



Next-generation energy performance certificates: End-user needs and expectations

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ABSTRACT

Implementation of Energy Performance Certificates (EPCs) varies significantly across EU Member States in terms of scope and available information, resulting in limited reliability, compliance, market penetration or user acceptance. This paper, therefore, investigates the end-user perspectives towards future development of EPCs to support EPC schemes in the EU. Without a full insight into what end-user's demand and need, it is impossible to make accurate assessments of how EPCs will become key drivers for deep renovation, environmental impact reduction and healthy buildings. A survey with 2563 end-users of EPCs was conducted on ten innovative EPC features in five EU countries (Denmark, Greece, Portugal, Poland, and Romania), including building owners and occupants to learn about their needs and expectations. The results highlight that the features are viewed most positively if homeowners or tenants are energy conscious and energy performance is an important aspect when buying or renting property. Furthermore, the insights gathered through the analysis of the survey provide suggestions for public authorities on how EPC methodologies could be customised to support the advancement of EPC schemes. Further work includes testing and validation of methodologies that are being developed in different EU Member States as a part of the H2020 X-tendo project.

1. Introduction

Buildings are responsible for 35% of the global energy demand and 38% of the global energy-related CO₂ emissions (UNEP, 2020). While Europe has been continuously making efforts to improve the performance of its building stock through several legislative, regulatory, market and financial mechanisms (Economidou et al., 2020), energy performance certificates (EPCs) have been instrumental in achieving some success (Volt et al., 2020; Brocklehurst, 2017; Khazal and Sønsteby, 2020). The EPCs were introduced by the European Union almost 20 years ago and have continuously gained significance. They were first introduced by the Energy Performance of Buildings Directive (EPBD) in 2002 (EU, 2002) with the aim to make the energy performance of individual buildings more transparent. The EPBD recast, which took place in 2010 (EU, 2010) reinforced the legislation by introducing

independent quality control of EPCs, penalties for non-compliance, the obligation to display the energy label in advertisements, a mandatory requirement to hand out a copy of the EPC in sale and rent transactions and the improvement of featured recommendations.

EPC has faced some criticism earlier and it is clear that it needs to overcome multiple challenges before the Europe-wide implementation is effective (Atanasiu and Constantinescu, 2011). A survey of 618 real estate agents in 8 EU Member States studied the impact, role and influence of EPCs in the building market and found several issues in their practical applications such as their usefulness and reliability (Pascuas et al., 2017). Another study in Norway found no empirical evidence linking the EPCs influence on prices of real estate (Olausson et al., 2017). At the same time the EPC, with its surrounding infrastructure of trained experts and rich databases, also represents a huge opportunity for the EU. This has been recognised by the European Commission, by including

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EPC as a specific focus of the upcoming revision of the EPBD (EC, 2020). EPCs could be an effective force that triggers a new wave of renovation activities across the EU if the full potential is explored (EC, 2020; Li et al., 2019). To become a catalyst for energy renovations, the future EPCs must provide an improved and more reliable service tailored to the end-users.

All Member States had introduced EPC regimes by 2015, implying that more than 28 EPC frameworks and methodologies exist in the EU and the UK (Simple and Jenkins, 2020). There is also regional difference in some countries, for example, Belgium has three separate EPC frameworks. Information available from Member States suggests that around 6 million residential EPCs are issued every year (Concerted Action EPBD, 2019). The UK is leading the market uptake with more than 20 million issued EPCs (Concerted Action EPBD, 2019). It also has the most EPCs per capita with 0.31, followed by Belgium, Ireland, Denmark and Portugal (Volt et al., 2020). Different implementation approaches have led to a diverse set of instruments, varying in terms of scope and available information, and resulting in some cases in limited reliability, compliance, market penetration and acceptance (BPIE, 2014).

Good practices have shown that an EPC can become more than just an informative tool for end-users (Olausen et al., 2017). When accurate and well structured, EPC schemes can become powerful tools for services providers in order to identify business opportunities. Additionally, EPCs can also empower policymakers with better data on the building stock and enable them to monitor the impact of policies and financial support schemes (Kostova, 2020). To realise these additional benefits, EPC schemes must be properly implemented, well managed, and supported by effective legislative and compliance mechanisms. Only in this way the EPCs will increase the market value of energy-efficient buildings and effectively support the transition towards a highly efficient building stock (ZEBRA2020, 2016). An EPC that integrates new indicators like real energy consumption could strengthen the role of buildings in the energy system by enabling additional services, including demand response and dynamic pricing. A more harmonised European calculation methodology for the EPCs could increase comparability between regions, trust, and market uptake. For example, the ALDREN project has been exploring the potential for a common European voluntary certification scheme for non-residential buildings (Zirngibl et al., 2019). Aspects like indoor environmental quality (comfort, health, etc.) and smart data usage are not covered significantly in all EPC regimes (Volt et al., 2020).

The EPC typically comprises a label indicating the energy performance level of the building, general information about the building (age, location, etc.) together with recommendations on how to improve

the building's performance. The EPC indicators are already a powerful tool in some countries where the certificate is embedded within and recognised by the real estate market (Kostova, 2020). Despite the obvious potential, the introduction of new indicators has been limited (Dorizas et al., 2018).

The EPC is one of the EU's main existing tools used to facilitate the decarbonisation of the building stock, though only a few countries have identified their possible benefits (EC, 2020; Li et al., 2019). The United Kingdom, France and the Netherlands are using them to set mandatory minimum energy performance standards for existing buildings, while Portugal is using the EPC database to enable a user-friendly one-stop-shop and to integrate other policies and instruments (Volt et al., 2020). In contrast, in other countries such as Germany, the EPC scheme is much focused on past performance and it does not enjoy great popularity (Amecke, 2011). The broader use of EPCs and their information includes supporting local authorities, real estate agencies and research activities and formulating urban energy policies (Pasichnyi et al., 2019). In some countries, as Germany, Estonia, Ireland and Austria, homeowners need to have the EPC to access public grants and low-interest loans (EC, 2014). In addition, EPCs can also be used to monitor and evaluate policies and to develop more impactful future policies. Fig. 1 illustrates some of the potential functions that EPC enables.

While the evolving role of EPCs is promising, yet the acceptance by public or their success is very much dependent on the perception, willingness to use, and interest of the end-users in EU member states. A few studies have highlighted in the past that EPCs have shown limited use to homeowners (Abreu et al., 2017; Christensen et al., 2014) but many believe they can be instrumental in overcoming the challenges of decarbonisation, deep renovation, access to finance, tailored advice, healthy buildings, real-estate prices, future energy conservation and sustainability as a whole (Andelković et al., 2021; Khazal and Sønstebo, 2020; von Platten et al., 2019; Wilhelmsson, 2019).

The analysis presented in this paper was carried out in the frame of the X-tendo project (X-tendo, 2019), which is developing a framework of ten "next-generation EPC features" aiming to improve compliance, usability and reliability of EPCs. The main objective of this paper is to study the end-users needs and expectations towards the future EPCs through a survey conducted in five European countries. Findings from this research would enable addressing the issues such as limited reliability, compliance, market penetration and acceptance by the end-users. The survey methodology and results are presented and discussed to find out the most interesting areas of action that end-users consider important and useful. It is organized as follows: Section 1 introduces EPCs and the importance to achieve the challenging goals

