crossCert

Next-generation of Energy Performance Assessment and Certification

D2.4 EPC cross-testing procedure

Task 2.2 Design of Cross-Assessment Tests

WP2 Cross Assessing EPC Paradigms

Authors: Norberto Fueyo (UNIZAR), María Herrando (UNIZAR), Antonio Gómez (UNIZAR)

Date: 16/06/2022

crossCert: Cross Assessment of Energy Certificates in Europe
Grant Agreement (GA) No: 101033778
From 1 Sept. 2021 to 31 Aug. 2024
H2020-LC-SC3-2018-2019-2020 / H2020-LC-SC3-EE-2020-2

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 101033778

DELIVERABLE FACTSHEET

Document title	**EPC cross-testing procedure**
Deliverable	D2.4
Responsible Partner	UNIZAR
Contributors	All crossCert partners
Reviewers	HWU
Work Package	WP2
Task	2.2
Version	2.9
Version date	16/06/2022
Type of deliverable	R

Dissemination level	
X	PU = Public
	CO = Confidential, only for members of the consortium (including the EC)

Document status		
Review status		Draft
		WP leader accepted
	X	Coordinator accepted
Action requested		To be revised by partners
		For approval by the WP leader
		For approval by the Project Coordinator
	X	To be delivered to the Commission

Document History

Version	Date	Main modification	Entity
2.5	06/04/2022	First complete draft to partners	UNIZAR
2.6	25/04/2022	Version revised by partners	All
2.7	27/04/2022	Version ready for delivery	UNIZAR
2.8	02/06/2022	Version updated with folder locations	UNIZAR
2.9	16/06/2022	Table in Sec 4.5 updated	UNIZAR

DISCLAIMER OF WARRANTIES

"This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 101033778"."

This document has been prepared by crossCert project partners as an account of work performed within the framework of the EC-GA contract no 101033778. This document reflects only the author's view. The Agency and the Commission are not responsible for any use that may be made of the information it contains.

Neither the Project Coordinator, nor any signatory party of crossCert Project Consortium Agreement, nor any person acting on behalf of any of them:

(a) makes any warranty or representation whatsoever, express or implied,
  (i). with respect to the use of any information, apparatus, method, process, or similar item disclosed in this document, including merchantability and fitness for a particular purpose, or
  (ii). that such use does not infringe on or interfere with privately owned rights, including any party's intellectual property, or
  (iii). that this document is suitable to any particular user's circumstance; or

(b) assumes responsibility for any damages or other liability whatsoever (including any consequential damages, even if the Project Coordinator or any representative of a signatory party of the crossCert Project Consortium Agreement, has been advised of the possibility of such damages) resulting from your selection or use of this document or any information, apparatus, method, process, or similar item disclosed in this document.

EXECUTIVE SUMMARY

This report is the main outcome of Task 2.2, Design of cross-assessment tests. It is the result of the work by the partners since the beginning of the project (M1) to establish a protocol for cross testing EPCs across participating countries. The protocol will continue to be refined, in the light of the cross testing experience, until M12 (Aug 2022).

The report describes a cross testing procedure that circumvents two major practical obstacles in carrying out cross testing among the partners: the first is widely-varying climate conditions across the countries, which limit the applicability of the software used in one country to the test buildings in another country. The second obstacle is the language of the EPC software in each country, which limits meaningful access from project partners from alternative countries. A third obstacle is that the data required may be very different among countries, and the cross testing activity in crossCert brings this diversity to the forefront. We are partially addressing this obstacle by creating a *Neutral Data Inventory* for reporting input data.

The deliverable includes a review of the status of EPCs in the crossCert countries, to set out the status quo and provide a basis for the development of the methodology and indeed for the rest of the crossCert project.

The cross testing requirements from downstream work packages (WP3-WP6) are set out, as these bear an influence on the activities in WP2. These requirements have been summarised from a series of meetings between the respective WP partners and the WP2 coordinators, held in preparation for this deliverable.

We describe the rationale for selecting the buildings that will be the subject of cross testing, viz:

1. To prioritise buildings for which the tester has a complete set of building data.
2. To include as many buildings as possible with available measurements, to facilitate the determination of the EPC performance gap.
3. To ensure a good distribution of buildings across all building typologies

A full list of buildings, comprising 147 buildings, is provided.

Then we address the cross testing protocol. This has entailed the classification of the cross test buildings into three ensembles:

- P (or project-wide) buildings: a set of seven buildings that will be tested in all countries. A detailed, dynamic energy model will be developed for these buildings, to allow for a quantitative assessment.
- C (or climate-clustered) buildings: sets of buildings located in similar climatic areas in different countries, which are therefore amenable for testing with EPC software for several countries.
- L (or local) buildings: the remaining buildings in each partner's set, which will be tested locally and the test results will be compared across countries.

We describe in detail the methodology we have used for selecting buildings for the P and C ensembles. We then set out a protocol for testing the buildings in each of these three groups.

The final section summarises the role in the project of each of the three cross-testing rounds. While round 1, using existing certificates, will be more procedural, the scope and extent of rounds 2 and 3 will depend on the new EPC protocols developed at the time, and embedded in software; in any case, the contributions of these new proposals towards the goals of crossCert (increased accuracy, added value, human centricity and EU harmonisation) will be assessed.

Four appendixes detail the method to be followed for the climatic classification of a building location; for the format of the *Neutral Data Inventory* and the *Neutral Results Report*, which crossCert proposes for homogeneous reporting across the different EPC methodologies in the project; and some indications for the contents of the *EPC Generator Experience Report*, which summarises the user-centric aspects of the cross-testing experience.

TABLE OF CONTENTS

1 Introduction

The cross testing procedure is central to the work that will be performed under WP2, *Cross Assessing EPC Paradigms*, and particularly to Task 2.3 *Cross-Testing*, where the actual tests will be conducted by the crossCert partners. Furthermore, the tests performed in this WP will feed the analysis carried out in subsequent WPs in crossCert. Notably:

- WP3 will use the experiences from the cross assessment exercise to derive technical guidelines for EPC's;
- WP4 will use the learnings from cross testing as the basis to propose added-value improvements that would facilitate the integration in administrative databases, adapt the EPC to the user and investor needs, link to audits, logbooks and building renovation passports, and be integrated into one-stop shops;
- WP5 will analyse the user experience from these tests, and use this analysis as the basis for further research on the training of EPC issuers and on EPC promotion and marketing;
- WP6 will distil recommendations for EPC harmonisation based on the cross testing experience, and concrete knowledge items will be curated in the EPC Knowledge Exchange Centre.

The design of the cross testing must meet the following requirements:

- The multiple EPC dimensions (such as technical, implementation, exploitation, social and legal) should be assessed;
- The results obtained have to be comparable among countries (since EPC tests are carried out in ten European countries);
- The information compiled must be systematic, complete, valuable and easy-to-process for the development of the next project tasks.

The testing evaluates objective numerical parameters such as energy consumption, CO_2 emissions or the performance gap, but also procedures and methodologies, such as the renovation measures proposed by EPCs, the EPC implementation, EPC data exploitation, EPC legal framework or the experts' training/requirements and, subjective aspects like the comfort scale (if available). Technological neutrality and the observance of ISO/CEN standards are also assessed.

This deliverable specifies the cross-testing exercise. It is set out as follows:

- The first section following this introduction summarises the current EPC status in the crossCert countries;
- The next section sets out successively how cross testing will contribute to the needs of WP3, WP4, WP5 and WP6;
- The next section presents the buildings that have been selected by the testing partners;
- Then, the cross testing procedure to be carried out by the partners is described;
- The final section addresses the three cross-testing rounds foreseen under crossCert.

First, we succinctly summarise previous research on subjects related to the goals of crossCert, in the form of literature publications and reports of research projects.

1.1 Related publications

(Literature references can be found in Section 7).

Research regarding EPCs has increased considerably in the last decade. Thus, the number of publications (indexed in Scopus) has increased from 9 publications per year in 2004 to 87 in 2018 (Li et al, 2019). The research work has been very diverse, from the methodology used to prepare the EPCs (e.g. Abela et al, 2016) to the use of the data obtained with the EPCs for the development of energy policies (e.g. Pasichnyi et al, 2019).

The research proposed in CrossCert, whereby experts from one EU country test the methodology of other countries, is completely new. This will allow us to obtain relevant conclusions regarding the harmonisation of certificates.

No similar research has been found in the literature. Indeed, EPC comparisons are made, using surveys and questionnaires proposed to experts, among the different aspects of preparing an Energy Performance Certificate (input data, software, quality control, databases). However, no research papers have been found that use in a country the methodology developed in a different one.

