.
- Public bodies in Member States need quality compliance methods and this feature would support this.

Italian experts found the code is fit for the structure of their national database. The EPC database feature is a good basis to start updating EPC systems. Every region in Italy has a regional database. The property of EPC data is regional and data in each regional database may be very specific; data processing for the whole country is based on a reduced dataset, common to all regional databases. Denmark already has a running risk-based control system thus, the feature was tested on enhancing the functionalities of their database. In Greece, the national database is under only one ministry and thus the algorithms were tested without any major issues.

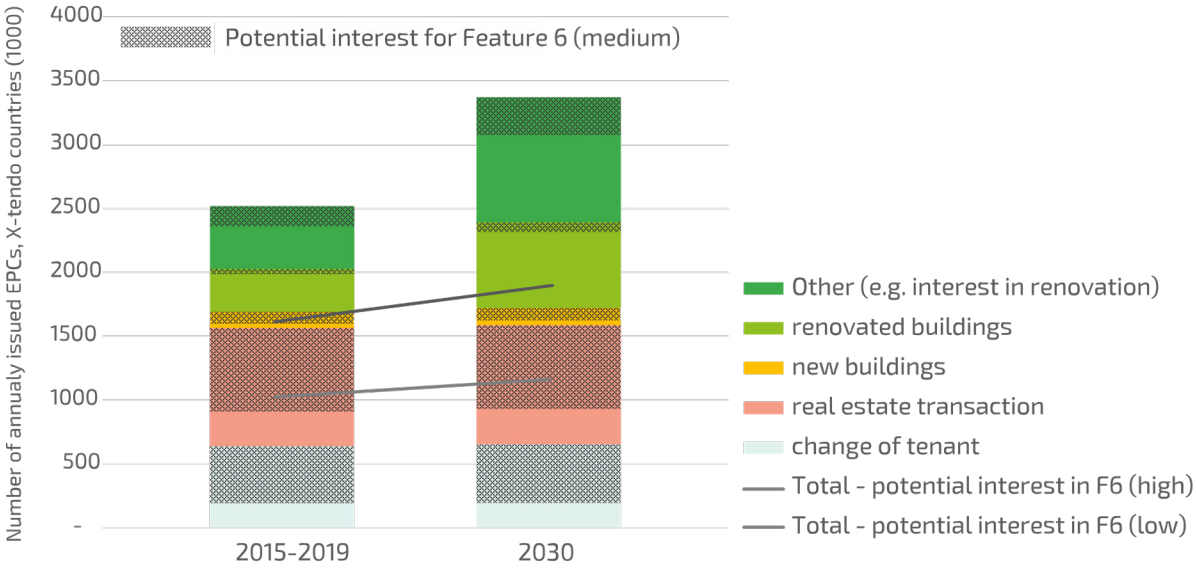
4.4 Estimation of the quantitative replicability potential

In this chapter, an estimation on the quantitative replicability potential of this feature is provided in the X-tendo countries. This follows the methodology described in section 3. *Figure 7* shows the number of annually issued EPCs by the different trigger points in the X-tendo countries. In the period 2015-2019, about 2.5 million EPCs were issued annually. The largest part resulted from real estate transactions, followed by new building construction, while EPCs due to the change of tenant and building renovation according to available data and the chosen assumptions have lower relevance. In shaded colours, the figure shows the share of EPC end-users which potentially show special interest in this feature, according to the factors determined in *Table 13* and *Table 14*[7] in *Annex 1*. A high relevance is assumed in particular for 'new buildings', 'real estate transactions' and 'change of tenant', leading to a range of 44%-64% of all EPC-end-users showing potential interest in the results of the EPC databases feature. The total number of interested EPC end-users for all trigger points is estimated to about 1.11 – 1.62 million in the base year which may increase to 1.23 – 1.91 million EPC-end-users in the year 2030, as indicated by the grey lines. However, in contrast to other features, it should be noted that the quality assurance measures developed for EPC databases refer to indirect use for EPC-end-users.

The bandwidth (low-high) results from two factors: (1) The potential interest of EPC-end-users was assigned by categories, each representing a range, for example 20-40% of EPC-end-users are estimated to be interested. (2) The interest may differ significantly between the buyer and the seller, in particular in the case that a building does not perform very well according to a certain indicator. Thus, for the "lower" case, a lower value of interest (typically the interest of the seller) is assumed, whereas for the "higher" case a higher value (typically representing the interest of the buyer) is considered. For Feature 6, no strong difference in the interest in the EPC databases is assumed for the buyer vs. the seller. Thus, the difference results only from the bandwidth of the estimation.

[7] The shaded areas (labelled as medium) in Figure 8 were derived as the average of the low/high range depicted in Table 14.

Figure 7 – Number of annually issued EPCs by trigger points and the estimated share of potentially interested EPC end-users, total of X-tendo countries (Feature 6). Historical data 2015-2019, projection until 2030.



4.5 Next steps for implementationl

4.5.1 Calculation method and quality assurance

Both in national and regional databases, EPCs are stored as machine readable data. Thus, Italian experts recommend that the EPC database must be set up in machine-readable formats. Danish experts advised that the next steps would need more focus on visualisations while making provisions for feedback. They also intend to make additional checks, for example, if an EPC assessor made several EPCs on the same date in various locations within long distances. It can also provide material for training or put a limit on the number of EPCs per day. Italy identified that the tool can be used at the regional level and in different Member States. Some parameters can be chosen to check, for example, not only to say that this EPC is wrong but to highlight outliers beyond the percentile. It is unlikely that all the regions will start using this tool, but it can be useful to harmonise the different databases. Greek experts consider it to be useful to notify the EPC assessor, as a warning, if a value is beyond a certain percentile. Such a system will have to identify common mistakes in data entry to provide information for the training sessions.

4.5.2 Capacity building for delivery bodies and training needs for assessors

It is important to clearly communicate the quality assurance results to energy auditors in a structured way, therefore contributing to their training and skills development. Concepts must be developed on how to apply the results from the EPC database quality control to educate energy auditors/consultants. Public authorities need a joint effort of professionals with IT (python) and engineering, data analysis and/or statistical knowledge skills and mixed teams are necessary to improve the existing EPC databases. The target group are the experts at the EPC database authority for the EPC database feature. In the long term, the easy use of the database will encourage all stakeholders to access the information, improving the quality of the construction sector.