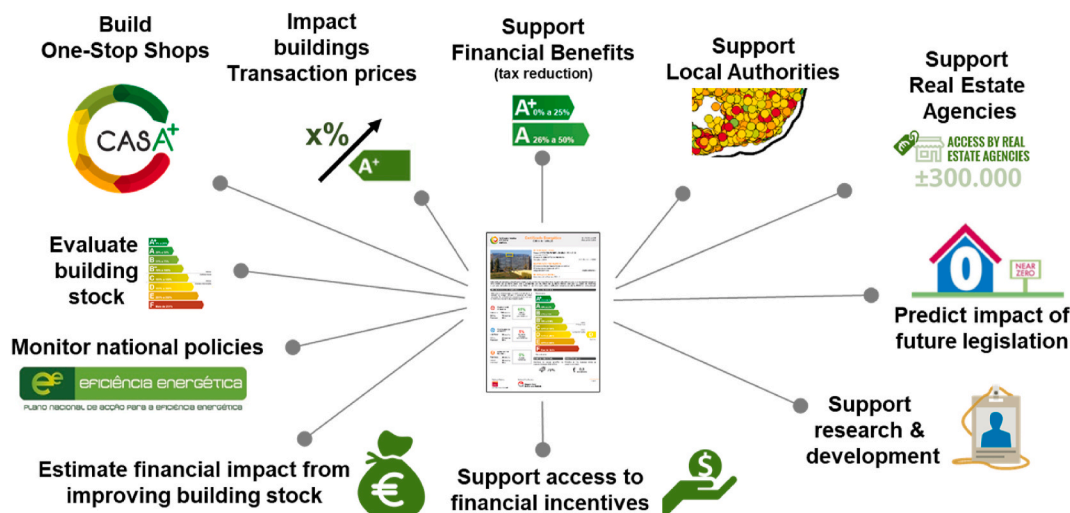


Fig. 1. Role of EPCs in Portugal besides energy performance information (Volt et al., 2020).

towards the building stock energy efficiency and EU climate targets as well as the role it can have by supporting end-users in achieving these goals; Section 2, presents the survey methodology, namely the questionnaire development, sample size and incidents rates; Section 3 discusses the survey results considering the X-tendo 10 developed features, namely (i) smart readiness indicator, (ii) indoor 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; and finally, Section 4 that presents the major conclusions and future work.

2. Methodology

The methodology applied to explore the end-users needs and expectation towards the next generation EPCs is presented here. A survey was conducted in five EU countries with the goal to learn more about the specific needs of the homeowners, landlords and tenants regarding the innovative EPC features when renting, buying, selling, or renovating a house or apartment. The consumer survey was conducted in April 2020 using online interviewing methodology (CAWI- Computer Assisted Web Interview) (Macer and Wilson, 2016) during which it was live for 2.5 weeks. An online access panel of pre-recruited individuals in all countries who have agreed to take part in research were used as a sampling frame. Respondents were randomly drawn from the online panels based on their profile data (gender, age, region) to ensure a sample representative of the general (online) population in terms of these three characteristics. Since the number of EPCs in the residential sector is significantly higher than for the commercial sector, which predominantly use private certifications (e.g. LEED (LEED, 2021), BREEAM (BREEAM, 2021), DGNB (DGNB, 2021)), the focus of the study was on the residential sector.

A questionnaire was designed with the established criteria for country selection, sample size and stakeholder selection. A quick analysis of the nine project's implementation countries (Austria, Belgium, Denmark, Estonia, Greece, Italy, Poland, Portugal, and the UK) was carried out in order to cover a representative sample of EU countries. These countries were checked regarding the following criteria:

- Inclusion as test countries in the X-tendo project;
- Geographic representation (South, North, East and Central Europe);
- Country size (larger area);
- Tenure status in the population (variation in share of owners vs tenants) (EUROSAT, 2021);
- Percentage (%) of consumers having moved in the past five years (EUROSTAT, 2021);
- EPC regime (variation in the strength of EPC compliance checking and compliance rates) (Jamieson et al., 2015).

Finally, five countries were selected (see Fig. 2) with a mix of front-runner (with well-developed EPC regime) countries such as Denmark, slow-starter (with developing EPC regimes) such as Portugal and Greece and cautious adopter (with late advances in EPC regime) countries such as Poland and Romania.

2.1. Questionnaire development

The questionnaire was prepared based on the 10 features which are being investigated in the X-tendo project. Each feature lead developed questions targeting end-users, which would help in defining how the features can be best designed to fit the needs of the respondents' representing end-users of future EPCs. This is important to make sure that the features are user-friendly and will be helpful for homeowners, buyers, tenants, sellers, and landlords. The survey questionnaire was translated into the national languages of the five surveyed countries.

2.2. Sample size

A total of 2563 end-users took part in the survey with varying sample sizes of 501–519 per country. The target group of the survey were homeowners, landlords and tenants (18 years or older) who had:

- a) Bought, rented, sold, let, or renovated property in the past five years (2015–2020);
- b) Attempted to buy, rent, sell, let, or renovate property in the past five years (2015–2020);
- c) Taken first steps or planned to buy, rent, sell, let, or renovate property.

Table 1 lists different activities (buy, rent, sell, let and renovate) of the target groups whether they have been completed or not, in different proportions for each country sample. The majority of respondents were homeowners (69%), almost one-third (30%) owned at least one rental property as landlord and about a quarter (24%) were tenants.

Among the respondents that bought a property or had attempted/planning to do so, the majority (58%) used or intended to use the property as their primary residence; only 8% planned to rent it out. Most of the respondents lived in a flat/apartment (41%) or detached house (35%), fewer in a semi-detached or terraced house (6% and 7%, respectively). However, the proportions varied slightly between the survey countries. Overall, 62% lived in a large city or the suburbs/outskirts of a large city, while 13% resided in a rural area, though here differences could also be observed between countries. The majority of respondents described their household as a 'couple' with or without children (40% and 25% respectively) and about half were full-time employed (51%).

2.3. Incidence rates

An overall higher incidence rate of 85% was calculated based on the overall participation, which was ensured through the screening questions at the beginning of the survey. An initial incidence rate test was also conducted with 100 respondents in each country to assess the target group and to check if the eligibility criteria needed adjustment, since if the survey is too targeted, it may result in lower incidence rates. The screening questions helped in eliminating respondent bias. The focus of the survey was on a very specific audience of people who have bought, rented, sold, let, or renovated property in the past five years. After the final survey was conducted, a variation in incidence rates was noticed for the five surveyed countries with the highest being 94% for Poland and the lowest being 71% for Denmark. This is because people who were found not to have enough knowledge about the topic during the screening questions were eliminated from the final sample size considered in the analysis. The percentage among homeowners and tenants with less than primary, primary or lower secondary education that were not eligible to participate was higher (34%) than the percentage among those with upper secondary or post-secondary education (15%) or tertiary education (11%), suggesting that the activities are more frequently performed by individuals with higher education. This was done to ensure quality but could lead to some difference between countries in the final results specially Denmark and this is taken into account in this paper.

3. Results and discussion

The findings are presented for the total sample, per survey country,

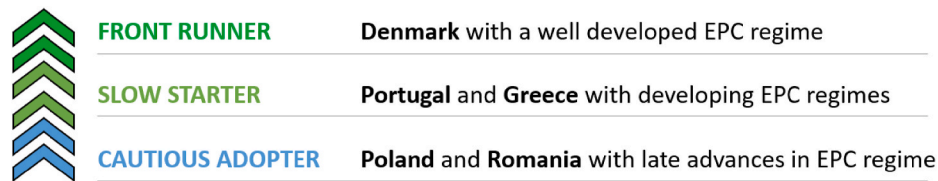


Fig. 2. Countries selected for the survey.

Table 1

Distribution of responses for three target groups (homeowners, landlords, tenants) by country.

	Denmark (n = 512)	Greece (n = 519)	Poland (n = 501)	Portugal (n = 514)	Romania (n = 517)
(a) Who bought, rented, sold, let, or completed a renovation in the past five years					
Bought	26.5%	11.8%	32.8%	21.4%	26.3%
Rented	21.3%	29.6%	13.6%	20.3%	14.1%
Sold	10.7%	8.7%	6.3%	12.4%	11.6%
Let	10.8%	22.6%	12.7%	12.1%	12.5%
Renovated	54.2%	62.1%	82.1%	52.3%	73.2%
(b) Who attempted to buy, rent, sell, or let in the past five years					
Buy	19.9%	16.4%	22.6%	24.7%	25.7%
Rent	22.4%	33.9%	19.1%	5.1%	17.8%
Sell	12.0%	17.1%	13.2%	20.8%	17.6%
Let	9.5%	19.5%	7.3%	25.4%	13.6%
(c) Who planned to buy, rent, sell, or let in the past five years					
Buy	20.8%	23.4%	30.8%	35.2%	35.5%
Rent	15.9%	22.8%	14.7%	3.1%	13.2%
Sell	13.1%	15.5%	13.7%	22.6%	17.7%
Let	7.5%	12.6%	9.3%	16.4%	14.2%

and by subgroup (for example, age group, tenure status, education level, area of residence) where the differences are statistically significant¹ and relevant to the context. They were then analysed in more depth regarding the needs of the feature development and country implementation in order to find the results most relevant for the project. This section presents the findings of the survey for each feature that was covered by the questionnaire as new technical features (smart readiness, comfort, outdoor air pollution, real energy consumption, district heating) and innovative features to handle EPC data (EPC databases, building logbook, enhanced recommendations, financing options, and one-stop-shops). The survey also measured general awareness and interest in home energy issues which are first, shortly presented followed by other results.