The topics that research articles usually address are varied. In many cases, they focus on studying the performance gap (assessment and investigation of the performance gap causes), the application of the EPC databases for the development of energy efficiency policies in the building stock, and the influence of EPCs in decision making by users. However, in crossCert the comparison will not be limited to a single aspect but all dimensions of energy certificates. The research works cited below bear some similarities with partial aspects of the work that will be carried out in crossCert.

Jenkins et al (2017) tested the EPC methodology in the UK. In this work, five different certifiers issued EPCs for 29 homes, and the results obtained were compared. Considerable discrepancies were observed in the energy rating obtained for the same building by the different issuers and relevant discrepancies in the total habitable area, efficiency of lighting, windows, and heating systems. One of their main conclusions was that the certifier training was essential. In many cases, the certifier is trained to use the software but does not know the physics behind the software. This has an impact on the EPC quality.

Semple and Jenkins (2020) compared methods and input data to generate EPCs in six European countries: UK, France, Germany, Italy and Poland. The comparison focused on the default values used in the generation of certificates, especially the U-value, which is one of the determining values of the EPC results. This paper reveals significant variation in the methods used to identify and assess the building energy consumption among the European countries analysed.

Tronchin and Fabbri (2012) carried out an experiment in which 162 certifiers issued an EPC for the same dwelling in Italy. No identical energy consumption value was obtained, and the labels obtained ranged from A to E depending on the issuer, although 70% rated the home correctly (D). Again, this work highlights the importance of the issuer's training.

Tronchin and Fabbri (2010) tested different software (from official methodologies, research software and very simplified software) to calculate the energy performance of the same building in Italy. It was shown that the methodology and software have a very relevant influence on the results obtained.

The report by Arcipowska et al. compares how the EPC methodologies of each country face the calculations and obligations set for the EPCs. It addresses all the dimensions of EPCs (input data, software, quality control, databases, training of the issuers, etc..) in the investigated countries. This is a comprehensive comparison, but crossCert will go beyond its scope as experts will use and assess the methodologies and software of other countries.

1.2 Related projects

This section analyses other projects that share with crossCert the purpose of improving current EPC schemes. The projects reviewed are those that have received funding in similar H2020 calls as crossCert, but in different years. These projects are: QualDeEPC, X-tendo, U-CERT, ePANACEA, D^2EPC, E_DYCE, EPC_RECAST). Recently started projects such as EU_SuperHub, iBRoad2EPC and TIMEPAC have not been reviewed since the material generated by these projects is still scarce.

QualDeEPC elaborated a report, Gokarakonda et al. (2020), with a comprehensive comparison of the EPCs practices in each EU country addressing multiple parameters (EPC software, default values for input data, user-friendliness, requirements for EPC issuers, among others). Other reports from this project, Kostova et al. (2010) and Gokarakonda et al. (2020), describe country-specific assessments of success factors for EPCs, options for improvement and gaps, shortcomings and national priorities. These deliverables were

elaborated through desk research and workshops with stakeholders in each country, where participants answered questionnaires and discussed potential options for enhancing the existing national EPC schemes.

X-tendo has developed a toolbox with new indicators/features (Smart Readiness, Comfort, Real Energy Consumption, EPC databases, among others) for future EPC schemes. Prior to the tool development, a report, Volt et al. (2020), was elaborated to obtain a more comprehensive understanding of the existing EPC frameworks and to identify existing gaps that features intended to be developed can address. Country-specific assessments were made for end-user needs and expectations for the Next- Generation Energy Performance Certificates (Schmatzberger and Zuhaib, 2020). These reports have been elaborated through desk research, the information provided by project partners and survey questionnaires to stakeholders. The new indicators/features developed have been assessed in the X-tendo partner countries. This testing has been performed through data collection, measurements, surveys, checklists and rating calculations, and applied by different partners, thus obtaining country-specific results for each new feature (X-tendo toolbox).

U-CERT, among other objectives, aims to introduce the next generation of user-centred Energy Performance Assessment and Certification Scheme to value buildings holistically and cost-effectively, and to facilitate the convergence of quality and reliability using the EPB (Energy Performance of Buildings) standards. Under this context, and as a starting point, U-CERT assessed each partner country's status concerning EPB Assessments and Certification schemes (REHVA et al., 2021). Additionally, a country-specific assessment of national EPC user-friendliness and user perception has been performed (IRI-UL et al., 2021).

The objective of the ePANACEA project is to develop a holistic methodology for energy performance assessment and certification of buildings that can overcome the current EPCs issues. ePANACEA comprises the creation of a prototype (the Smart Energy Performance Assessment Platform) using the most advanced techniques in dynamic and automated simulation modelling, big data analysis and machine learning, inverse modelling or the estimation of potential energy savings economic viability check. ePANACEA has elaborated country-specific assessments to design the methodology and the platform. Thus, Maia et al. (2021) present an overview of the current EPC policy and implementation frameworks in the implementing countries, Austria (focus Styria), Belgium (focus Flanders), Germany, Greece, Finland and Spain, The overview comprises environment, recommendations, end-user perception, technology uptake, energy assessment, and rating system. Muhr (2021) provides insights on study participants' knowledge, perception and use of the EPC and their critiques and needs. These reports have been elaborated through desk research, interviews with stakeholders and online workshops. Other similar reports have been generated concerning user-friendliness (Muhr, 2022) and status and initiatives on building renovation passports (Androutsopoulos et al., 2021).

D^2EPC aims to set the ground for the next generation of dynamic EPCs for buildings. The foundations of the proposed framework are the building smart-readiness level and the corresponding data collection infrastructure and management systems. As a part of the project WP1 (WP1: Foundations for next-generation dynamic EPCs (dEPCs): Identifying challenges, needs and opportunities), several reports (Morsink-Georgali et al., 2020; Panteli et al., 2021) have been elaborated on the status of current EPC schemes and stakeholder requirements in the EU countries. Desk research and field research (surveys, interviews) have been employed to produce these reports.

E-DYCE aims to combine innovative approaches with established and available tools to create a methodology capable of implementing scalable, adaptable and accurate dynamic energy performance certification (DEPC). Under this context, a report (Pomianowski 2020) has been prepared to analyse the current situation of national EPCs (partner countries participating in E-DYCE) with a particular focus on calculation tools and methods and their compliance with the E-DYCE goals.

In summary, most of these "sister projects" have carried out country-specific assessments on the current status of EPCs. In some cases, they have developed comprehensive assessments; in other cases, they

have focused on more specific aspects related to the particular objectives of each project. These evaluations are generally descriptive, comparing situations of approaches in each country for the multiple aspects of EPCs.

2 EPC status in the countries represented in crossCert

In this section, we provide context for the design of the cross testing protocol to be presented later in this deliverable. Figure 1 summarises the EU directives that bear an influence on EPC and energy efficiency in buildings. In subsequent subsections, we provide a summary, prepared by the crossCert partners, of the EPC status in the respective partner countries and of the software used for energy certification.

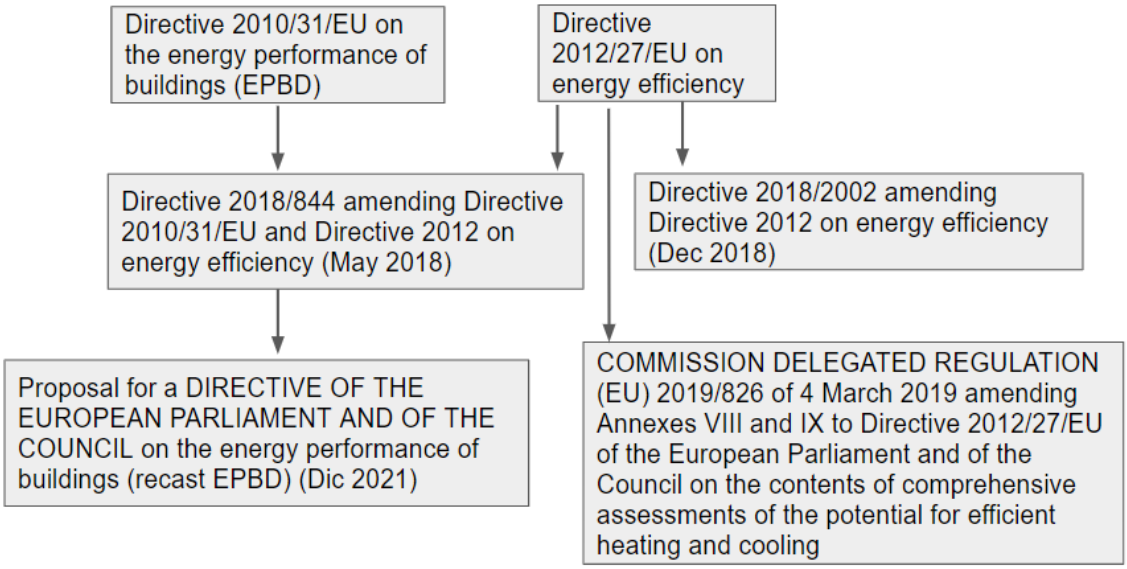


Figure 1. EU directives that bear an influence on EPC and energy efficiency in buildings.