4.5.3 Political discourse/ Market and end-user awareness

Researchers are interested in this database. For public authorities it is essentially important for policies. There is not much interested from the from the homeowner in the databases, rather only in their own EPCs. Since the trust on EPC quality is low, there is no interest at the moment from the market and they rely more on energy audits. The database does not contain data that is interesting for the SMEs, since there is no information on building components.

4.6 Conclusions

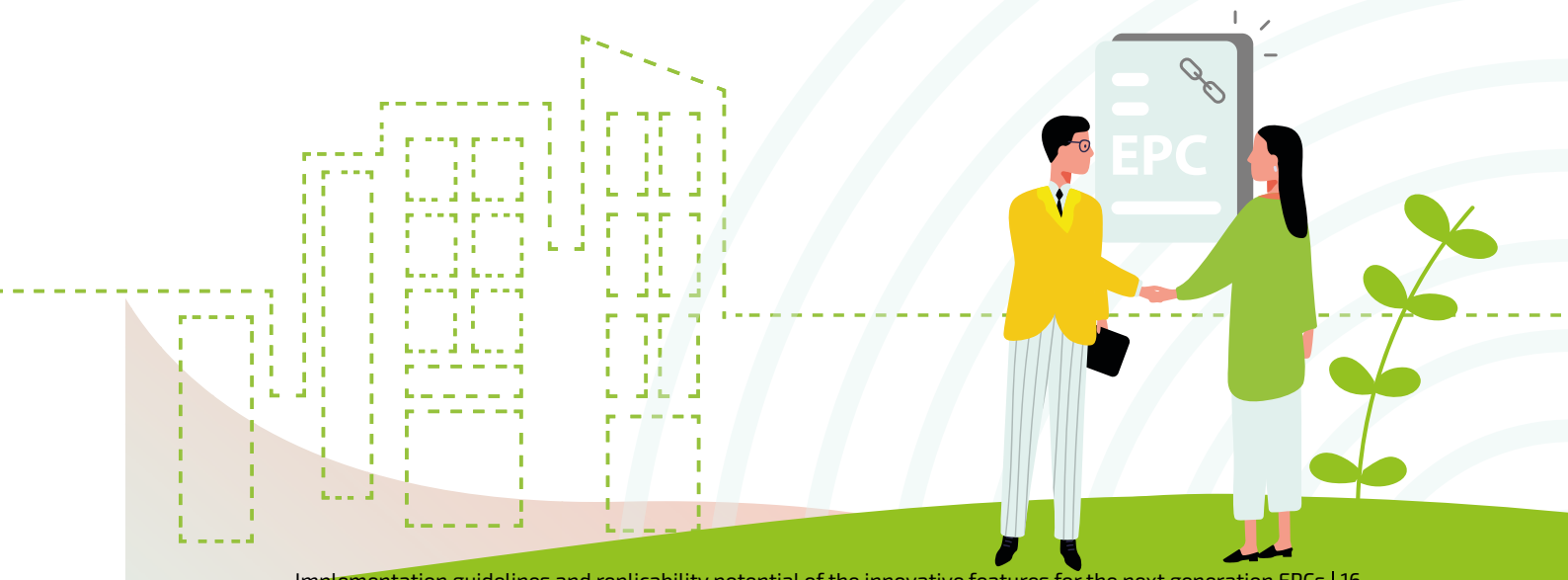
Article 19 in the proposed revision of EPBD 2021 [25] makes it mandatory for each Member State to set up a national database for the energy performance of buildings, to allow data to be gathered on the energy performance of the buildings and on the overall energy performance of the national building stock. There is more emphasis on making the database public in compliance with EU and national data protection rules. It is also expected that Member States exchange data with the Building Stock Observatory once a year. To ensure coherence and consistency of information, Member States are required to make their databases interoperable and integrated with other administrative databases containing information on buildings, such as the national building register and digital building logbooks. This X-tendo feature is directly linked to the Annex VI of the revised EPBD, where independent control systems for energy performance certificates are highlighted together with a validity check of inputs data including an on-site check, maximum deviations from energy performance of buildings and differing elements from defaults that should be evaluated for the issued EPCs. The X-tendo EPC database feature has developed robust quality check mechanisms that could support a systematic risk-based quality control of completed EPCs. The outcomes from the verifications can define the threshold values to be implemented on on-site checks for issuing EPCs and if integrated with a feedback loop to the energy auditors and EPC issues, can improve the EPC issuing practices. Based on the impact assessment for this feature, the total number of interested EPC end-users for all trigger points is estimated to about 1.11 -1.62 million in the base year which may increase to 1.23 -1.91 million EPC end-users in the year 2030. In contrast to other features, it should be noted that the quality assurance measures developed for EPC databases, are in any case, of indirect use for EPC-end-users. That is why there is not a significant increase in EPC end-users due to the implementation of this feature which is of higher interest and relevance to public authorities.

Key takeways:

- The EPC database feature is directly linked to the Annex VI of the revised EPBD, where independent control systems for energy performance certificates are highlighted together with a validity check of inputs data.
- The feature has robust quality check mechanisms that could support a systematic risk-based quality control of completed EPCs.
- The feature includes a feedback loop to energy auditors and EPC issuers, to improve the EPC issuing practices.
- The feature is designed for public authorities and therefore, it is not of high direct relevance for EPC end-users.
- Application of the code structure does not entail additional investments to update EPC databases and can be easily adapted to specific countries.
- Expert programming knowledge is essential for database management and it is required to execute the code and provide quality assurance checks GDPR is highlighted as the main barrier in giving access to EPC data for end-users and other beneficiaries in most of the countries.
- The developed methodology can be applied to any EPC database, national or regional and is replicable in other countries.