3.1. General awareness and interest in home energy issues

Comfort, heating source and energy efficiency are considered as important aspects when buying or renting property by the vast majority of homeowners and tenants surveyed (73%, 69% and 67%, respectively). A smaller but still considerable percentage (34%) indicated that the presence of smart technology is important. The heating source is of higher relevance to homeowners and tenants in Greece, Poland, and Romania than in Denmark and Portugal. However, this may be explained by the fact that central heating is in general rare in Portugal and district heating is the most common heating source in Denmark, a country which is known as one of the most energy efficient economies in the world. Overall, respondents in Romania stand out as viewing the energy performance of a building as very relevant when renting or

buying property. At the same time, the Individual Building Renovation Roadmaps (iBRoad) project (iBRoad, 2021) has shown that Romania has a comparable high average residential energy consumption which may play a role in the perceived importance (iBRoad, 2018a). It is also noteworthy that older homeowners and tenants surveyed attribute more weight to the heating source and energy efficiency than younger age groups. Expectedly, the same applies to respondents that are in general more conscious about energy use and energy efficiency at home. A large proportion of the total sample (2563 respondents) tried to reduce the amount of energy they used at home (78%) or thought there was more they could do to reduce their usage (72%). However, only 40% of respondents were more concerned about having a warm and comfortable home than saving energy.

3.2. New technical features

3.2.1. Smart readiness

The smartness of a building refers to the ability of a building to use information and communication technologies to actively and efficiently respond to the needs of occupants and the grid, improving energy efficiency and overall building performance. The “Smart Readiness Indicator” (SRI) is a voluntary European scheme for rating the technological readiness of a building to make use of smart technology (Verbeke et al., 2020). Smart technologies in buildings can aid in creating healthier and more comfortable buildings with better energy performance and can also facilitate the integration of renewable energy sources in future energy systems. The SRI scheme is intended to raise awareness about the benefits of smart buildings by making building smartness more tangible for building users, owners, tenants and smart service providers.

Table 2 shows the percentage for the total group of respondents surveyed as well as results per country. The majority of end-users surveyed have a positive attitude towards smart homes.² Around three-fourth (75%) of respondents see its value in increasing comfort and 78% in saving energy at home. Fewer are concerned about security related risks; one-third (31%) question the security of smart homes in terms of its proneness to hacking. To which extent the opinions are based on respondents’ own experiences or common perception is open – 50% stated being familiar with smart technology, 31% were unsure. Still, the majority (68%) would like to live in a smart home, though it is not seen as one of the most important aspects when buying or renting property. Around the same percentage (63%) would like to have information on the presence of smart technology in their EPC.

Respondents who indicated that energy efficiency is important when buying or renting property are more likely to agree that smart technology helps to save energy (81% in contrast to 57% for whom energy efficiency is not important). Though Denmark is considered one of the four leading EU countries when it comes to smart readiness (BPIE, 2017), consumers surveyed in Denmark indicated to be less familiar with smart technology (36% indicated being familiar and 29% were unsure) than the average of the sample. The majority shows a positive

¹ Pairwise tests of the equality of column proportions (via z-test) and column means (via t-tests) were produced. Pairwise comparison means comparing all pairs of something (i.e., countries, socio-demographic categories etc.). A significance level of 0.05 is used for these tests.

² Definition used in the survey: “A smart home uses smart technology (internet-connected devices for monitoring appliances and systems) to share information between systems in order to optimise the building’s performance, from heating and ventilation to air conditioning and security.”

Table 2
Overview of respondents' opinions on smart readiness.

	Total (n = 2563)	Denmark (n = 512)	Greece (n = 519)	Poland (n = 501)	Portugal (n = 514)	Romania (n = 517)
% being familiar with smart technology	50%	36% [#]	61% [#]	50%	45% [#]	56% [#]
% agreeing that smart homes increase the comfort of their occupants	75%	58% [#]	74%	77%	83% [#]	83% [#]
% agreeing that smart homes help to save energy	78%	68% [#]	84% [#]	74% [#]	79%	83% [#]
% agreeing that smart homes are not secure because they can be hacked	31%	29%	30%	32%	32%	31%
% that would like to live in a smart home	68%	48% [#]	78% [#]	66%	73%	76% [#]
% that consider the presence of smart technology important when buying or renting property	34%	14% [#]	41% [#]	31%	34%	47% [#]
% that would like to have information on the presence of smart technology in the EPC	63%	44% [#]	69% [#]	66%	60%	76% [#]

[#]Significant differences compared to the total.

attitude towards smart homes but again less than the average. This difference may stem from the circumstance that smart technology is more frequently addressed in public discourses, which includes both positive and negative debates that reveal the complexity of smart technology. Some might see this information as redundant given the common practice of energy-efficient technical installations in (new) buildings. The advantage of energy saving is also perceived by a larger proportion of respondents with tertiary education (82%) compared to respondents with less than primary, primary, and lower secondary education (62%).

There are differences in socio-demographic characteristics in terms of end-users' knowledge of and opinions on smart homes. Men are more often familiar with smart technology than women (55% and 45%, respectively), but they also have less trust in its security (32% compared to 23% of women think that smart homes are not secure because of their proneness to hacking). In terms of age, younger consumers surveyed have a higher probability of having knowledge on related technology (60% of 18–24 years old and 41% of 65+ years old), while older homeowners and tenants are more confident in saving energy with smart technology (82% of 45 or older compared to 66% of 18–24 years old).

3.2.2. Comfort and outdoor air pollution

Comfort (e.g., good indoor air quality and thermal comfort, no draught) and outdoor air pollution at home are relevant for consumers surveyed and they would like to have information on related indicators in their EPCs. Specifically, the level of indoor air quality (IAQ), the efficiency of the ventilation system and the impact of outdoor air pollution on indoor air quality would be of interest for respondents (see Table 3). The majority of respondents (66%) also would like to have information on the building's impact on outdoor air pollution in the EPC, but in comparison to comfort the percentage that would like to have this information is lower. Homeowners and tenants in Denmark see less value of the comfort related information in their EPCs which may be related to detailed requirements on thermal comfort, indoor air quality and ventilation in the Danish Building Regulation (BR10) (Kunkel et al., 2015) and generally better air quality in the country (EEA, 2020). On the other hand, it may be related to the awareness of Danish respondents on the issues of comfort and outdoor air quality having less than primary, primary, and lower secondary education (38%).

Various aspects were that are important for the personal comfort at home were outlined for respondents such as: (i) Indoor air quality (no stuffy, humid, or mouldy air, no odour), (ii) Thermal and ventilation comfort (comfortable indoor temperature, no draught), (iii) Visual comfort (natural light, external view, reduced glare), and (iv) No noise nuisance (no noise from outside such as road traffic, construction). Fig. 3 shows which proportion of respondents consider each of the four aspects as most important. In Romania, there are differences between homeowners and tenants concerning visual comfort and noise nuisance: visual comfort has a higher value for tenants (ranked first or second by 51%) than homeowners (ranked first or second by 35%). No noise nuisance is

more important for consumers surveyed who own their home (ranked first or second by 38% and by 26% of those that rent). In Poland, significantly more people ranked 'no noise nuisance' first than in the other countries (30% in contrast to 20% on average). Research on acoustic comfort has shown that residents in Poland are widely dissatisfied with the acoustic insulation of walls between dwellings and that acoustic requirements for internal walls are lower compared to other European countries (Nowak and Kania, 2018).

Respondents ranked the four aspects in order of importance starting with Indoor air quality as highest, followed by thermal and ventilation comfort, visual comfort, and noise as lowest. A variation between age groups was observed regarding visual comfort: 47% of 18–24 years old consumers surveyed ranked this aspect first or second, compared to 35% of 55+ years old. This suggests that younger people perceive visual comfort as more important than older people.