2.1 Regulatory aspects in the crossCert countries

2.1.1 Spain

- **Regulation:** Directive 2018/844 was transposed in RD 390/2021, from 1st June 202. This RD deprecates the previous RD 235/2013 (which was a transposition of Directive EPBD 2010).
- **Body/institution responsible for:** EPC contents and process are determined by the Advisory Committee for EPCs (which falls under the relevant Ministry).
- **EPC is compulsory for:**
  - Buildings that are constructed, sold or rented out to a new tenant;
  - Buildings where a total useful floor area over 250 m^2 is occupied by a public authority and frequently visited by the public.
- **Who can perform EPCs**: Architects, building engineers, and most engineers
  - The new regulation (RD 390/2021) states that a new regulation is expected before the end of 2022, to consider EPC issuers' specific knowledge and professional skills on the performance of EPCs
- **Certificate temporal validity:** maximum 10 years, except for buildings with an Energy Label G for which the maximum validity is 5 years (RD 390/2021)

- **Control and verification:** The relevant institution in each region ("Autonomía") establishes and performs independent verification and control of EPCs through sampling methods for EPCs issued in that year. There are two types of verification: verifying the validity of building data used; and complete verification of obtained results, recommendations and in situ visit to the building.
- **Official Registry/Database:** the EPC, along with a building energy evaluation report in electronic format (xml), should be submitted to the relevant institution in each region and (new from RD 390/2021), this information should be sent to the National Centralised Administrative Registry.
  - It is uncertain whether the database will be accessible, at national or regional levels.
  - In public buildings, EPCs must be displayed in a printed format on a well visible spot.

2.1.2 Croatia

- **Regulation:**
  - HR-Building Act (OG 153/13, 20/17, 39/19, 125/19);
  - HR-Ordinance on energy audits and energy certification of buildings (OG 88/17, 90/20, 1/21, 45/21)
  - HR-Ordinance on control of energy certificates of buildings and reports on regular inspections of heating systems and cooling or air-conditioning systems in buildings (OG 73/15, 54/20)
  - HR-Ordinance on persons authorised for energy certification, energy audits of buildings and regular inspections of heating systems and cooling or air-conditioning systems in buildings (OG 73/15, 133/15, 60/20)
- **Body/institution responsible for:** the regulation, certificate contents, process, registry, control, inspection, and authorization of energy certifiers (energy auditors) are determined by the Ministry of Physical Planning, Construction and State Assets.
- **EPC is compulsory for:**
  - Buildings where a total heated floor area over 250 m^2 is occupied by a public authority and frequently visited by the public;
  - New buildings before issuing a use permit;
  - Apartments, functional parts of buildings or buildings that are for rent or sale.
- **Who can perform EPCs**: Educated and authorised energy certifiers: architects, civil, mechanical and electrotechnical engineers:
  - Education required for energy certifiers: 2 modules (first for simple and second for complex technical systems) and once every two years additional education to update knowledge after authorization;
  - Authorization: Two types: for a physical person or a legal entity.
- **Certificate temporal validity:** 10 years.
- **Control and verification:** Ministry of Physical Planning, Construction and State Assets establishes and performs independent verification and control of EPCs through sampling methods based on issued EPCs
- **Official Registry/Database:** the EPC along with a building energy audit report should be submitted to a digital database (IEC) run by the Ministry;
  - Only energy certifiers can access the database and browse issued EPCs. The IEC data is partly available to the public in the form of extracts from the Register of authorised certifiers, the list of holders of the Training Programme for authorised certifiers and an extract from the Register

of Issued Energy Certificates. The database contains energy certificates issued from 1 October 2017 through the IEC.

2.1.3 Malta

- **Regulation:** Directive 2018/844 was transposed in the Legal Notice 47 of 2018
  - Superseded regulation: Legal Notice 261 of 2008 / Legal Notice 376 of 2012
- **Body/institution responsible for:** EPC procedures, contents and format are determined by the Building and Construction Authority (BCA), which falls under the Ministry for Transport, Infrastructure and Capital Projects. All EPCs are registered with BCA.
- **EPC is compulsory for:**
  - Buildings that are constructed, sold or rented out to a new tenant;
  - Buildings where a total useful floor area over 250 m^2 is occupied by a public authority and frequently visited by the public.
- **Who can perform EPCs**: "EPB assessors" duly registered with the Building Regulation Office, and in possession of a warrant to practice the profession of architect and, or civil/structural engineer, or mechanical or electrical engineer, and who has also successfully undertaken a period of training on the assessment of the EPC built in Malta.
- **Certificate temporal validity**: 10 years (unless major renovations or alterations to the building/installation have taken place).
- **Control and verification:** the BCA performs control and verification of EPCs. A random selection of at least a statistically significant percentage of all the EPCs issued annually is performed and subjected to verification.
- **Official Registry/Database:** the EPC data is uploaded by the EPB assessors in electronic format (xml) together with a photo of the façade or front elevation, site plan and comments/recommendations on the dedicated web platform;
  - The database is not public.

2.1.4 United Kingdom

- **Regulation:** Energy Performance of Buildings (England and Wales) 2012 https://www.legislation.gov.uk/uksi/2012/3118/contents/made and Energy Performance of Buildings (Scotland) 2008 https://www.legislation.gov.uk/ssi/2008/309/contents
- **Body/institution responsible for:** Building Research Establishment (BRE) responsible for accrediting software, certification, National Calculation Methodology, and training relating to UK EPCs
- **EPC is compulsory for:** Required before sale/renting of all properties (previously part of wider "Home Information Pack" when selling dwellings)
- **Who can perform EPCs**: Wide range of EPC assessors with quite varied backgrounds - require accreditation via training course (~5 days for residential EPC)
- **Certificate temporal validity:** Last for 10yrs, ~€100-140 cost per assessment
- **Control and verification:** A Scheme Operating Requirements protocol was introduced in April 2012 which included a quality assurance audit of EPCs, based on a small sample of EPCs held on the registry. A "Smart Audit" scheme was introduced in 2016 to target EPCs that were deemed as being at higher risk of being incorrect, rather than just using a random sample.

- **Official Registry/Database:** When approved, EPCs can be accessed:
  - Energy and Wales EPC registry for residential and non-residential EPCs https://www.gov.uk/find-energy-certificate
  - Scotland EPC registry for residential and non-residential EPCs https://www.scottishepcregister.org.uk/

2.1.5 Slovenia

- **Regulation:** Energy Efficiency Act (ZURE) (http://www.pisrs.si/Pis.web/pregledPredpisa?id=ZAKO8136#) and Rules on the methodology of production and issuance of energy performance certificates for buildings (http://www.pisrs.si/Pis.web/pregledPredpisa?id=PRAV11883#)
- **Body/institution responsible for:** Ministry of infrastructure
- **EPC is compulsory for:** Obligatory for public buildings, new buildings or buildings sold
- **Who can perform EPCs**: licensed EPC issuers (required technical background).
- **Certificate temporal validity:** 10 years (unless major renovations or alterations to the building/installation have taken place)
- **Control and verification:** No real quality controls are enforced. It might change with the new national directive
- **Official Registry/Database:** Public registry of all EPCs integrated into an official geospatial registry and is publicly accessible in pdf format In public buildings, EPCs must be displayed in a printed format on a well visible spot

2.1.6 Greece

- **Regulation:** Directive 2014/40/EU → LAW 4409/2016 (since 31/10/2016)
- **Body/institution responsible for:** Overall Administration: Ministry of Energy EPC Registry: Centre for Renewable Energy and Saving Reference EPC Calculations Software: Technical Chamber of Greece.
- **EPC is compulsory for:** Selling, leasing or deep renovation of buildings or building units. ALso for the participation in funding schemes for Energy Performance Enhancement.
- **Who can perform EPCs**: Certified Engineers (most expertises) In the past, relevant certified seminars and/or a written test were required for certification.
- **Certificate temporal validity:** 10 years
- **Control and verification:** The Ministry of Energy performs random checks of EPCs from the registry Validation of input data and calculations is performed on desk. If necessary, an on-site validation is then performed
- **Official Registry/Database:** EPC calculations input data in electronic format (xml) are submitted to the National Registry of EPCs (www.buildingcert.gr). The calculations are performed again on the server and the data are checked.