Key action points:

- Develop useful visualizations while making provisions for feedback in databases.
- EPC databases must be set up in machine-readable formats



5

CONCLUSIONS AND POLICY RECOMMENDATIONS

Overall, the ten features developed and tested in the X-tendo project provide a promising direction to advance the existing EPC schemes. It would not only support taking necessary measures for enhancing the energy performance but extend it beyond that as well. Provision of information to owners and tenants as well as relevant market actors is necessary to give a push to renovation rates and depths across the EU. Each feature aims to enrich the EPCs with such information that enables decision-making by stakeholders. The features developed in the project were tested in X-tendo countries and then the experts who tested them provided deeper insights and appropriate directions, drivers and barriers investigated from social, economic, market and policy perspectives which provided a realistic estimation for its implementation and replicability across the different Member States. Quantitative impact assessments using the trigger points for each feature were conducted to evaluate the impact of feature implementation in terms of increase in share of EPCs. While it is clear that most of the features are directly useful to the end-user, others are meant for quality assurance such as EPC database, tracking progress by public authorities such as district heating, and planning and setting targets for environmental policies using the outdoor air pollution feature.

Each feature is distinct in its application and entails careful planning for its implementation across the Member States. Findings stated thereof in this report from the X-tendo countries are promising and could be replicated in other Member States after careful evaluation in the context of their existing EPC regime. The developed features are provided in the form of a toolbox for public authorities so that it enables effective implementation of more than one feature in the update of the EPC system. All the features build on existing EPC data with additional data inputs that may entail additional training for EPC assessors.

Some key general conclusions derived for all the features are:

- An underlying need for all the features is the establishment of the right conditions and quality assurance of EPC databases at national level giving access to public and other relevant stakeholders.

- New or revised EPCs must not be burdened with a lot of new information for the end-user. Information on the first page must be prioritised for the end-user application. Thus, it should be considered which information is presented on the EPC (on paper) and which on the digital EPC or DBL.

- New features must not overload the assessor's work because it risks the quality, cost and reliability of EPCs.
- Automation and simplification of procedures are necessary for overcoming major issues regarding interoperability and data exchange.
- User-friendliness of features is highlighted as one of the most important drivers during tests of all features and more research is needed in this regard, because so far, most features were tested with experts, not with end users.
- EPCs must be coherently linked with other instruments such as DBL and building renovation passports to increase their impact.
- Training is required for some features to upskill and improve the competence of the workforce responsible for delivering EPCs. Some features do not require training at all, while others have methods, either simple or complex, with different training needs.
- New features must be voluntary in the initial stages of implementation and should be integrated once they showcase acceptance and demand in the building sector.
- All the features are compatible for different building typologies and construction periods. Some features have two calculation methods, one more simple and less reliable, while the other is more complex and reliable. Each method can fit different building typologies (e.g. a detailed SRI is needed for large commercial buildings, CARP and CORP of the comfort tool can be used for school, office and residential buildings).
- Calculation methods were adjusted for individual test countries. However, this presented challenges in different aspects such as missing databases to complete calculations, measurement issues, regional restrictions due to Covid-19, etc.
- All the features have the potential to increase the uptake of renovation if implemented, however, this varies for features that are more directed toward public authorities.
- Stakeholders consider GDPR to be a major barrier for many of the features. Therefore, it requires careful evaluation at Member State level for successful implementation, since it can be shown that the understanding of GDPR issues in the context of EPC data is very different in different EU Member States.
- It is important to establish partnerships and alliances between public and private stakeholders to overcome the market barriers and enable affordable solutions for the implementation of the features.
- Some features demonstrate a marginal increase in cost burden for the end-users of EPC, while some need specific mechanisms to be set up to function (e.g. enhanced recommendations, EPC databases).

Achieving a balance between targets, standards and support measures is necessary to achieve the decarbonisation of the building sector and EPC is a promising policy instrument capable of advancing the EU in this direction. The revised EPBD emphasises that better coverage of the building stock with EPCs is a precondition for its improvement, but at the same time Member States would need to ensure that they are affordable. It also mentions that the EPC should provide additional information to the owner or tenant to foster renovation of the building sector. This would provide a necessary push to unlock private and public funding and subsidies.

X-tendo features were developed from this perspective to empower the end-user with more information and help them take necessary actions for renovation. All the features have been found to have relevance in the test countries with differences in needs and application. Experts found that all the data gathered by the new features is highly relevant for public authorities, but not all outputs are relevant to the end-user. They stressed the importance that the EPC should not lose its main focus and purpose (energy performance) and other outputs can be provided in the DBL.

National policies are framed under the regulations set out in EPBD, thus the X-tendo project has identified a series of recommendations for policy uptake and formulation that would be beneficial in the implementation of new features. These have been compiled below after rigorous development and testing of features in the X-tendo countries.

Next steps for a successful implementation

Plan and prepare mechanisms to link EPCs with new instruments such as Building Renovation Passports, DBL and SRI.

Revise EPC calculation methodologies with a vision to integrate new features developed following the European Standards.

Set up independent control systems to ensure data for EPCs is of high quality.

Ensure that the EPC schemes are in line with more ambitious EU and national goals and targets.

Promote the implementation of new features using market and non-market mechanisms to raise awareness among the public and other relevant stakeholders.

The new features can help to track the progress on policies and support in enforcing mandatory standards by using EPCs for compliance.

Conduct cost-benefit analysis at national level to determine the feasibility of features and their economic impact to build trust in markets.

Selective implementation and independent pilot studies in national contexts would support in meeting MS individual policy goals.

Evaluate national or regional building stock characteristics and estimate the need for new developed features.

Incorporate medium and long-term horizons for the upgradation of the EPC system and on-set of new features.

Advancing comparability and consistency

Promote comparability of features across Member States by following harmonised approaches at EU level.

Consistency with regional policy and standards must be maintained to promote acceptability and reliability of new features.

Set up more ambitious and rigorous quality check mechanisms in EPCs, EPC databases, and check consistencies within and between databases.

Phase-out redundant EPC systems and provide continuous access to interoperable databases, thus increasing transparency and trust.

Adopt standards, methods and tools that promote transparency and accountability in the EPC system.

Market, business models and training needs

Encourage an integrated approach to renovation using the new features and promoting wider benefits such as health and environmental benefits.

Foster collaboration between private and public actors in creating an environment and enabling conditions for supporting job creation and increase investments in renovation with features such as DBL and OSS.