3.2.3. Real energy consumption

The feature real energy consumption refers to the determination of the energy performance of a building based on measured energy use and related data. Respondents perceive different information related to their current and past energy use (smart meters, use by appliance, and use at the same time in the previous week) as helpful in reducing their energy consumption at home, as illustrated in Table 4. As much as 80% of the respondents think that a monthly overview of energy consumption of each appliance in the household is helpful to better manage energy usage. Comparisons with similar household are also perceived as helpful by a large majority (61%), though less useful than data related to the own household. A similar attitude can be observed in regard to information in the EPC: 71% would like to have information on the energy use and costs of previous occupants, i.e., related to their own home.

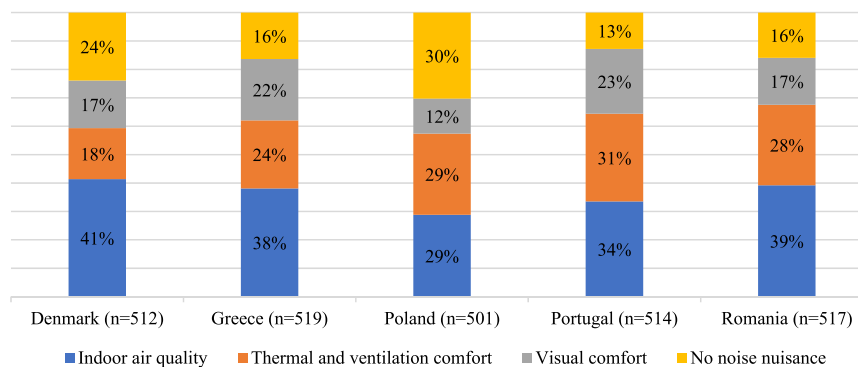
Respondents are most willing to give consent to energy advisors (e.g., energy auditor, qualified experts) (70%) and utilities and energy suppliers (69%) to use their energy consumption data to provide them with tailored information on how to reduce energy use (see Fig. 4). More than half would agree to provide this information to their municipality (53%) or to contractors (e.g., installers, craftsmen) (57%). Roughly one-third (36%) would give consent to financial institutions. Consumers surveyed who are conscious about their energy use at home are in general more willing to give consent to third parties.

Portugal stands out as the country where the least percentage would like to have information on the energy use and costs of previous occupants on their EPC (58% compared to 71% on average and for example 79% in Poland). This may be related to increased energy affordability and changes in socio-economic profiles of the Portuguese population, and thus different energy consumption patterns between occupants and over time (EC, 2017; iBRoad, 2018b). Respondents in Portugal are also more willing to provide their energy consumption data to the municipality to provide them with tailored information on how to reduce energy use (65% compared to 53% on average). In Denmark, respondents indicated the helpfulness of including real energy consumption related

Table 3

Overview of respondents' opinions on comfort and outdoor air pollution related information in the EPC.

	Total (n = 2563)	Denmark (n = 512)	Greece (n = 519)	Poland (n = 501)	Portugal (n = 514)	Romania (n = 517)
% that consider comfort important when buying or renting property	73%	63% [#]	73%	69% [#]	77%	83% [#]
% that would like to have information on the level of indoor air quality in the EPC	83%	78%	81%	85%	82%	88%
% that would like to have information on the impact of outdoor air pollution on indoor air quality in the EPC	75%	64% [#]	74%	80% [#]	72%	83% [#]
% that would like to have information on the efficiency of ventilation system in the EPC	80%	70% [#]	83% [#]	83% [#]	79%	84% [#]
% that would like to have information on the building's impact on outdoor air pollution in the EPC	66%	54% [#]	70% [#]	68%	63%	74% [#]

[#]Significant differences compared to the total.**Fig. 3.** Most important aspect for personal comfort at home by country (n = 2563).**Table 4**

Overview of respondents' opinions on real energy consumption related information in the EPC.

	Total (n = 2563)	Denmark (n = 512)	Greece (n = 519)	Poland (n = 501)	Portugal (n = 514)	Romania (n = 517)
% that thinks real-time feedback on their energy use via a smart meter helps to better manage energy usage	77%	61% [#]	82% [#]	83% [#]	79%	82% [#]
% that thinks that a monthly overview of energy consumption of each appliance in the household helps to better manage energy usage	80%	61% [#]	85% [#]	85% [#]	85% [#]	83%
% that thinks that a comparison of their energy use with similar households helps to better manage energy usage	61%	52% [#]	66% [#]	67% [#]	61%	62%
% that thinks comparison of their energy use today with that of the same time last year helps to better manage energy usage	77%	69% [#]	81% [#]	80%	81% [#]	76%
% that would like to have the energy use and energy costs of previous occupants on their EPC	71%	70%	72%	79% [#]	58% [#]	76% [#]
% that would like to have the energy performance score of similar buildings nearby in their EPC	62%	56%	65%	68%	59%	61%

[#]Significant differences compared to the total.

information in the EPC to be lower compared to the answers of respondents in the other countries involved (except in relation to the energy use and costs of previous owners). There are about 26% younger consumers (18–24 years old) in Denmark who among all age groups are least interested in real energy consumption feedback which could also be related to their knowledge levels regarding the importance of energy use. Still, more than half of Danish respondents indicated information related to real energy consumption on the aspects questioned (see Table 4) to be helpful.

3.2.4. District energy

The district energy feature aims to inform the EPC users on the efficiency and climate effect of the nearby district heating (or cooling) network. It would also indicate whether the building can be connected to a low-temperature district heating grid. Two-third of respondents (67%) consider information on the current and estimated future

efficiency, CO₂ emissions and share of renewables in the closest district heating system as interesting. Slightly less (61%) are also interested in the distance of their building to the existing district heating grid – more than half (57%) would like to see this information in their EPC (Table 5). These details are more appealing for consumers that are conscious about their energy use.

Around 64% of households in Denmark are connected to district heating used for space heating and hot water combined. In 2014, almost 50% of produced district heating came from renewable sources (DEA, 2020). Respondents in Denmark show less interest in information related to district heating which may be related to the fact that it is already an important component of the Danish energy system and incorporated in energy policy targets. Homeowners and tenants with at least secondary education (15%) show more interest in this information than those with less than primary, primary and lower secondary education (38%). District heating is mainly available to residents in urban

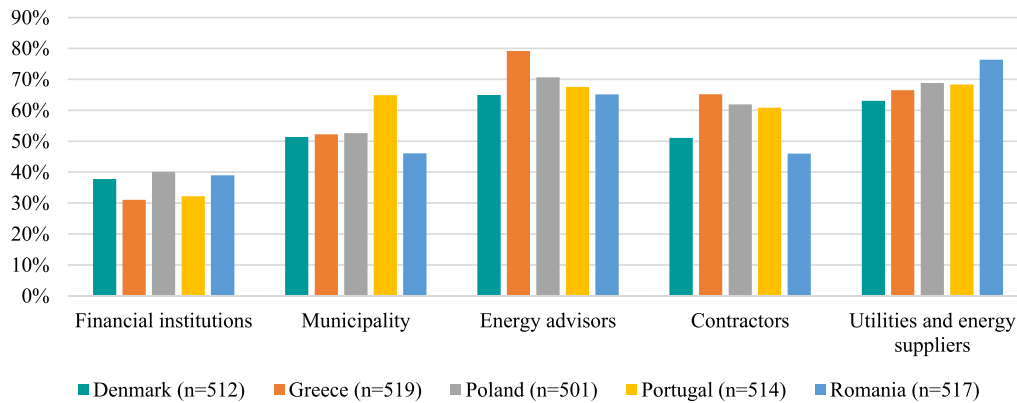


Fig. 4. Willingness to provide consent to third parties to use energy consumption data for tailored information on how to reduce energy use (n = 2563).

Table 5

Overview of respondents' opinions on district energy related information in the EPC.