2.1.7 Poland

- **Regulation:** The mandatory EPC was implemented on 1st January 2009. Law on Energy Performance of buildings from 2014 (consolidated text in Journal of Law Dz. U. 2021 poz. 497). Ordinance from 2015 on the methodology of building energy performance calculations and Energy Performance Certificate (Journal of Law 2015, pos. 376).

- **Body/institution responsible for:** the Minister responsible for the construction sector (at the moment Ministry of Economic Development and Technology)
- **EPC is compulsory for:** Buildings or functional parts of buildings that are for rent or sale, for new buildings to obtain permission for construction; Buildings (>250 m2) of public authorities, courts, prosecutor's offices
- **Who can perform EPCs**: EPB assessors" registered in Ministry database, including architects, civil/structural engineers, mechanical or electrical engineers, or successfully passed relevant postgraduate studies
- **Certificate temporal validity:** 10 years (unless major renovations or alterations to the building/installation have taken place)
- **Control and verification:** on the basis of random selection
- **Official Registry/Database:** Persons allowed to execute EPC (16 544 records); citizens can access part of the database (to list of persons as above, to EPC of public buildings).

2.1.8 Bulgaria

- **Regulation:** Energy Efficiency Act; Energy Efficiency Act Ordinance Е-РД-04-1 (2016) for energy auditing, certification and assessment of energy savings of buildings; Ordinance Е-РД-04-2 (2016) for energy consumption indicators and energy performance of buildings; Ordinance Е-РД-04-1 (2018) or the circumstances subject to entry in the registers under the Energy Efficiency Act, the entry and receipt of information from these registers, the conditions and the procedure for qualifying by the energy efficiency consultants; Spatial Planning Act Ordinance 7 (2009/last amendment 2015) for energy efficiency of buildings
- **Body/institution responsible for:** Building norms, certificate contents are processed by the Ministry of Regional Development and Public Works and the Ministry of Energy. Registry, control, inspection. Authorization of energy certifiers (energy auditors) by Sustainable Energy Development Agency (an executive agency under Ministry of Energy)
- **EPC is compulsory for:** Public buildings (buildings that are used by a large number of people) > 250 m2; Apartments, functional parts of buildings or buildings that are for rent or sale
- **Who can perform EPCs**: Educated and authorised energy certifiers; Education for energy certifiers involves a two-week full-day training course + examination; Authorised legal entities are eligible to certify any building – the team must include 3 employed energy certifiers – architect/civil engineer; HVAC/thermal engineer; electrical engineer. Authorised physical persons are eligible to certify buildings < 500 m2 (one of the backgrounds above)
- **Certificate temporal validity:** 10 years (existing buildings); 3-6 years (new buildings)
- **Control and verification:** Sustainable Energy Development Agency (SEDA)
- **Official Registry/Database:** Information based on the energy audit including energy class, energy performance and other most important energy and building data can be accessed on the SEDA webpage. More detailed data base including an assessment of energy-saving measures recommended in the energy audits can be provided by the SEDA by official request

2.1.9 Denmark

- **Regulation:** Statutory Order no. 1300 of 3 September 2020 on the promotion of energy savings in buildings Executive Order no. 1651 of 18 November 2020 on energy labelling of buildings Provisions on the publication of EPCs on the Public Information Server (OIS)

- **Body/institution responsible for:** The certification scheme is overall managed, monitored and controlled by the Danish Energy Agency An agency under the Ministry of Climate, Energy & Utilities
- **EPC is compulsory for:** It is mandatory to have an energy performance certificate (EPC) when selling or renting out buildings. Mandatory for all buildings over 60 m2, which applies to all types of homes, public buildings etc. Public Buildings: When a ·new public building of 60-250 m2 is certified for the first time, there is only a requirement for a certificate if the building is to be sold or rented out. All public buildings over 250 m2 must be certified regularly
- **Who can perform EPCs**: A certified energy consultant, who must undergo a training course and pass the associated exam to be able to perform EPCs In addition, the consultant/company must be certified and registered with the Danish Energy Agency. There are certified energy consultants throughout the country.
- **Certificate temporal validity:** 10 years
- **Control and verification:** The Danish Energy Agency is the Authority controlling and monitoring the quality of the EPCs. A selection is controlled to ensure that the set rules are followed and to control quality. Further, the purpose is to provide knowledge about the scheme to help increase the general quality of the EPC scheme.
- **Official Registry/Database:** All EPCs are registered in a central database administered by the Danish Energy Agency (DEA) and are displayed on a website accessible to the public.

2.1.10 Austria

- **Regulation:** OIB Guideline 6 - Energy performance of buildings; ÖNORM B 8110-5 Thermal insulation in building construction - Climatic conditions & user profiles; ÖNORM B 8110-6-1 Heat energy demand and cooling demand; ÖNORM H 5057-1 Overall energy efficiency of buildings - Air conditioning energy demand; ÖNORM H 5050-1 Overall energy efficiency of buildings - calculation of the total energy efficiency factor; ÖNORM H 5056-1 Energy use for heating systems; ÖNORM H 5058-1 Energy use for cooling systems; ÖNORM H 5059-1 Energy use for lighting.
- **Body/institution responsible for:** Federal states are responsible for the building regulation. The Austrian Institute of Construction Engineering (OIB) is a non-profit organisation constituted by the federal states and provides guidelines on construction engineering requirements (incl. energy performance). Federal states incorporate the guidelines into the building regulation.
- **EPC is compulsory for:** EPC is provided at the point of rent or sale as well as for construction permit & subsidies; Residential, non-residential, newly constructed or major renovated buildings must be below a specific heat energy demand, primary energy demand, CO2 emissions and overall energy performance factor. The minimum requirements depend on the gross surface/volume ratio.
- **Who can perform EPCs**: All engineering offices (architects, civil engineers, electricians...).
- **Certificate temporal validity:** 10 years
- **Control and verification:** Quality check: There are automatic checks of several results and data entered into the EPC calculation program. Uploaded EPCs are tested for plausibility and undergo random exact control and verification checks (ca. 3% a year).
- **Official Registry/Database:** 4 of the Austrian federal states use the ZEUS database, others have their own or none. There is a national EPC-database (other EPC-DB should be linked to this DB) but there is no compromise on its use at the moment.

2.2 Procedures and Software

2.2.1 Spain

- **General procedure for new and existing buildings:** Several alternatives:
  - LIDER-CALENER (HULC): 3D geometry + S3PAS (DOE-2) calculation;
  - CYPETHERM HE Plus, SG SAVE: using EnergyPlus + 3D geometry + BIM.
- **Simplified procedure for existing buildings** (mostly used): CE3 and CE3X, there is no building geometry, it is based on the climatic zone (range of HDDs/CDDs). It performs an interpolation of introduced data with a database of loads of building simulations using LIDER-CALENER.

2.2.2 Croatia

- **Energy audit:** obligatory (before EPC issuing) for buildings where a total heated floor area over 250 m^2 is occupied by a public authority and frequently visited by the public, new buildings before issuing a use permit and buildings that are for rent or sale.
- Analysis of bills and data on energy (heat, electricity) and water consumption in the last 3 years (energy modelling).
- **Procedure:** Performing the calculations needed to issue an EPC, using appropriate software (there are several available on the market).

2.2.3 Malta

- **Procedure for dwellings:** The national calculation tool developed is the 'Energy Performance Rating of Dwellings in Malta' (EPRDM). Used for both design and asset rating EPCs
- **Procedure for non-dwelling EPCs**: iSBEMmt methodology and software: Simplified Building Energy Model. Used for both design and asset rating EPCs.

2.2.4 United Kingdom

- **Procedure**: Genesis of the UK steady-state calculation approach goes back 26 years Standard Assessment Procedure (SAP/RdSAP) and Simplified Building Energy Model (SBEM) for domestic and non-domestic buildings (with DSM options) EPCs and input information registered on a lodgement database
  - England/Wales:
    - Residential: EPC is based on SAP rating, an energy cost metric (1-100). It is also a requirement to get a new home Design Energy Rating (DER) < Target Emission Rating (TER)
    - Non-residential: EPC is based on the ratio between modelled Building Emission Rate (BER) and Standard Emission Rate (SER).
  - Scotland:
    - Residential: similar to England/Wales but slightly different assumptions (and different TER)
    - Non-residential: EPC rating based on an absolute BER measure of kgCO2/m2

2.2.5 Slovenia

- **Energy audit:** In Slovenia, the term 'Energy audit' refers to a visit to the building for an EPC issuance
- **Procedure:** Calculation of building physics parameters with commercially available software (KI Energy or URSA), collecting the energy consumption information for the last three operating years

(only for public buildings) and inserting the determined values into the National software for EPC documentation preparation.