Consider GDPR in data handling of the new features, ensure that data is owned by the homeowner and avoid business models based on trading data.

Promote more collaborative and open-source knowledge systems for EPCs.

Promote the implementation of new features using market and non-market mechanisms to raise awareness among the public and other relevant stakeholders.

Support the implementation of additional features with a more complex methodology including the training and upskilling of EPC assessors.

REFERENCES

[1] I. Maia, L. Kranzl, Z. Toth, J. Volt, C. Monteiro, and R. Fragoso, "X-tendo- D4.4 Description of methodologies and concepts for the technical implementation of each feature regarding improved handling and use of EPC data in selected implementing countries," Brussels, 2021.

[2] S. Zuhaib, G. B. Pedraz, J. Verheyen, J. Kwiatkowski, M. Hummel, and V. Dorizas, "X-tendo- D3.1- Exploring Innovative Indicators for the Next- Generation Energy Performance Certificate Features," Brussels, 2020.

[3] S. Schmatzberger and S. Zuhaib, "End-User Needs and Expectations of the Next-Generation Energy Performance Certificates Scheme October 2020," Brussels, 2020.

[4] S. Zuhaib, S. Schmatzberger, and J. Volt, "Guidance Note on the Next-Generation Energy Performance Assessment and Certification Scheme," Brussels, 2020.

[5] Z. Borragán Pedraz, G., Sheikh and R. Broer, "Smart Readiness Indicator," Brussels, 2021.

[6] N. Rosa, R. Fragoso, S. Zuhaib, and R. Broer, "One-stop-shops," Brussels, 2021.

[7] N. Rosa, R. Fragoso, S. Zuhaib, and R. Broer, "Financing options," Brussels, 2021.

[8] I. Maia, L. Kranzl, S. Zuhaib, and R. Broer, "Enhanced recommendations," Brussels, 2021.

[9] Z. Toth, J. Volt, S. Zuhaib, and R. Broer, "Building logbook," Brussels, 2021.

[10] I. Maia, L. Kranzl, S. Zuhaib, and R. Broer, "EPC databases," Brussels, 2021.

[11] M. Hummer, D. Schmidinger, S. Zuhaib, and R. Broer, "District Energy," 2021.
Jan Verheyen, Sheikh Zuhaib, and Rutger Broer, "Real energy consumption," Brussels, 2021.

[12] Jan Verheyen, Sheikh Zuhaib, and Rutger Broer, "Real energy consumption," Brussels, 2021.

[13] J. Kwiatkowski, S. Zuhaib, and R. Broer, "Outdoor Air Pollution," Brussels, 2021.

[14] S. Zuhaib, V. Dorizas, and R. Broer, "Comfort Indicator," Brussels, 2021.

[15] M. Hummel, D. Campbell, D. Weatherall, and C. Green, "D5.2- Real Energy Consumption testing and results," Brussels, 2022.

[16] M. Hummel, D. Campbell, D. Weatherall, and C. Green, "D5.2- EPC databases testing and results," Brussels, 2022.

[17] M. Hummel, D. Campbell, D. Weatherall, and C. Green, "D5.2- District Energy testing and results," Brussels, 2022.

[18] M. Hummel, D. Campbell, D. Weatherall, and C. Green, "D5.2- Outdoor Air Pollution testing and results," Brussels, 2022.

[19] M. Hummel, D. Campbell, D. Weatherall, and C. Green, "D5.2- Enhanced Recommendations testing and results," Brussels, 2022.

[20] M. Hummel, D. Campbell, D. Weatherall, and C. Green, "D5.2- One-Stop-Shops testing and results," Brussels, 2022.

[21] M. Hummel, D. Campbell, D. Weatherall, and C. Green, "D5.2- Building Logbook testing and results," Brussels, 2022.

[22] M. Hummel, D. Campbell, D. Weatherall, and C. Green, "D5.2- Financing options testing and results," https://x-tendo.eu/wp-content/uploads/2020/01/X-tendo_deliverable5.2_Feature9_FinancingOptions_Final.pdf, 2022.

[23] M. Hummel, D. Campbell, D. Weatherall, and C. Green, "D5.2- Comfort testing and results," Brussels, 2022.

[24] M. Hummel, D. Campbell, D. Weatherall, and C. Green, "D5.2- Smart Readiness Indicator testing and results," Brussels, 2022.

[25] European Commission, Proposal for a Directive of the European Parliament and of the Council on the energy performance of buildings (recast), vol. 0426. 2021, pp. 10–27.

[26] EC, Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the energy performance of buildings (recast). Brussels, 2021.

[27] P. Zangheri et al., "Progress of the Member States in implementing the Energy Performance of Building Directive," Brussels, 2021.

[28] Z. Toth, I. Maia, N. Rosa, and J. Volt, "Technical specifications of Energy Performance Certificates Data Handling: Understanding the Value of Data," Brussels, 2020

ANNEX 1

7.1 Methods and data for estimation of the quantitative impact of implementation of new EPC features

For each country and considered year the following equations were applied to estimate the number of annually issued EPCs (E).

$$E = E_{tenant} + E_{sales} + E_{new} + E_{reno} + E_{other}$$

with

E	Number of annually issued EPCs
E_{tenant}	Number of annually issued EPCs triggered through the change of a tenant
E_{sales}	Number of annually issued EPCs triggered through the sale of a property
E_{renov}	Number of annually issued EPCs triggered through building renovation
E_{other}	Number of annually issued EPCs triggered through other occasions, e.g. the need for advice for renovating the building

In case of rented single family houses or in case that in a certain country an EPC needs to be issued for each apartment of an apartment buildings, E_{tenant_1} applies:

Under the assumption that

$$T_{contract} > T_{EPC}, E_{tenant\_1} = \frac{n_{tenant}}{T_{contract}}$$

Whereas, for apartment buildings in countries where for these buildings only one EPC needs to be issued, E_{tenant_2} applies:

Under the assumption that

$$T_{contract} > T_{EPC}, E_{tenant\_2} = \frac{n_{tenant}}{n_{dwell}(T_{EPC} + \varepsilon)}$$

with

$T_{contract}$	Average duration of Tenancy contracts
T_{EPC}	Validity period of EPCs
n_{tenant}	Total number of rented dwellings and non-residential buildings
n_{dwell}	Average number of dwellings per building
ε	Factor, considering the deviation of changing tenants and the validity of EPCs over time; assumed to be 20% of the validity period of EPCs

For the other trigger points j, the following equation is applied:

$$E_j = \sum_i n_{j,i} \cdot f_{j,i}$$

with

$n_{j,i}$ Number of trigger point (i.e. number of dwellings and non-residential buildings being sold (excluding new buildings, being constructed, being renovated or other) in building category i.