	Total (n = 2049)	Denmark (n = 512)	Greece (n = 519)	Poland (n = 501)	Romania (n = 517)
Estimated future efficiency, CO ₂ emissions and share of renewables in the closest district heating system	67%	54% [#]	71% [#]	69%	74% [#]
Current efficiency, CO ₂ emissions and share of renewables in the closest district heating system	68%	55% [#]	71%	70%	76% [#]
Distance of the building to the existing district heating grid	61%	38% [#]	71% [#]	65%	71% [#]
Distance of the building to the existing district heating grid in the EPC	57%	35% [#]	65%	63%	69%

Note: Portugal was not considered since district energy is not a common solution; [#]Significant differences compared to the total.

areas and, therefore, of less interest for the rural population (State of Green, 2018). Romania has a high share of tertiary (21%) and upper secondary educated (20%) respondents compared to less than primary (9%) which ascertains those respondents are aware of this topic and have shown a high interest in the information. 62% of residents in large cities are interested in the current efficiency, CO₂ emissions and share of renewables in the closest district heating system, compared to 37% in rural areas. This urban-rural difference is not observed in other countries. Respondents who have recently renovated or are planning to do so are more often interested in information on district heating, as illustrated by Fig. 5.

3.3. Innovative features to handle EPC data

3.3.1. EPC databases

EPC databases refers to databases that store all available EPCs and

their underlying data. They are a valuable tool for public authorities to source building stock information. A well-developed EPC database can also interoperate with other national registers and provide benchmarking values for the building stock. In this context, it is very important to check the compliance of the EPC data, including with the national assessment methodology. When buying or renting a property, respondents consider a comparison of the energy efficiency score of their property with other properties in the neighbourhood more useful (68%) than with all properties in the country (49%). Even more useful is a comparison with similar properties (78%). This perception is the same across the survey countries (Table 6). The majority (62%) would like to have the energy performance score of similar buildings nearby in their EPC. More 50% respondents from all age groups (18–55+) express usefulness of this information and it is more interesting for homeowners and tenants that have recently renovated (or plan to renovate) (63% compared to 52% who did or do not renovate) and residents in the suburbs or outskirts of a large city (65% compared to 51% from rural areas).

One-third of respondents (35%) would agree that information about their building's energy performance is included in a publicly accessible database if it is fully anonymous (Fig. 6). Fewer (24%) would agree if the postal code would be visible and again less (15%) if the exact address would be displayed. 12% would not agree to this at all and 14% do not know how they would decide. Denmark and Portugal offer full public access with protected privacy already to their databases, however the other three countries do not (Kaya et al., 2018).

3.3.2. Building logbook

Building logbooks are repositories for detailed building information. They function as a single point of input, access and visualisation of all the information associated with a building unit throughout its lifecycle. For the majority of respondents (66%) it would be important to receive a document or folder with all the building-related documents (dwelling's condition, maintenance activities, etc.) if they decided to buy or rent a property. The presence of this building logbook would be more important for homeowners and tenants that are conscious about their energy use, as well as for older age groups (51% of 18–24 years old consumers surveyed stated it is important compared to 71% of those older than 55, probably because younger consumers are more likely to think about short-term rent and, therefore, consider a logbook less relevant). Homeowners and tenants would find it more useful to find information on the condition of walls and roofs, window glazing and insulation, and the equipment age in the logbook, as illustrated in Fig. 7. 4% do not consider any of the information presented in the survey helpful. The perceived usefulness of each aspect is similar across the survey countries.

In a survey taken in 2017–2018 on the markets for Individual

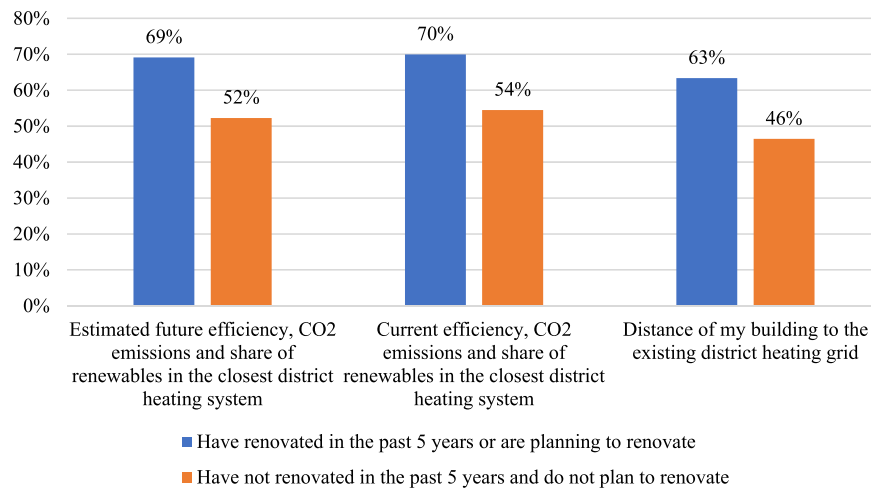


Fig. 5. District Energy-degree of interest in information by renovation experience for all countries (n = 2049).

Table 6

Overview of respondents' opinions on EPC databases information in the EPC.

		Total (n = 2563)	Denmark (n = 512)	Greece (n = 519)	Poland (n = 501)	Portugal (n = 514)	Romania (n = 517)
usefulness of comparing the energy efficiency score of a property with that of	..all properties in the country	49%	41% [#]	58% [#]	48%	47%	50%
	..all properties in your region	60%	47% [#]	75% [#]	61%	60%	57%
	..other properties in the neighbourhood	68%	61% [#]	75% [#]	72% [#]	67%	64%
	..properties similar to the one you want to buy/rent	78%	71% [#]	83% [#]	81%	79%	78%
	% that would like to have the energy performance score of similar buildings nearby in their EPC	62%	56%	65%	68%	60%	61%

[#]Significant differences compared to the total.

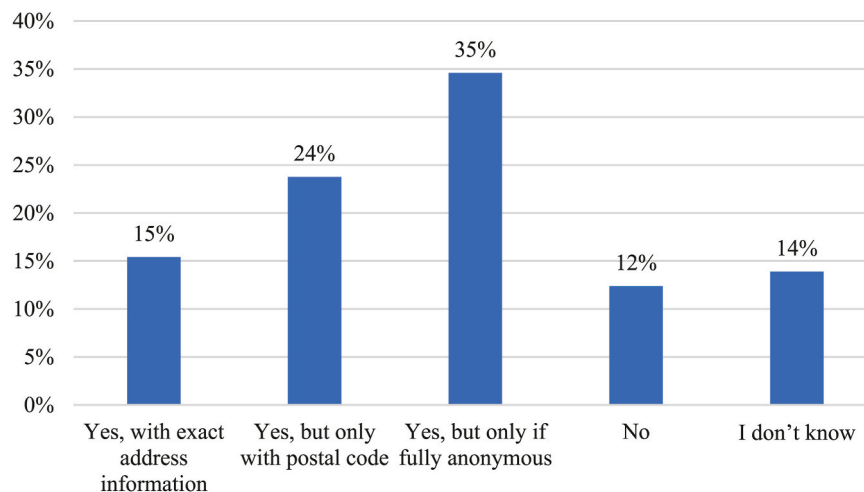


Fig. 6. Agreement that information about the buildings energy performance is included in a publicly accessible database (n = 2563).

Building Renovation Roadmaps, consumers in Poland and Portugal were asked which information they would like to find in a building logbook (Volt et al., 2018). In that study, respondents found information related to the condition of the property and specifications of heating systems and other equipment more relevant than, for example, the contact details of previous contractors and transaction prices. This is in line with the findings of the survey considered in this paper.

Homeowners and tenants were also asked if they would like to receive a building logbook. Among the ones that received a building

logbook, of similar, the majority (67%) keeps it up to date and thinks it is useful (55%). One-fourth (24%) do not keep it up to date with new information on maintenance or alterations to the property but think it would be useful (Fig. 8).