2.2.6 Greece

- **National Reference Software for EPC Calculations**: TEE-KENAK calculation engine based on the EPA-NR tool Open data format (XML). Developed by the National Observatory of Athens for the Technical Chamber of Greece.
- Various **commercial software tools** are available that provide a more user-friendly interface while using the same TEE-KENAK calculations engine.

2.2.7 Poland

- **Software**: Audytor OZC, ArCADia-TEROMCAD PRO 2020 and others

2.2.8 Bulgaria

- **Energy audit**: obligatory for all existing buildings, simplified (visual check) for new buildings.
- **Procedure**: Unified methodology included on Ordinance 7, based on EN ISO 13790 and other standards, 2006-2008
- **Software:** EAB; EECalc; Shtrakov

2.2.9 Denmark

- **Procedure:** The Danish Energy Agency's guidelines for energy consultants are set out in the 'Handbook for energy consultants'

2.2.10 Austria

- **EPC calculation tools** available on the market are validated by authorities.
- **EPC calculation method** is used in some regions for energy consultancy and by energy advisors (subsidised by regions).
- A tool is under development as a renovation passport based on EPC calculation tools.

2.3 The Energy Performance Certificate

2.3.1 Spain

- **What does a typical certification entail:** Gather data, calculations, perform IPC;
  - A technician should visit the building at least once, maximum 3 months before issuing the EPC
- **EPC documents**: EPC report + label + electronic report (xml) + digital files with procedures + annexes and supporting calculations + recommendations of use.
- **Basic info of EPC**:
  - Building identification, the procedure used and applicable legislation;
  - Energy label (in terms of NRPE, CO_2 emissions, heating & cooling demand);
  - Description of the energy characteristics of the building;
  - Potential energy efficiency interventions: these should be technically viable and include payback time estimation (new from RD 390/2021). It might include comfort improvements;
  - Date of the building visit and description of verifications and tests (new from RD 390/2021);
  - Currently, there is NO link to building renovation passports or any other.

- **Are there any plans to change the certification procedures in the near future?** The Ministry is working on an updated calculation methodology for EPCs. The modifications will affect software and reports, including contents and formats of EPC. An update is expected throughout 2022.
- **Basis/methodology of EPC calculation:**
  - For the calculation of the energy demand and energy consumption, the procedures should consider, in a simplified or detailed way, the evolution of the thermal processes on an hourly basis, the performance of the HVAC systems and the contributions of renewable energies.
  - The dynamic methodologies, on an hourly basis, simplified or detailed, should follow the EN ISO 52016-1
  - CE3 and CE3X perform an interpolation of introduced data with a database of loads of building simulations using LIDER-CALENER

2.3.2 Croatia

- **What does a typical certification entail:** Certifiers must visit the building and perform an energy audit before issuing the EPC.
- **EPC documents**: A report of the building energy audit and the EPC are uploaded to the digital database (IEC) by the certifier and then are validated by the Ministry of Physical Planning, Construction and State Assets (each EPC has its own barcode).
- **Basic info of EPC**:
  - Building identification, the procedure used and applicable legislation;
  - Energy labels (one label related to Qhnd and one label related to Eprim), data on CO_2 emissions, energy demands);
  - Description of the energy characteristics of the building (envelope and technical systems);
  - Information if the building is nZEB;
  - Potential energy efficiency interventions: these should be technically viable and include investment cost and payback time estimation. They should also include the optimal combination of possible energy efficiency measures;
  - Date of the building visit and description of verifications and tests (new from RD 390/2021);
  - Currently, there is NO connection to the building renovation passport, digital building logbook or other building databases.
- **Are there any plans to change the certification procedures in the near future?** No, the new methodology of performance of energy audits of buildings applies from 1 July 2021 according to which energy certification includes the calculation of the necessary specific annual energy for heating and cooling of the building for reference climate data, the calculation of specific annual primary energy, specific annual energy delivered and specific annual carbon dioxide emissions.
  - The other changes are planned to ensure the digitalization and functionality of the Croatian multiplatform Spatial Planning Information System (ISPU) which contains, among others, a digital register of energy certificates containing about 300,000 certificates. integration of this register with other modules such as Geoportal, eLicence, eRegister of spatial plans, ePlans as well as eConstruction diary has been carried out in 2022 and currently, certificates are added to the objects to which they relate. Thus, buyers in the real estate market will be able to see any object that has a certificate by the end of 2022.

- **Basis/methodology of EPC calculation:** The methodology of the calculations is based on the standard HRN EN ISO 13790:2008. The model used is a quasi steady-state model with a monthly time step. The annual value of the energy required for heating is calculated as a sum of positive monthly values. The software for determining the energy performance of the building includes modules defining the characteristics of the building, thermal gains and losses, thermomechanical heating, cooling and consumable hot water systems, lighting and inspection of the energy certificate. The program enables dynamic hourly calculation of the required thermal energy of the building.

2.3.3 Malta

- **What does a typical certification entail:** A site visit by the assessor is obligatory in the case of asset rating EPCs.
  - Issuers should collect data concerning the building envelope (walls, glazing, roof, shading) and systems (HVAC, lighting, renewable energy)
- **EPC documents**: the EPC XML file, a façade photo or front elevation plan, building site plan and recommendations report.
  - The EPC shall include reference values and shall be accompanied by a recommendation report.
- **Basic info of EPC**:
  - Building type
  - The energy rating for dwellings (kWh/m2·year, CO2 emissions); Energy label (A-G) for non-dwellings
  - Description of the energy characteristics of the building (building envelope and technical systems)
  - Potential energy efficiency interventions
  - The recommendation report shall indicate cost-effective measures for improving the EPC rating.
- **Are there any plans to change the certification procedures in the near future?** The BCA plans to update/revise the software tools EPRDM and iSBEM during the next 2 - 3 years to better reflect the buildings' reality in Malta and conform with the latest technical guidelines and minimum standards.
- **Basis/methodology of EPC calculation:** Quasi-steady-state models. The EPRDM procedure (dwellings / residential buildings) is based on ISO EN 13790:2008 'Energy Performance of Buildings – Energy Use for Space Heating and Cooling' and uses the simplified monthly method. ASimplified Building Energy Model (iSBEM) is used for non-residential buildings.

2.3.4 United Kingdom

- **What does a typical certification entail:** In-person visit by a trained, certified, energy assessor. Costs and duration of assessment can vary considerably
- **EPC documents**: Hard and/or e-copy of the EPC is provided with standard metrics and visuals. In England and Wales, an online version of the EPC can be accessed via the registry - this is public domain but the building owner can block this from being visible. The online version of the EPC is not just an e-copy of the EPC, it has categorised outputs that can be browsed in a different format.
- **Basic info of EPC**:

- Energy rating; Baseline kWh and kgCO2 estimates; Recommended energy efficiency measures; Estimated energy costs before and after recommended measures; energy efficiency rating of individual building elements (e.g. wall, floor, etc); contacts for advice on energy efficiency

- **Are there any plans to change the certification procedures in the near future?** Early-stage discussions in the UK and Scottish Governments about other metrics, use of real energy data, and secondary assessments that could complement existing EPC assessments. Also recent use of online EPCs in England and Wales.
- **Basis/methodology of EPC calculation:** Standard Assessment Procedure (SAP) for residential buildings; Simplified Building Energy Model (SBEM) for non-residential buildings. Both steady-state. Some non-domestics buildings at a certain size can use dynamic simulation methods (using software IES-VE or TAS)

2.3.5 Slovenia

- **What does a typical certification entail:** visit the property for data gathering and calculations with one of the available software.
- **EPC documents**: If the EPC document of each building exists, it is available in the national portal of the Ministry of the Environment and Spatial Planning and the Surveying and Mapping Authority of the Republic of Slovenia (https://www.e-prostor.gov.si/access-to-geodetic-data/ordering-data/). The EPC document is in PDF or XML file and includes the general information of the building with building photo, building energy consumption and suggested renovation measures.
- **Basic info of EPC**:
  - Energy label, meta-information;
  - Suggestions for envelope and systems retrofitting and improvements. Suggestions are often generic, not tailored to the specific building;
  - It is supposed to include comments by the EPC issuer that guides how to approach potential improvements;
  - No links with external platforms (passports).
- **Are there any plans to change the certification procedures in the near future?** New rules on energy efficiency and technical guidance are still not in force (no predicted deadline), including a revision of existing EPC schemes according to the most recent EPBD.
- **Basis/methodology of EPC calculation:** The calculation methodology is specified in Rules on the methodology of production and issuance of energy performance certificates for buildings and is based on standards SIST EN ISO 13789; SIST EN ISO 6946; TSG-1-004.