$f_{j,i}$ Correction factor, considering e.g. that some non-residential buildings might not need an EPC, or that for apartment buildings in some countries only one EPC per building needs to be issued.

The number of EPC end users potentially interested in a certain feature k (E_k^*) was determined by estimating the share of interested end-users per trigger point j and feature k ($S_{j,k}$)[12] in certain ranges and partly distinguishing whether the interest refers to the buyer or the seller (or the tenant/landlord) of property. Subsequently, the number of potentially interested EPC end-users is estimated by following equation:

$$E_k^* = \sum E_{j,k} \cdot S_{j,k}$$

As described in *Table 13* and *Table 14*, the factors $S_{j,k}$ were estimated by project partners leading the development of the feature in the project. Thus, there is some subjectivity in the assessment and comparison between features is possible only to a limited extent.

For the 2030 projection, it was assumed that the number of tenants, real estate transactions and new building constructions follows the same linear trend as in the past 10 years, while all the factors specified above remain the same. For the number of renovated buildings, we assumed a doubling of the number from the period 2015-2019. In addition to the renovated buildings, it is assumed that another 50% of building owners is interested in receiving advice for building renovation (i.e. the trigger point "other"). Overall, a strong increase in building renovation activities, moving towards the targets of the fit-for-55 package is assumed.

According to the approach described in *chapter 3*, the number of EPCs issued for each trigger point are estimated. For this purpose, historical data is used on the trigger points, i.e. on the number or real estate transactions, number of rented dwellings and building permits, if available by type of building according to sources in *Table 12*.

[12] See Table 13 and Table 14

Table 12 – Data sources of trigger points

Country	Data sources
Austria	European Central Bank - Statistical Data Warehouse. *https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=430.RESH.A.AT._T.N._TR.NTRA.AT2._Z.N._Z*. 22 Feb 2022; Österreichische Nationalbank. *https://www.oenb.at/Publikationen/Volkswirtschaft/immobilien-aktuell.html.* 09 Feb 2022; Statistics Austria. *http://www.statistik.at/web_en/statistics/PeopleSociety/housing/housing_conditions/index.html.* 09 Feb 2022; Statistics Austria. *https://statcube.at/statistik.at/ext/statcube/jsf/tableView/tableView.xhtml.* 09 Feb 2022; Statistics Austria. *https://www.statistik.at/web_de/statistiken/menschen_und_gesellschaft/wohnen/wohnungs_und_gebaeudeerrichtung/fertigstellungen/026021.html.* 03 March 2022;
Belgium	Eurostat. *http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do.* 02 March 2022; Statbel (Directorate General Statistics - Statistics Belgium). *https://statbel.fgov.be/en/open-data/sales-real-estate-belgium-according-nature-property-land-register.* 01 Feb 2022; Statbel (Directorate General Statistics - Statistics Belgium). *https://statbel.fgov.be/en/themes/housing/building-stock#figures.* 03 Feb 2022; Statbel (Directorate General Statistics - Statistics Belgium). *https://statbel.fgov.be/en/themes/housing/building-permits#figures.* 14 Feb 2022;
Denmark	Statistics Denmark. *https://www.statbank.dk/EJEN88.* 02 Feb 2022; Statistics Denmark. *https://www.statbank.dk/statbank5a/selectvarval/saveselections.asp.* 02 Feb 2022; Statistics Denmark. *https://www.statbank.dk/statbank5a/SelectTable/Omrade0.asp?SubjectCode=6&ShowNews=OFF&PLanguage=1.* 15 Feb 2022;
Estonia	European Central Bank - Statistical Data Warehouse. *https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=430.RESH.A.EE._T.N._TR.TOOT.EE2._Z.N.RO.* 24 Feb 2022; Republic of Estonia Land Board. *https://www.maaamet.ee/kinnisvara/htraru/Result.aspx.* 03 Feb 2022; Statistics Estonia. *https://andmed.stat.ee/en/stat/majandus__ehitus__ehitus-ja-kasutusload/EH045/table/tableViewLayout2.* 14 Feb 2022; Statistics Estonia. *http://andmebaas.stat.ee/Index.aspx?lang=en&DataSetCode=KVE01#. 24* March 2022; Statistics Estonia. *https://andmed.stat.ee/en/stat/majandus__ehitus__ehitus-ja-kasutusload/EH046/table/tableViewLayout2.* 15 Feb 2022;