3.3.3. Enhanced recommendations

Enhanced EPC recommendations means to provide advice on measures of renovation considering its impact on energy performance, carbon emissions and costs. These are mainly for building transactions

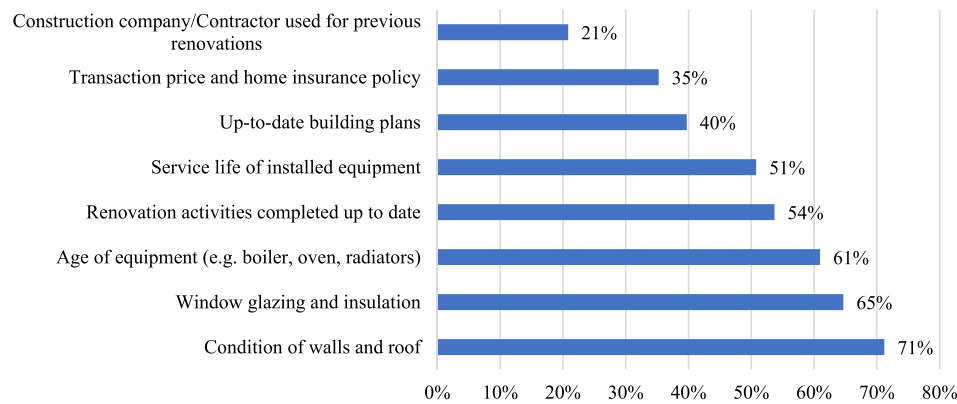


Fig. 7. Perceived usefulness of different information in the building logbook (n = 2563).

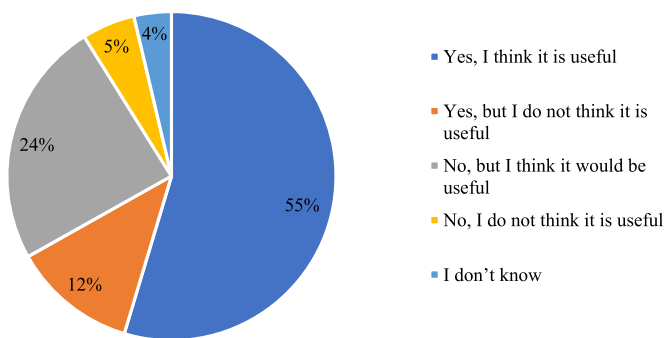


Fig. 8. View on the building logbook (n = 2563).

(sell/buy/renovate), and how EPC recommendations can be linked with the national long-term renovation and climate strategies for the building stock. If respondents were to make their home more energy efficient³, they would find it useful to have details on previous energy renovations, information on available measures and relevant recommendations in their EPCs (82%). Younger respondents (18–24 years old) would find this information less useful than older age groups. Also, homeowners and tenants in rural areas see less value in these details. Overall, recommendations are more appreciated by consumers surveyed who are conscious about their energy use and who consider energy efficiency important when buying or renting property.

Respondents were specifically asked which information they would consider most useful. As shown in Fig. 9, more than 50% respondents consider cost related information as most useful. Technical details are considered as less useful, though still relevant. In particular, homeowners and tenants who are conscious about their energy use consider the different information and recommendations listed in Fig. 9 useful.

3.3.4. Financing options

Financing options aims to integrate the information on financial support for the end-users in the EPC and its specific recommendations to help to persuade building owners to undertake an energy renovation. Respondents find it useful to have information in their EPCs on how to access different financing options for renovations (71%). This information is perceived as helpful particularly by consumers who have renovated or are currently (planning to) renovating to increase the energy efficiency of their home (77% compared to 58% who did or do not

renovate for energy efficiency). About 79% of respondents in Greece consider it useful to have in their EPCs information on how to access financing options for renovations. Previous studies have shown that in order to encourage (energy) renovation in the country, consumers need to receive advice and information on available financial support (iBRoad, 2018c) and bureaucratic barriers to receive loans from financial institutions have to be reduced (Hellenic Republic, 2018). It was also noted that there is a significant financial gap for energy efficiency interventions in Greece, while at the same time Greek residents are among the ones most affected by energy poverty in Europe (Artola et al., 2016).

As shown in Fig. 10, Greece and Romania presented the highest interest in maintenance and operation costs, with almost two-thirds of respondents saying they find this information useful. Portugal and Greece show the most interest in receiving information on payback time of the renovation (48% and 47% of respondents respectively), with Denmark showing the least (36%) probably due to higher share of responses (38%) from respondents having less than primary, primary, and lower secondary education levels.

3.3.5. One-stop-shops

One-stop-shops are transparent and integrated advisory tools/venues, which aim to accelerate energy renovations by informing, motivating, and assisting building owners throughout the renovation journey, from beginning to end. As shown in Table 7, majority of homeowners and tenants (57%) would use a one-stop-shop with the goal of asking renovation-related questions and get in contact with building professionals – if it was free. One-fourth (25%) would be willing to pay a small fee for such services. Those that are, in general, more conscious about their energy use at home would be rather willing to pay for the services.

The survey findings show that no category of information or services is favoured over the other to receive in a one-stop web portal for renovation-related questions (Fig. 11). Calculations, advice and price quotes for renovation measures are equally interesting services for around half of homeowners and tenants. At least one-third would also like to receive information related to the EPC and specific details on companies and installers.

Noteworthy, the interest in the option of online quotations varies across the survey countries. This service appeals more to consumers in Greece (65%) and Portugal (63%) than Poland (40%), Romania (36%) and Denmark (34%).

- Fewer respondents in Denmark would like to receive details on the services proposed by companies and/or installers and direct access to them.

³ Definition of 'energy efficiency' used in the survey: "By energy efficient we mean making a home more efficient in saving energy, e.g., by installing wall insulation, or installing a more efficient heating system."

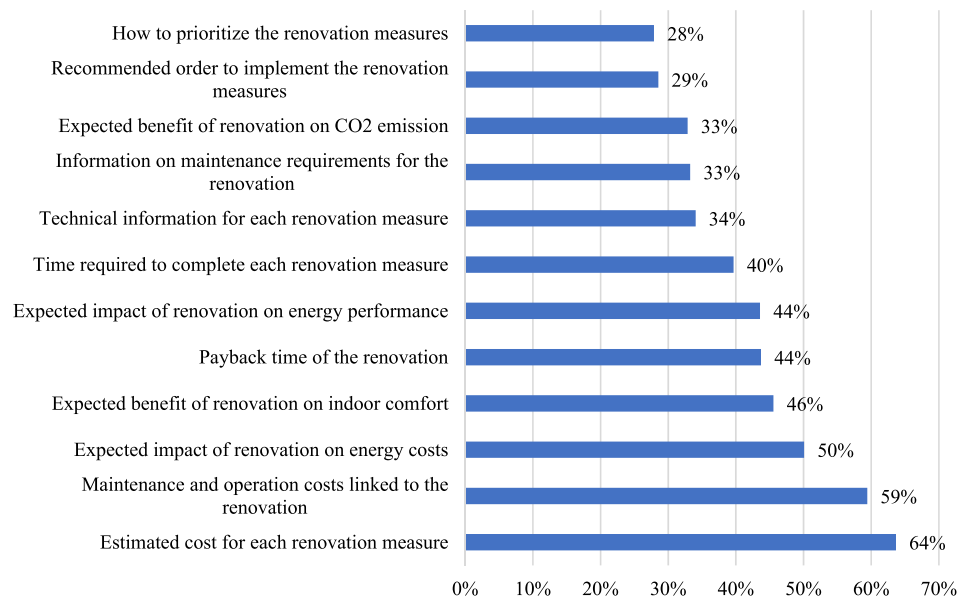


Fig. 9. Usefulness of enhanced recommendations and information (n = 2563).

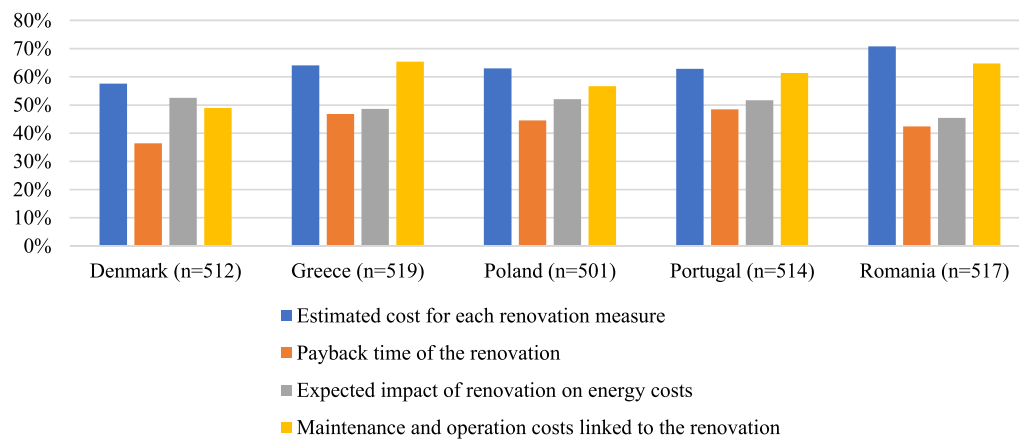


Fig. 10. Enhanced recommendations: type of information respondents find useful to receive (n = 2563).