2.3.6 Greece

- **What does a typical certification entail:** Mandatory on-site visit by the energy expert.
- **EPC documents**: XML file with the calculations, including input data, photo of the building, floor plans, and site plan (or Google maps screenshot).
- **Basic info of EPC**:
  - Energy Class Label;
  - Calculated primary energy consumption of reference and existing building;
  - Calculated annual CO2 emissions;
  - Photo of the building; building address, use, total area, heated area;

- Breakdown of primary energy consumption per energy use;
- Suggested improvement measures: New energy label and payback time estimation;
- No link to building renovation passport.

- **Are there any plans to change the certification procedures in the near future?** A reform of the regulations is underway.
- **Basis/methodology of EPC calculation:** Quasi-steady-state model with a monthly step. ISO 13790:2008.

2.3.7 Poland

- **What does a typical certification entail:** The auditor should gather data from the documentation, it is also recommended to visit the building.
- **EPC documents**: building energy audit report with the calculations, input data, information and photo (not necessary) of the building, recommendations (not necessary).
- **Basic info of EPC**:
  - Building identification and basic data (e.g. year of construction); Building type;
  - Description of the thermal characteristics of the building (envelope and technical systems).
  - The energy rating for dwellings (kWh/(m2·year)), CO2 emissions, the share of RES in final energy consumption).
  - Potential energy efficiency improvement measures: should be technically viable.
  - Currently, there is NO connection to building energy audits (renovation passport), which is the base of building thermo-modernisation.
- **Are there any plans to change the certification procedures in the near future?** Not expected, the latest update is from 2019, Poland still does not have a long term renovation strategy and that' is where EPCs were updated.
- **Basis/methodology of EPC calculation:** The methodology is specified in the "Regulation of the Minister of Infrastructure and Development of February 27, 2015 in the case of the methodology for determining the energy-saving features of buildings or parts of buildings and experiences with energy-saving features" with changes made in 2019.

2.3.8 Bulgaria

- **What does a typical certification entail:** Certifiers must visit the building and perform an energy audit (for existing buildings) and make visual checks (for new buildings), including an interview with the owner/technical staff. They should also study the existing building documentation (data for calculation), make measurements on-site and analyse the bills, data on energy (heat, electricity) and water consumption in the last 3 years (energy modelling) as well as climate data for the respective time period. The energy data should be additionally adjusted to standard climate conditions according to the climate zone where the building is located. Then an energy model of the building is developed based on the national methodology and the annual final energy consumption of the building is determined. It should be calibrated to the measured energy data adjusted by climate. If the calibration is done at an indoor temperature different from the norms, then a second energy model is developed where the indoor temperature corresponds to the norms for the respective building type. The so-called "normalised" energy consumption is used to determine the energy performance of the building. The energy class is determined by a comparison of the specific annual primary energy consumption to the values in the predefined

scale for the same type of building. A third energy model is then created to calculate the savings from the energy saving measures. The savings are determined by comparison of the results in the second energy model and the third energy model.

- **EPC documents**: Full documentation consists of: a building energy audit report; a summary (both in paper and digital format) and the energy performance certificate. The report is a free text, although the minimal content is regulated by an ordinance.
  - One unofficial requirement by the controlling body (SEDA) is to include in the report all print screens from the energy modelling. The summary is in a standardised excel format.
  - The energy-saving measures determined by the energy auditor (EPC issuer) should be allocated to 12 predefined groups of measures included in the national database.
  - The building owner is obliged to present to SEDA electronic versions of the report and the summary; an originally signed copy of the summary on paper; and a copy of the original EPC on paper. The EPC is issued in one original paper copy and it belongs to the building owner.
  - The owners should present a copy of the certificate in a visible place in the building. If SEDA finds inaccuracies or incompleteness in the documents usually it requests corrective actions directly from the energy auditors.
- **Basic info of EPC**:
  - General building data;
  - Energy class; energy performance; distribution of energy by building systems by %, the share of renewable energy;
  - Building envelope; characteristics of the energy conversion systems;
  - Distribution of the annual energy consumption by building systems; HDD;
  - Existing buildings: charts for energy consumption baseline and distribution of specific energy consumption by building systems – condition, normalised and after measures, ESM packages, projected energy consumption and CO2 emissions.
- **Are there any plans to change the certification procedures in the near future?** EN ISO 52000 group of standards are translated and accepted but national annexes are not developed, and their development is not scheduled yet.
- **Basis/methodology of EPC calculation:** The methodology of the calculations is based mainly on the standard EN ISO 13790 and other standards related to the energy calculations for different building components, all issued in the period 2006-2008. The calculations are done monthly.

2.3.9 Denmark

- **What does a typical certification entail:** The energy consultant prepares an EPC and an EPC report based on a review of all building conditions and installations that are important for energy performance.
- **EPC documents**: A two-page Summary Report and an EPC Report (see basic info below).
- **Basic info of EPC**: The report contains calculations of the building's energy consumption and proposals for improvements to the building's energy conditions. A new more user-friendly format of the EPC report was launched in September 2021 to highlight:
  - The most relevant measures to improve energy performance;
  - Economic and climate benefits of the measures;

- How these can be done concretely;
- The most important information about the building and the energy improvements are now summarised on the first 2 pages of the report.

- **Are there any plans to change the certification procedures in the near future?** There are plans to further improve the EPC scheme, e.g. to focus more on non-energy benefits (e.g. indoor climate)
  - New Building Hub: Creation of a unified digital platform for building and consumption data, which is spread over several different registers. The platform will provide better opportunities to streamline energy consumption in buildings through better use of data and facilitate the work of collecting and using data. A test facility was planned to be established in 2021 and completed in 2022
- **Basis/methodology of EPC calculation:** The calculation methodology complies with the requirements for energy frame calculations in the SBI instructions 231 (SBI = Danish Enterprise and Construction Authority, now part of Aalborg University). These instructions are generally used to document that a building complies with the energy framework in the Building Regulations. It is associated with the tool BE18. Buildings can be certified according to calculated or actual consumption. The calculated consumption is based on standard assumption while the certification based on actual consumption requires an operating record with monthly readings of energy consumption over at least 1 year.

2.3.10 Austria

- **What does a typical certification entail:** The assessor receives the building plans and the details of the building components either from the building owner or through an on-site visit (which is not obligatory). Then he calculates the EPC and uploads it to the respective database.
- **EPC documents**: EPC itself
- **Basic info of EPC**: The first page contains information about the owner of the building, site information and the year of construction. Furthermore, there is the efficiency scale and the main efficiency criteria such as the heat energy demand, primary energy demand, CO_2 emissions and the overall energy efficiency factor as well as explanations of these values (printed in very small font). The second page contains the mentioned values in detail and for different climates (reference climate and on-site climate). On the following pages, all the input details of the EPC calculation can be seen.
- **Are there any plans to change the certification procedures in the near future?** Not at the moment.
- **Basis/methodology of EPC calculation:** Steady-state.

2.4 EPC software

As a part of the preparation for WP2, a review was conducted of the software used in the cross testing countries for producing EPCs. Table 1 shows a list of the software available in the partnership countries; the information has been provided by the crossCert testing partners indicated after the country's two-letter country code.

Table 1. EPC software in the partnership countries.

Country	Software	Language
AT-AEA	ETU Software (all building types)	German
BG-ENEFFECT	EAB Software (all building types), EECalc (all building types)	Bulgarian
DK-ECN	Energy10 - Energy +	Danish
ES-EREN	Official software ce3X / HULC	Spanish
GR-CRES	Official EPC calculations software (TEE-KENAK) and commercial pre- and post-processors	Greek
HR-REGEA	Energetski certifikator (official software) and DST Tool (unofficial - in parallel)	Croatian
MT-MIEMA	iSBEM (non-dwellings); EPRDM (dwellings)	English
PL-KAPE	No official software, unofficial - Audytor OZC, ArCADia-TEROMCAD PRO 2020 and others	Polish
SI-IRI UL	URSA, or KnaufInsulation,	Slovenian
UK-HWU	SAP (e.g. commercial package Stroma) for residential; iSBEM for small non-domestic/IES-VE for larger non-domestic	English

3 Relation of cross-testing with the rest of WPs

This section outlines how WP2 interacts with other downstream WPs. Such interaction is the basis for the specification of the cross-testing protocols that are developed later in this document.