Country	Data sources
Greece	European Central Bank - Statistical Data Warehouse. *https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=430.RESH.A.GR._T.N._TR.NTRA.GR2._Z.N._Z*; 21 Feb 2022; European Central Bank - Statistical Data Warehouse. *https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=430.RESH.A.GR._T.N._TR.NPRO.GR2._Z.N._Z.* 21 Feb 2022; European Central Bank - Statistical Data Warehouse. *https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=381.SHI.A.GR.TOOT.P.* 21 Feb 2022; European Central Bank - Statistical Data Warehouse. *https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=381.SHI.A.GR.TRAT.P.* 21 Feb 2022; Hellenic Statistical Authority. *https://www.statistics.gr/en/statistics/-/publication/SOP03/2021-M10.* 17 Feb 2022;
Italy	Agenzia Entrate *https://www.agenziaentrate.gov.it/portale/documents/20143/264865/NON_RESIDENZIALE_2011_2020_definitiva.zip/edc366cf-1b6e-0255-f8ca-4c9e95482a90.* 05 April 2022; ENTRANZE. *www.entranze.eu*. 05 April 2022; European Central Bank - Statistical Data Warehouse. *https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=430.RESH.A.IT._T.N._TR.NTRA.IT2._Z.N._Z.* 24 Feb 2022; European Central Bank - Statistical Data Warehouse. *https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=430.RESH.A.IT._T.N._TR.NPRO.IT2._Z.N._Z.* 24 Feb 2022; European Central Bank - Statistical Data Warehouse. *https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=430.RESH.A.IT._T.N.NTR.HCOM.IT2._Z.N._Z.* 24 Feb 2022; Italian National Institute of Statistics. *http://dati.istat.it/Index.aspx?lang=en&SubSessionId=a3e8b60c-9cbd-4992-8941-b3847ef50c3d.* 02 March 2022; Osservatorio del mercato immobiliare, "RAPPORTO IMMOBILIARE 2021", Agenzia delle Entrate, 20/05/2021, Table 38, page 59; Osservatorio del mercato immobiliare, "RAPPORTO IMMOBILIARE 2018", Agenzia delle Entrate, 22/05/2018, Table 35, page 56; *https://www.agenziaentrate.gov.it/portale/web/guest/schede/fabbricatiterreni/omi/pubblicazioni/rapporti-immobiliari-residenziali.* 05 April 2020; Statista. *https://www.statista.com/statistics/677565/number-of-rental-agreements-registered-in-italy/#:~:text=The%20number%20of%20rental%20agreement,to%201.5%20million%20in%202020.* 03 Feb 2022;
Poland	European Central Bank - Statistical Data Warehouse. *https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=430.RESH.A.PL._T.N._TR.NPRO.PL2._Z.N._Z*. 16 Feb 2022; European Central Bank - Statistical Data Warehouse. *https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=430.RESH.A.PL._T.N._TR.TRAT.PL2._Z.N.RO.* 16 Feb 2022. Statistics Poland. *https://stat.gov.pl/en/topics/municipal-infrastructure/municipal-infrastructure/real-estate-sales-in-2020,2,13.html.* 08 Feb 2022; Statistics Poland. *https://stat.gov.pl/en/topics/industry-construction-fixed-assets/construction/construction-results-in-2020,1,14.html.* 28 Feb 2022;

Country	Data sources
Portugal	Eurostat. *http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do.* 07 March 2022; Statistics Portugal. *https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_indicadores&indOcorrCod=0008330&contexto=pi&selTab=tab0&xlang=en.* 10 Feb 2022; Statistics Portugal. *https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_indicadores&indOcorrCod=0007838&contexto=bd&selTab=tab2.* 10 Feb 2022; Statistics Portugal. *https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_publicacoes&PUBLICACOESpagenumber=1&PUBLICACOESstema=55534.* 10 Feb 2022; Statistics Portugal. *https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_indicadores&indOcorrCod=0009632&contexto=bd&selTab=tab2.* 10 Feb 2022; Statistics Portugal. *https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_indicadores&indOcorrCod=0008329&contexto=bd&selTab=tab2.* 10 Feb 2022; Statistics Portugal. *https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_indicadores&indOcorrCod=0008320&contexto=bd&selTab=tab2.* 17 Feb 2022; Statistics Portugal. *https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_indicadores&indOcorrCod=0008335&contexto=bd&selTab=tab2.* 17 Feb 2022; Statistics Portugal. *https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_indicadores&indOcorrCod=0008334&contexto=bd&selTab=tab2.* 17 Feb 2022; Statistics Portugal. *https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_indicadores&indOcorrCod=0008330&contexto=bd&selTab=tab2&xlang=en.* 17 Feb 2022;
Romania	European Central Bank - Statistical Data Warehouse. *https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=430.RESH.A.RO._T.N._TR.NPRO.RO2._Z.N._Z.* 15 Feb 2022; European Central Bank - Statistical Data Warehouse. *https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=381.SHI.A.RO.TOOT.P.* 15 Feb 2022; European Central Bank - Statistical Data Warehouse. *https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=430.RESH.A.RO._T.N._TR.TRAT.RO2._Z.N.RO.* 15 Feb 2022; National Institute for Statistics – ROMANIA. *http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table.* 22 Feb 2022; Paul Cosmin Alin ENACHESCU & Genifera Claudia BANICA, 2019. "Analysis Of The Real Estate Market In Romania From The Point Of View Of The Number Of Transactions During 2009-2018," Scientific Bulletin - Economic Sciences, University of Pitesti, vol. 18(3), pages 39-46. *https://ideas.repec.org/a/pts/journl/y2019i3p39-46.html.* 08 Feb 2022;
Scotland	Registers of Scotland. *https://www.ros.gov.uk/data-and-statistics/house-price-statistics.* 07 Feb 2022; Scottish Government. *https://www.gov.scot/publications/housing-statistics-stock-by-tenure/.* 07 Feb 2022; Scottish Government. *https://www.gov.scot/publications/housing-statistics-for-scotland-new-house-building/.* 07 Feb 2022;

For the countries AT, DK, EE, PL, and PT it is considered that in case of apartment buildings, in most cases there is only one EPC issued for the whole building, not for each apartment. For the countries BE, GR, IT, RO and the UK (Scotland) it is considered that EPCs need to be issued for each apartment.

The resulting historical time series for the issued EPCs were then compared to the total number of issued EPCs according to reports [27][28] and selected sources from Table 12. The deviations were calibrated using the approach to the historical and observed data. Subsequently, the relevance of trigger points for each feature is estimated. For this purpose, the share of EPC end-users is estimated, for which the feature might be interesting along the various trigger points. As the tables below indicate, the relevance might differ between the buyer and seller perspectives. This was taken into account by considering both perspectives, where relevant and adding this to the range of results (high/low).