Table 7

Overview of respondents' opinions on one-stop-shops.

	Total (n = 2563)	Denmark (n = 512)	Greece (n = 519)	Poland (n = 501)	Portugal (n = 514)	Romania (n = 517)
% that would be willing to pay a small fee for such a service	25%	26%	26%	21% [#]	20% [#]	32% [#]
% that would use the service but only if offered for free	57%	48% [#]	63% [#]	60%	64% [#]	51% [#]
% that would (probably) not use the service	10%	15% [#]	6% [#]	10%	10%	9%

[#]Significant differences compared to the total.

- Consultation on technical solutions for specific measures would be particularly interesting for respondents in Greece (66%) but less so in Portugal (44%).
- The proportion of respondents interested in EPC related information is lower in Poland than in the other countries.
- Homeowners and tenants surveyed in Romania would specifically appreciate direct access to companies and/or installers that best match their needs.

A higher number of respondents with lower secondary education or less do not consider any of the services relevant to receive (14% compared to 9% and 6% of individuals with up to post-secondary non-tertiary education and tertiary education, respectively). The same applies to respondents from rural areas (13% vs 7% on average), this is particularly noticeable concerning the service to rank companies and/or installers according to price and quality; 38% of homeowners and tenants in rural areas would like to have this service compared to 52% of

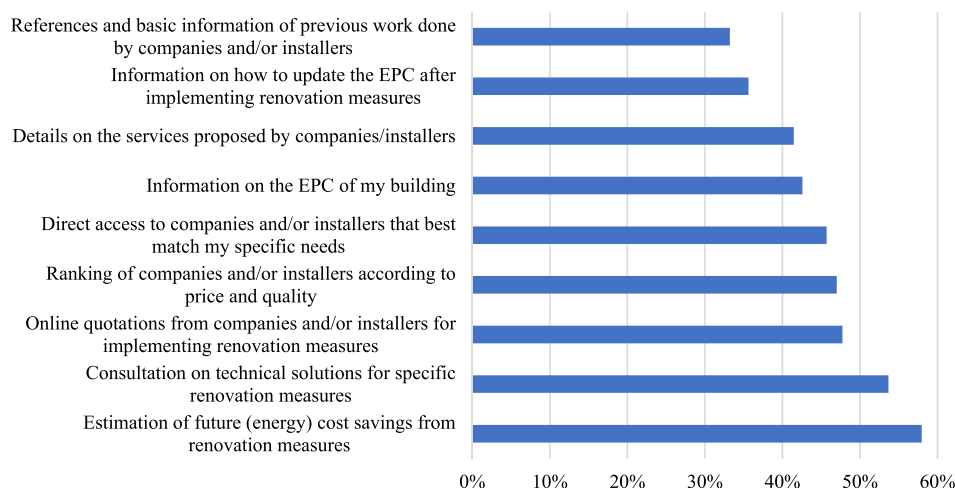


Fig. 11. Services consumers would like to receive in a one-stop-shop (n = 2563).

residents in large cities.

4. Conclusions and policy implications

The survey results demonstrate a rather energy-conscious attitude and the ideas of the ten features were perceived positively, despite occasional unfamiliarity with concepts such as smart technology. There were only small differences in the perceived importance of the different elements of the ten features, some being seen as slightly more beneficial or interesting than the others. Based on the interest of end-users it is more likely that public bodies or energy agencies responsible for EPC schemes in Greece, Poland and Romania would welcome smart readiness, real energy consumption, financing options more than Denmark and Portugal. Outdoor air pollution, district energy and building log-books received mostly neutral interest. However, comfort, EPC databases and one-stop-shops drew high interest from the end-users of all five countries.

In general, a higher number of respondents are interested in information that has a direct relevance for their home and household. For example, feedback on the real energy consumption is perceived as more useful when it provides a comparison with the previous year than with similar households. For the EPC database, it would be more valuable for respondents to see the energy efficiency score of similar properties than all properties in the neighbourhood. At the same time, consumers want to ensure confidentiality of the data they share. Enhanced recommendations and financing options have a higher relevance if the suggested renovation work is intended to improve the energy performance of the home. Regarding renovations, information on costs has the highest informative value for respondents; this is visible in the sections of enhanced recommendations and one-stop-shops. However, the willingness to pay for these services is rather low and thus it may need careful integration into public frameworks. The ten features are viewed most positively if homeowners or tenants are conscious about their energy use at home and energy performance is an important aspect when buying or renting property. Likewise, interest in features is highest if respondents have recently completed or started a renovation project, or if they aim to improve the energy efficiency of their homes. Recurring variations in perceptions and attitudes can be found in relation to area of residence (urban vs rural) and age group (for example, for smart readiness, enhanced recommendations and one-stop-shops). Differences between homeowners and tenants are not significant with regards to the importance of the energy efficiency when buying or renting property or making their home more energy efficient through renovations.

The current EPCs have not been tailored to the needs of the end-user.

Displaying only the energy performance of the building brings limited benefits to most people, especially when the content is conveyed in technical terms. Results outline that new EPC features could enhance the usefulness and attractiveness of the instrument. Revisions of the Energy Performance Building Directive (EPBD) could strengthen EPCs and make them more dynamic for the Member States. The results of the survey clearly outline that new features can help further improve them and increase knowledge on energy efficiency and the importance of high quality renovation. This is particularly important as in the private residential sector, the ones deciding on renovation measures are the owners (and to a much lesser degree tenants). Therefore, it is crucial that public bodies and European regulators realise the potential of new features that are specifically useful to these groups and easily understandable for them. It must be made compulsory under the EPBD to set up a central/regional EPC register for all Member States to make information accessible to all stakeholders. EPC must be made an integrated tool for financing deep renovation and accessing one-stop-shops in Member States policies. In particular, a more harmonised European calculation methodology for the EPC could increase the comparability between regions, confidence and market uptake for features like smart readiness, comfort, real energy consumption and district energy. A new standard, guidance, or policy document would help Member States develop their EPC regimes. In this direction, this study provided practical findings that significantly inform Member States to improve reliability, compliance and market penetration of EPCs and advance towards updating their existing EPC system. The next steps and further work include the development, testing and validation of the ten features in some Member States by the public authorities and energy agencies.

CRedit authorship contribution statement

Sheikh Zuhair: Conceptualization, Methodology, Investigation, Formal analysis, Writing – original draft, Writing – review & editing. **Senta Schmatzberger:** Methodology, Investigation, Formal analysis, Writing – original draft, Writing – review & editing. **Jonathan Volt:** Investigation, Writing – original draft, Writing – review & editing. **Zsolt Toth:** Supervision, Investigation, Writing – original draft, Writing – review & editing. **Lukas Kranzl:** Investigation, Writing – review & editing. **Iná Eugénio Noronha Maia:** Investigation, Writing – review & editing. **Jan Verheyen:** Investigation, Writing – review & editing. **Guillermo Borragán:** Investigation, Writing – review & editing. **Cláudia Sousa Monteiro:** Writing – review & editing. **Nuno Mateus:** Writing – review & editing. **Rui Fragoso:** Investigation. **Jerzy Kwiatkowski:** Investigation, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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References