The crossCert work plan envisages that, generally, all building testing activity will be conducted under WP2, where most of the relevant data will be collected. This data, plus the user experience, will be analysed as required under WP3-WP6. Re-conducting testing activities may be occasionally needed to conclude the work under WP3-WP6.

3.1 Relation with WP3 - Deriving technical Guidelines for EPCs

The Performance Gap analysis to be performed under T3.1 *Performance gap assessment* needs EPC input and data to be recorded in a consistent, country-neutral fashion for all buildings in the crossCert ensemble.

For this purpose, two country-neutral inventories have been developed:

- The Country Neutral crossCert Data Inventory, which records the data needed for the EPC software to be run. An inventory has been proposed by the WP2 coordinator UNIZAR in the form of a spreadsheet (see Appendix B for a listing). It is foreseen that this inventory will require minor adjustments as the testing exercise progresses.
- A Country Neutral crossCert Result Report, which compiles the main output from the respective EPCs in a homogeneous format, and in the English language, so that they can be used in WP3 and across the project (see Appendix C for a listing).

Additionally, measured energy consumption data (needed for Performance Gap analysis) will be uploaded by the partners to the shared filing system, under *WP2/crossCert buildings*.

T3.3 *Evaluation of the renovation measures recommended by EPCs* and T3.4 *Verification and control* also requires a degree of qualitative data from the above. This includes a list of recommended energy efficiency measures (as worded in the EPC document of that particular country) for each tested building. Such a list is included under the Country-Neutral Result Report. Equivalent information relating to recommended measures may not always be available when applying assessment methods from one country to that of

another country; such measures are sometimes only generated if a full EPC is produced for a building (which might not be possible for all cross-testing of buildings for non-local assessment methods).

For WP3 work, there is also a need for a standardised way of recording the EPC method or framework of each country in terms of agreed parameters (calculation methodology, assessment framework, format of EPC document). This will help WP3 partners understand how a particular country differs from other countries in their response to the EPBD, and WP3 can try to use this information to understand the impact of this on EPC outputs. This information will also help the crossCert goal of proposing steps towards harmonisation of next-generation EPC approaches (e.g. in T3.5 *Are new EPC paradigms a significant improvement?*), and in making general recommendations. For instance, it can be instrumental in determining whether harmonisation should be restricted to "clusters" of countries that use certain EPC approaches, or whether recommendations can be more generally made.

Part of this information on EPC methodology in each country is provided above in Section 2 *EPC status in the countries represented in crossCert*. However, a more detailed assessment will be provided under Deliverable *D3.1: Review of approaches to EPC assessment across chosen member states*. This assessment will also refer as needed to pre-existing similar work, such as that arising from the Buildings Performance Institute Europe and other EU projects.

3.2 Relation with WP4 - Increasing the value of EPCs

WP4 is largely a prospective piece of research (*Integration of EPCs in the Administration databases*; *Adapting EPCs to user and investor needs*; *Linking next-generation of EPCs to energy audits, logbooks and BRPs*; *EPCs and one-stop-shop*), and therefore there is little interaction with WP2.

A link between WP2 and WP4 is the existence, contents and access conditions of national or regional EPC databases. These databases will be partly examined as a part of cross testing.

3.3 Relation with WP5 - Towards human-centred EPCs

In respect of WP5, the main relationship is the transfer of useful information coming out from the actual cross-testing activities, particularly for desktop research and analysis. In terms of data and information, the information to be transferred is summarised in Table 2 below.

Table 2. Relation with WP5 - information to be transferred to WP5.

Item of interest	Context
Transfer of useful information	• Transfer of "people-centred" contents relevant for WP5, particularly good (and bad) practices in the design of EPCs, training of EPC issuers, and finally promotion and marketing of EPCs. • For T5.4, the gathering of information on promotional/informational processes, obligations and materials in the partners' own countries. • For the interactive/co-production activities with different target groups, when collecting data and information throughout WP2 (e.g. EPC information and cross-testing stages) it is important to collate such information to highlight these interactions. • To integrate WP2 results in D5.5 there is a need to have clear references to people-centred aspects in WP2 activities and outcomes. Testing will therefore need to account for aspects of EPC design, training of EPC issuers (including aspects on customer service and interaction), and finally EPC promotion and marketing. Conclusions and insights regarding these aspects should be communicated to WP5 task leaders to integrate them into their final reports. • During the cross tests specific attention should be paid to the human behaviour aspects of the building occupants: how is it taken into

	account in the EPC calculation? Is there any information about it in the EPC? Are there any measures related to that in the EPC?
Standardisation of descriptions/lingo/metrics	• To standardise the description of EPC approaches across the various countries. Although aesthetically, many EPCs look similar, the different aspects of the EPC framework (calculation methodology, software, application, output metrics etc) should be categorised in a replicable way.
Accounting for visual and practical aspects of the EPC products and services	• Standardisation and visualisation of this information will be important for T5.2 and other workshops/engagement activities with user groups.
Specification of individual aspects of EPC schemes that crossCert can hope to improve within the scope of the project	• crossCert should categorise the specific aspects of EPCs that we are seeking to improve (that are within the scope of crossCert), and obtain specific feedback on these aspects through all WP activities. Having such categories (e.g. calculation methodology, application, assessment delivery, EPC document etc) used consistently throughout crossCert would help identifying what areas crossCert is aiming to improve, and should begin in WP2.
Support in defining quality indicators for people-centred EPCs	• WP5 will do desk research combined with targeted interviews/focus groups with project partners, cluster (or sister) projects, the crossCert LOI contacts, Energy Agencies and municipalities (e.g. in Germany) to identify the features of what makes a bad and what makes a good practice in terms of user-centred promotion measures for EPCs.
Avoiding overloading our research participant and researchers/partners	• The different aspects of current EPCs systems will be explored from different perspectives; this may entail approaching the same organisations in WP2-3-4-5 independently from each other, with the result that they may be overloaded and from a certain point not replying to questions.

Cross-testing activities under WP2 need to evaluate and manage ethics and data management risks. This is addressed by *D1.7 - Data Management Plan and IPR Management*.

3.4 Relation with WP6 - Harmonising/converging EPCs in Europe

WP2 is one of the pillars of the harmonisation recommendations to arise out of WP6; for these recommendations, WP6 will need the following from WP2:

- For Task 6.2 *The EPC Knowledge Exchange Centre*:
  - A summary of D2.1 regarding our research on the other initiatives (from each version)
  - A presentation or a summary of Task 2.3 results for the 3 rounds of testing, as compiled in task deliverables.
  - A summary of D2.4 *EPC cross-testing procedure*.
- For Task 6.3 *Recommendations for EPCs harmonisation*:
  - The results or a summary of task 2.3 as a base for the arguments for harmonisation.

4 Building selection

As a first step in the cross testing exercise, cross-testing partners have been asked to provide target buildings. The overall criteria for building selection have been:

1. To prioritise buildings for which the tester has a complete set of building data.
2. To include as many buildings as possible with available measurements, to facilitate the determination of the EPC performance gap.
3. To ensure a good distribution of buildings across all building typologies.

The table below shows the breakdown of buildings among countries and building typologies. The background colour in the cell with the number of buildings indicates the availability of data for performance gap assessment (see legend). The colour coding in the background of the country is used to indicate similar climatic conditions across countries (see below in this document).