Table 13 – Relevance of trigger points for each feature: Share of EPC end-users for which the feature might be interesting in different trigger points

	New building construction	**Building retrofitting (mandatory or not)**	**Real estate transaction**	**Other (e.g. interest in the improvement of building's energy performance)**
SRI F1	High; insight in impact is relevant for the owner of the new building for the 3 key functionalities; 1) comfort; 2) energy efficiency and operational performance; 3) interaction with the grid.	Medium; insight in impact is relevant for the owner of the building for retrofitting for the 3 key functionalities; 1) comfort; 2) energy efficiency and operational performance; 3) interaction with the grid.	Medium-Low for the seller; unless it shows good results as a selling argument. For the buyer, insight in impact is relevant for the 3 key functionalities; 1) comfort; 2) energy efficiency and operational performance; 3) interaction with the grid.	Medium; SRI scores SRI in 3 key functionalities; 1) comfort; 2) energy efficiency and operational performance; 3) interaction with the grid; not all relate directly to energy performance.
Comfort F2	High; because Comfort (thermal, IAQ, acoustic, visual) has a direct relevance to the end-user especially in the residential sector.	Medium-High; if retrofitting is not mandatory and High if retrofitting is mandatory. Comfort assessment would be preferred by owners.	Medium-High; for buyers, High for sellers and Medium-high for renters. The interest would vary based on the type of transaction.	Low; co-relation of energy performance and comfort not very clear to the end-user.

	New building construction	Building retrofitting (mandatory or not)	Real estate transaction	Other (e.g. interest in the improvement of building's energy performance)
Outdoor air pollution F3	High; in terms of Indoor Air Purity Index, as the quality of internal environment is important for the users. Medium-Low; in terms of Local Air Pollution Contributor Index. The pollutant emissions from the building are less important for the users.	Medium; in terms of Indoor Air Purity Index, as the retrofitting measures might increase the quality (purity) of internal air. Medium; in terms of Local Air Pollution Contributor Index. The index can be used by the users to verify the environmental results of the modernisation.	Medium-Low; in terms of Indoor Air Purity Index, the value of the property can be higher if a better indoor environment is assured. In terms of Local Low, air Pollution Contributor Index. The pollutant emission for the building are not the most important parameters considered in real estate transaction.	High; both indexes can be used in verification of the building modernization results. In this case the Local Air Pollution Contributor Index has a higher value as the goal of the modernisation is to decrease emission.
Real energy consumption F4	Low; similar to EPC, but the indicator will only be available after a one-year operational period. May be implemented for commissioning and as such have indirect influence.	High; indication of actual energy performance forms the best basis for energy retrofitting decisions.	Medium-High for the buyer; is very relevant for indication of actual energy performance and cost. Medium-low for the seller; unless it shows good results as a selling argument.	High; indication of actual energy performance forms the best basis for energy retrofitting decisions.
District energy F5	Low; the main benefit of the feature for building owners / user is to a) compare performance of own system with nearby DH, or b) see if other decentral low-temperature supply options are interesting; both not relevant in case of new construction.	Medium-Low; benefit is as described in column new construction; in case of renovation this can be a bit more relevant; however, potentially other aspects will play a more important role.	Low; for rental will probably not be relevant, for buying most probably other factor more important.	Medium-Low for building owners/user; the feature is more relevant for public dministrations and their urban planning. Thus, the more data is available from issued EPCs, the better.

	New building construction	Building retrofitting (mandatory or not)	Real estate transaction	Other (e.g. interest in the improvement of building's energy performance)
EPC databases F6	Medium-High; the quality of the EPC and trust in the information is important and can influence the decision of buyers of a new building.	Low; the quality of the EPC may be less relevant in the cases where the building is occupied by the owner because they may assess the building's performance more based on their own behaviour.	Medium-High; the quality of the EPC and trust of the information is important and can influence the decision of buyers of existing buildings.	High; In general. many actors have high quality EPCs and trustworthy information on that document.
Logbook F7	Medium; the construction phase is key to collect detailed information about the building, material and embodied carbon levels. Registering this data in a logbook can be linked to various private certifications, which can be valuable to the building owner.	Medium-High; logbooks enable better decision-making throughout the building lifecycle, including for energy renovations. Having all the information in one place is something building owners have been requested and something that can simplify the renovation process.	Medium; the construction phase is key to collect detailed information about the building, material and embodied carbon levels. Registering this data in a logbook can be linked to various private certifications, which can be valuable to the building owner (i.e. increase the financial value of the asset).	Medium-High; logbooks enable better decision-making throughout the building lifecycle, including for energy renovations. Having all the information in one place is something building owners have requested and something that can simplify the renovation process.
Enhanced recommendations F8	Low; the main benefit of the feature for building owners / user is to a) compare performance of own system with nearby DH, or b) see if other decentral low-temperature supply options are interesting; both not relevant in case of new construction.	Medium-Low; benefit is as described in column new construction; in case of renovation this can be a bit more relevant; however, potentially other aspects will play a more important role.	Low; for rental will probably not be relevant, for buying most probably other factor more important.	Medium-Low for building owners/user; the feature is more relevant for public dministrations and their urban planning. Thus, the more data is available from issued EPCs, the better.

	New building construction	Building retrofitting (mandatory or not)	Real estate transaction	Other (e.g. interest in the improvement of building's energy performance)
Financing schemes F9	Low; since usually financing schemes are given for energy efficiency improvement of existing buildings.	High; since usually financing mechanisms are related to the building renovation, namely the improvements related to energy efficiency.	High; EPCs are usually mandatory to be issued during the buy or rental of buildings, and therefore there might be some specific mechanisms that use the EPC as eligibility criteria. This can also be relevant to buyers to advise if there are financing mechanisms available to improve their future house.	High; the interest in improving the building energy performance of a house can be the trigger point for looking for funding.
One Stop Shop F10	Low; since usually one-stop-shops have information about the existing building and provide technical assistance to improve the existing house.	High; since usually one-stop-shops have information about the existing building and provide technical assistance to improve the existing house.	Low; since usually it is necessary to be a homeowner to have access to the information/ technical assistance available in the one-stop-shop. A potential buyer does not have access to the information of the house available in the OSS unless they are the owner.	High; the interest in improving the building energy performance of a house can be the trigger point for using the OSS to search for funding opportunities, technical assistance and get closer to the construction market.

Note

Rating	Percentage range
High	100-80%
Medium-High	80%-60%
Medium	60%-40%
Medium-Low	40%-20%
Low	20%-0%

The qualitative arguments, the rating table and discussion points were transferred into the following table, which was then used for the calculation of the share of EPC end-users for which the feature might be interesting, considering upper and lower boundaries as "high" and "low".