- EEA, 2020. Denmark - Air Pollution Country Fact Sheet 2020. European Environment Agency [Online]. Available: <https://www.eea.europa.eu/themes/air/country-fact-sheets/2020-country-fact-sheets/denmark>.
- X-tendo, 2019. eXTENDING the Energy Performance Assessment and Certification Schemes via a mOduLAR Approach. X-tendo project [Online]. Available: <https://x-tendo.eu/>.
- ZEBRA2020, 2016. The Impact of Energy Performance Certificates on Property Values and Nearly-Zero Energy Buildings: an Analysis for Professionals and Users [Online]. Available: <https://zebra2020.eu/publications/the-impact-of-energy-performance-certificates-on-property-values-and-nearly-zero-energy-buildings-2/>.
- Abreu, M.I., Oliveira, R., Lopes, J., 2017. Attitudes and practices of homeowners in the decision-making process for building energy renovation. *Procedia Eng.* 172, 52–59.
- Amecke, H., 2011. The Effectiveness of Energy Performance Certificates - Evidence from Germany. " Berlin.
- Andelković, A.S., et al., 2021. Building energy performance certificate—a relevant indicator of actual energy consumption and savings? *Energies* 14 (12), 3455.
- Artola, I., Rademaekers, K., Williams, R., Yearwood, J., 2016. Boosting Building Renovation: what Potential and Value for Europe? Study for the ITRE Committee. Dir. Gen. Intern. Policies. Policy Dep. A Econ. Sci. Policy, pp. 1–72. PE 587.326.
- Atanasiu, B., Constantinescu, T., 2011. A comparative analysis of the energy performance certificates schemes within the European Union: implementing options and policy recommendations. May 2010. In: Eur. Council. an Energy Effic. Econ. - Panel 2 Curr. Energy Effic. Policies, p. 10.
- Brocklehurst, F., 2017. What will you pay for an 'A' ? – a review of the impact of building energy efficiency labelling on building value. In: "ECEE Summer study, pp. 1259–1269.
- Christensen, T.H., Gram-Hanssen, K., de Best-Waldhober, M., Adjei, A., Jul. 2014. Energy retrofits of Danish homes: is the Energy Performance Certificate useful? *Build. Res. Inf.* 42 (4), 489–500.
- Concerted Action EPBD, 2019. EPBD key implementation decisions (KIDs) [Online]. Available: <https://epbd-ca.eu/archives/2479>.
- Dorizas, P.V., De Groot, M., Volt, J., 2018. The Inner Value of a Building: Linking Indoor Environmental Quality and Energy Performance in Building Regulation.
- EC, 2014. Financing the Energy Renovation of Buildings with Cohesion Policy Funding. European Commission, Brussels.
- EC, 2017. Energy Union Factsheet Portugal. European Commission, Brussels.
- EC, 2020. A Renovation Wave for Europe- Greening Our Buildings, Creating Jobs. European Commission, Brussels.
- Economidou, M., Todeschi, V., Bertoldi, P., D'Agostino, D., Zangheri, P., Castellazzi, L., 2020. Review of 50 years of EU energy efficiency policies for buildings. *Energy Build.* 225, 110322.
- EU, 2010. Directive 2010/31/EU of the European Parliament and the Council of 19 May 2010 on the Energy Performance of Buildings (Recast). European Union, Brussels, pp. 13–35.
- Hellenic Republic, 2018. Report on the Long-Term Strategy to Mobilise Investment in the Renovation of Private and Public Residential and Commercial Buildings in the National Building Stock. Athens.
- iBRoad, 2018a. Factsheet: Portugal Current Use of EPCs and Potential Links to iBRoad. Brussels.
- iBRoad, 2018b. Factsheet: Portugal Current Use of EPCs and Potential Links to iBRoad. Brussels.
- iBRoad, 2018c. Factsheet: Belgium - Flanders Current Use of EPCs and Potential Links to iBRoad. Brussels.
- iBRoad, 2021. Individual Building Renovation Roadmaps (iBRoad) Project [Online]. Available: <https://ibroad-project.eu/>.
- Jamieson, Max, Brajterman, O., Verstraeten, Y., Arbon, J., 2015. EPBD Compliance Study - Final Report. Brussels.
- Kaya, D., Çanka Kılıç, F., Öztürk, H.H., 2018. Energy Performance Certificate Database in Denmark. Berlin.
- Khazal, A., Sønsteby, O.J., 2020a. Valuation of energy performance certificates in the rental market – professionals vs. nonprofessionals. *Energy Pol.* 147, June.
- Kostova, D., 2020. Report on EPC Best Practices: QualDeEPC H2020 Project. Wuppertal.
- Kunkel, S., Kontonasiou, E., Arcipowska, A., Mariottini, F., Atanasiu, B., 2015. Indoor Air Quality, Thermal Comfort and Daylight - Analysis of Residential Building Regulations. " Brussels.
- Li, Y., Kubicki, S., Guerriero, A., Rezgui, Y., Oct. 2019. Review of building energy performance certification schemes towards future improvement. *Renew. Sustain. Energy Rev.* 113, 109244.
- Macer, T., Wilson, S., 2016. Focus Vision 2015 Annual MR Technology Report. London.
- Nowak, H., Kania, T., 2018. National and European requirements concerning acoustic insulation from air sounds for internal walls. *IOP Conf. Ser. Mater. Sci. Eng.* 415, 1.
- Olaussen, J.O., Oust, A., Solstad, J.T., 2017a. Energy performance certificates – informing the informed or the indifferent? *August Energy Pol.* 111, 246–254.
- Pascuas, R.P., Paoletti, G., Lollini, R., 2017. Impact and reliability of EPCs in the real estate market. *Energy Procedia* 140, 102–114.
- Pasichnyi, O., Wallin, J., Levihi, F., Shahrokni, H., Kordas, O., 2019. Energy performance certificates — new opportunities for data-enabled urban energy policy instruments? *Energy Pol.* 127, 486–499. April 2018.
- Seiple, S., Jenkins, D., Feb. 2020. Variation of energy performance certificate assessments in the European Union. *Energy Pol.* 137, 111127.
- State of Green, 2018. District Energy: Energy Efficiency for Urban Areas. Copenhagen.
- Verbeke, S., Aerts, D., Reynders, G., Ma, Y., Waide, P., 2020. Final Report on the Technical Support to the Development of a Smart Readiness Indicator for Buildings. Brussels.
- Volt, J., Fabbri, M., De Groot, M., 2018. Understanding Potential User Needs. Brussels.
- Volt, J., Zuhair, S., Schmatzberger, S., Zsolt, 2020. Energy Performance Certificates, Assessing Their Status and Potential. X-tendo project (H2020). Brussels.
- von Platten, J., Holmberg, C., Mangold, M., Johansson, T., Mjörnell, K., 2019. The renewing of Energy Performance Certificates—reaching comparability between decade-apart energy records. *September Appl. Energy* 255, 113902.
- Wilhelmsson, M., 2019. Energy performance certificates and its capitalization in housing values in Sweden. *Sustainability* 11, 21.
- Zirngibl, J., Mateo-Cecilia, C., Espigares-Correa, C., 2019. Alliance for Deep Renovation in Buildings. A Step Forward to the Common European Voluntary Certification Scheme. in E3S Web of Conferences 111, CLIMA 2019.
- UNEP, 2020. Global Status Report for Buildings and Construction: towards a Zero-Emission, Efficient and Resilient Buildings and Construction Sector. " Nairobi, 2020.
- BREEAM, 2021. BREEAM (Building Research Establishment Environmental Assessment Method) - Sustainability Assessment Method [Online]. Available: <https://www.breeam.com/>.
- DEA, 2020. Danish experiences on district heating. Danish Energy Agency [Online]. Available: <https://ens.dk/en/our-responsibilities/global-cooperation/experiences-district-heating>.
- DGNB, 2021. DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen)- German Sustainable Building Council rating system [Online]. Available: <https://www.dgnb.de/en/council/>.
- EU, 2002. Directive 2002/65/EC of the European Parliament and of the Council of 16 December 2002 on the Energy Performance of Buildings. Office Journal of the European Union, Brussels.
- EUROSTAT, 2021. Distribution of Population by Tenure Status, Type of Household and Income Group - EU-SILC Survey. European Commission [Online]. Available: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ilc_lvho02&lang=en.
- BPIE, 2014. Energy Performance Certificates across the EU: A Mapping of National Approaches. Brussels.
- BPIE, 2017. Is Europe Ready for the Smart Buildings Revolution: Mapping Smart Readiness and Innovative Case Studies. Brussels.
- LEED, 2021. LEED (Leadership in Energy and Environmental Design) Rating System [Online]. Available: <https://www.usgbc.org/leed>.
- EUROSTAT, 2021. Share of Population Having Moved to Other Dwelling within the Last Five Year Period by Tenure Status and Degree of Urbanisation. European Commission [Online]. Available: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ilc_hcmp05&lang=en.