Table 14 – Quantitative summary - Relevance of trigger points for each feature: Share of EPC end-users for which the feature might be interesting in different trigger points

	Change of tenant	Real estate transaction (buyer)	Real estate transaction (seller)	New building construction	Building retrofitting (mandatory or not)	Other, in particular: general interest in the potential improvement of building energy performance
F1	20%-40%	20%-40%	20%-40%	80%-100%	40%-60%	40%-60%
F2	60%-80%	80%-100%	60%-80%	80%-100%	60%-80%	0%-20%
F3 (indoor)	20%-40%	20%-40%	20%-40%	80%-100%	40%-60%	80%-100%
F3 (outdoor)	0%-20%	0%-20%	0%-20%	20%-40%	40%-60%	80%-100%
F4	60%-80%	60%-80%	20%-40%	0%-20%	80%-100%	80%-100%
F5 (low-temp)	0%-20%	60%-80%	0%-20%	80%-100%	60%-80%	60%-80%
F5 (DH-PEF)	0%-20%	40%-60%	0%-20%	60%-80%	20%-40%	20%-40%
F6	60%-80%	60%-80%	60%-80%	60%-80%	0%-20%	20%-40%
F7	40%-60%	60%-80%	20%-40%	40%-60%	60%-80%	60%-80%
F8	0%-20%	80%-100%	0%-20%	0%-20%	60%-80%	80%-100%
F9	0%-20%	80%-100%	0%-20%	0%-20%	60%-80%	80%-100%
F10	0%-20%	0%-20%	0%-20%	0%-20%	60%-80%	80%-100%

With $n_{t,i}$, the number of EPCs issued in year t due to trigger point i, the number of potentially interested EPC end-users in feature j is calculated as $\sum_i n_{t,i} f_{i,j}$, while the values in *Table 14* represent the shares $f_{i,j}$, where the lower and the upper range from *Table 14* is considered as the "low" and "high" result in the quantitative assessment of each feature.

Table 15 – Share of potentially interested EPC end-users by feature and country, 2030

		F1	F2	F3 (indoor)	F3 (outdoor)	F4	F5 (low-temp)	F5 (DH-PEF)	F6	F7	F8	F9	F10
LOW(+)	AUSTRIA	40%	66%	40%	12%	40%	32%	20%	50%	40%	10%	10%	10%
	BELGIUM	34%	46%	44%	30%	51%	33%	14%	39%	42%	31%	31%	31%
	DENMARK	41%	56%	47%	22%	42%	37%	21%	47%	42%	19%	19%	19%
	ESTONIA	38%	41%	53%	38%	49%	42%	18%	36%	44%	38%	38%	38%
	GREECE	28%	46%	38%	26%	64%	24%	8%	41%	46%	29%	29%	29%
	ITALY	34%	39%	48%	39%	60%	39%	14%	32%	47%	43%	43%	43%
	POLAND	46%	63%	49%	16%	24%	39%	26%	54%	35%	10%	10%	10%
	PORTUGAL	24%	61%	24%	2%	33%	6%	4%	59%	29%	1%	1%	1%
	ROMANIA	48%	56%	55%	27%	32%	47%	28%	45%	40%	22%	22%	22%
	SCOTLAND	40%	63%	42%	11%	23%	30%	20%	56%	32%	6%	6%	6%
HIGH (*)	AUSTRIA	60%	89%	60%	32%	66%	62%	47%	70%	67%	43%	43%	30%
	BELGIUM	54%	73%	64%	50%	84%	73%	47%	59%	75%	78%	78%	51%
	DENMARK	61%	80%	67%	42%	69%	68%	48%	67%	69%	53%	53%	39%
	ESTONIA	58%	67%	73%	58%	83%	81%	51%	56%	77%	85%	85%	58%
	GREECE	48%	68%	58%	46%	88%	50%	32%	61%	70%	57%	57%	49%
	ITALY	54%	64%	68%	59%	90%	72%	43%	52%	76%	81%	81%	63%
	POLAND	66%	91%	69%	36%	59%	82%	61%	74%	70%	60%	60%	30%
	PORTUGAL	44%	92%	44%	22%	76%	61%	47%	79%	72%	68%	68%	21%
	ROMANIA	68%	83%	75%	47%	65%	86%	60%	65%	73%	68%	68%	42%
	SCOTLAND	60%	93%	62%	31%	63%	80%	60%	76%	72%	66%	66%	26%

(*) Low and High shares result from the ranges indicated in *Table 14*.

GLOSSARY OF TERMS

AQI	Air Quality Index
BIM	Building Information Modelling
BREEAM	Building Research Establishment Environmental Assessment Method
CARP	Comfort Assessment Rating Procedure
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
CORP	Comfort Operational Rating Procedure
Covid-19	Infectious disease caused by SARS-CoV-2 virus
DBL	Digital Building Logbook
DGNB	Deutsche Gesellschaft für Nachhaltiges Bauen
DH	District Heating
DHW	Domestic Hot Water
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
GDPR	General Data Protection Regulation
GHG	Greenhouse gas
HVAC	Heating, Ventilation and Air-Conditioning
IAPI	Indoor Air Purity Index
IAQ	Indoor Air Quality
IEQ	Indoor Environmental Quality
LAPCI	Local Air Pollution Contributor Index
LEED	Leadership in Energy and Environmental Design
LTRS	Long-term Renovation Strategies
MEPS	Minimum Energy Performance Standards
MFH	Multi-Family House
MS	Member State
MVHR	Mechanical Ventilation and Heat Recovery
nZEB	Nearly Zero-Energy Building
OSS	One-Stop Shop
PA	Public Administration
PEF	Primary Energy Factor
RH	Relative Humidity
ROI	Return On Investment
SFH	Single-Family House
SRI	Smart Readiness Indicator
T	Temperature

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AAECR Asociația Auditorilor Energetici pentru Clădiri din România

ENEA

BPIE

КАПЕ CRES

Danish Energy Agency

adene Agência para a Energia

ENERGIE AGENTUR Steiermark

energy saving trust

ethink ENERGY RESEARCH

NAPE NATIONAL ENERGY CONSERVATION AGENCY

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