Table 3. Breakdown of buildings for cross-testing among countries and building typologies

Building typologies, actual count		CRES	REGEA	KAPE	ENEFFECT	MIEMA	EREN	ECN	AEA	HWU	IRI UL	Total in category
	Number of buildings in country	20	22	15	10	12	16	10	10	24	10	149
	Colour indicates climate	Greece	Croatia	Poland	Bulgaria	Malta	Spain	Denmark	Austria	UK	Slovenia	
Residential	Single family house	5		7	1	2		3	3	20		41
	Terraced house			1		2		2				5
	Multi-apartment Building	5		1	3			3	3			15
Tertiary sector	Educational	5	13	4	2	2	2		1	3	9	41
	Office	2		1	3	4	7	2	1			20
	Sports hall	1	3	1							1	6
	Healthcare buildings		3				2			1		6
	Public entertainment buildings				1							1
	Community/Public assemby buildings		3			2						5
	Social housing						2					2
	Retail buildings	2							1			3
	Buildings for religious activities											0
	Public security buildings											0
	Others						3		1			4
Industrial secto	Industrial buildings and warehouses											0

4.1 Austria

	Typology	Surface area, m2	Construction year	Building identificacion (eg address) and description	Data available?	Other comments
1	Single family house		1900	SFH 1_AT	EPC	Refurbished
2	Single family house	466	2011	SFH Hartl 2241_AT	EPC, real consumption (electricity, heat)	New building
3	Single family house	4452.26	2020	SFH Ploiner 1230_AT	EPC, real consumption (electricity, heat) (available from end of May 2022)	New building
4	Multi-apartment Building		2000	Lower Austria	EPC, real consumption (electricity, heat)	existing building
5	Multi-apartment Building	4370.3	1967	MFH Brunn Gebirge_AT	EPC, real consumption (heat)	partly refurbished (winc
6	Multi-apartment Building	2936	2019	MFH Vienna_AT	EPC, real consumption (heat)	New Building
7	Office		2009	AEA office_AT	EPC, real consumption (electricity, heat)	Existing Building
8	Retail buildings	4354	2017	Retail building_AT	EPC, details about the wall constructions, windows, HVAC-system, lighting system; real energy consumption for heating, warm water and electricity, submission plan, CAD drawings	New Building
9	Others			Accommodation - Good-Practic	EPC, plans	
10	Educational	11380	1979	Primary school without gym	EPC, plans	Refurbished in 2014

4.2 Bulgaria

	Typology	Surface area, m2	Construction year	Building identificacion (eg address) and description	Data available?
1	Multi-apartme	4939	1975	Gabrovo, 77-81 Magilyov blvd.	Yes (electricity and district heat, monthly, 2018-2020)
2	Multi-apartme	30 395	1975	Burgas, unit 1B "Slaveykov" RA	Partly (electricity and district heat, monthly, 2018-2020)
3	Multi-apartme	6144	1975	Gabrovo, 23-25 Magilyov blvd.	Partly (electricity and district heat, monthly, 2018-2020)
4	Single family	130	2008	Sofia, Pancharevo neighberhood, 9 Temenuga Str.	Yes (electricity - monthly, fuel consumption - yearly, 2020)
5	Public enterta	12425	1964	Gabrovo, 7 Vuzrazhdane Sq. - House of culture (Theater)	Yes (electricity and district heat, monthly, 2017-2019)
6	Office	1560	1967	Etropole, 1 Deveti Septemvri Sq. - Municipal office building	Yes (electricity and fuel consumption, monthly, 2017-2019)
7	Office	3176	1971	Berkovitsa, 4 Jordan Rachkov Sq. - Municipal office building	Yes (electricity and fuel consumption, monthly, 2019)
8	Office	9975	2004	Sofia, 14 Tsar Osvoboditel Blvd.	Yes (electricity and fuel consumption, monthly, 2019-2021)
9	Educational	6504	1976	Gabrovo, 48 Lyuben Karavelov Str.	Yes (electricity and fuel consumption, monthly, 2015-2017)
10	Educational	3263	1924	Dzhulyunitsa, 1 Stefan Stambolov Str.	Yes (electricity and fuel consumption, monthly, 2017-2019)

4.3 Denmark

	Typology	Surface area, m2	Construction year	Building identificacion (eg address) and description	Data available?
1	Single family	210	1995	Central Denmark Region	EPC, Real consumption data from smart meters available for electricity and heat
2	Single family	301	1863	Central Denmark Region	EPC, Real consumption data from smart meters available for electricity and heat
3	Single family	280	1935	Central Denmark Region	EPC, Real consumption data from smart meters available for electricity and heat
4	Terraced hou	78	1981	Central Denmark Region	EPC, Real consumption data from smart meters available for electricity and heat
5	Terraced hou	95	1988	Central Denmark Region	EPC, Real consumption data from smart meters available for electricity and heat
6	Multi-apartme	6145	1992	Central Denmark Region	EPC, Real consumption data from smart meters available for electricity and heat - DRAWINGS
7	Multi-apartme	1066	1937	Central Denmark Region	EPC, Real consumption data from smart meters available for electricity and heat -DRAWINGS
8	Multi-apartme	254	1900	Central Denmark Region	EPC, Real consumption data from smart meters available for electricity and heat
9	Office	280	1969	Central Denmark Region	EPC, Real consumption data from smart meters available for electricity and heat
10	Office	1048	1904	Central Denmark Region	EPC, Real consumption data from smart meters available for electricity and heat

4.4 Spain

	Typology	Surface area, m2	Constructio n year	Building identificacion (eg address) and description	Data available?
1	Educational	4700	2017	IESO Arroyo de la Encomienda, Valladolid	EPC. Electricity and natural gas consumption
2	Educational	5100	2018	IESO Cistérniga, Valladolid	EPC. Electricity consumption
3	Office	441	1992	Oficina ECYL, Benavente, Zamora	EPC. Electricity and natural gas consumption
4	Office	7000	2006	Edificio Usos comunes Parque Tecnológico de León	EPC. Electricity and natural gas consumption
5	Office	5800	2003	Edificio de oficinas "Solar" (Boecillo)	EPC, architecture project. Electricity and natural gas consumption
6	Office	3100	2018	Unidad de Valoración Servicios Sociales (Valladolid)	EPC, architecture project. Electricity and natural gas consumption
7	Others	1800	1920	Albergue Juvenil San Martin de Castañeda (Zamora)	EPC. Electricity consumption
8	Others	7513	2003	Museo Etnográfico de Castilla y León (Zamora)	EPC, architecture project. Electricity consumption
9	Others	1650	2012	Centro de Recepción de Visitantes. Ibeas de Juarros (	EPC, architecture project. Electricity consumption
10	Healthcare buildings	1350	2016	Centro de Salud de Lerma (Burgos)	EPC, architecture project. Electricity and natural gas consumption
11	Social housing	851	1981	Bloque de 9 viviendas en Simancas (Valladolid)	EPC, architecture project
12	Social housing	830	1986	Bloque de 11 viviendas sociales en Candeleda (Ávila)	EPC, architecture project
13	Office	670	2018	Oficina ECYL, Zamora	EPC, architecture project. Electricity consumption
14	Office	580	2018	Oficina ECYL, Valladolid	EPC, architecture project. Electricity consumption
15	Office	719	2016	Oficina ECYL, Salamanca	EPC, architecture project. Electricity consumption
16	Healthcare buildings	3314	2020	Centro de Salud de Aguilar de Campoo (Palencia)	EPC. Electricity consumption

4.5 Greece

	Typology	Surface area, m2	Construction year	Building identificacion (eg address) and description	Data available?
1	Single famil	144.58	1968	Trikala	All EPC input data, EPC calculation results
2	Single famil	95	1964	Larissa	
3	Single famil	86.97	1953	Athens	All EPC input data, EPC calculation results
4	Single famil	126.95	1955	Magnhsia	All EPC input data, EPC calculation results
5	Single famil	114.36	2005	Ioannina	All EPC input data, EPC calculation results
6	Multi-apart	191.843	1988	Zakynthos	All EPC input data, EPC calculation results
7	Multi-apart	109.19	1957	Athens	All EPC input data, EPC calculation results
8	Multi-apart	587.99	2005	Tripoli	All EPC input data, EPC calculation results
9	Multi-apart	387.33	1978	Athens	All EPC input data, EPC calculation results
10	Multi-apart	242.22	1975	Athens	All EPC input data, EPC calculation results
11	Educational	1189.39	1986	Kastoria	All EPC input data, EPC calculation results
12	Educational	640.71	1930	Patra	All EPC input data, EPC calculation results
13	Educational	3293.39	1991	Larissa	All EPC input data, EPC calculation results
14	Educational	1755	1983	Athens	All EPC input data, EPC calculation results
15	Educational	1742.5	1996	Kastoria	All EPC input data, EPC calculation results
16	Office	660.28	2008	Paros	All EPC input data, EPC calculation results
17	Office	2703.25	2004	Halkida	All EPC input data, EPC calculation results
18	Retail buildi	63	1970	Serres	All EPC input data, EPC calculation results
19	Retail buildi	27.05	1969	Ioannina	All EPC input data, EPC calculation results
20	Sports hall	156.68	2017	Athens	All EPC input data, EPC calculation results

4.6 Croatia

	Typology	Surface area, m2	Construction year	Building identificacion (eg address) and description	Data available?	Other comments
1	Educational	2284	1975	Konjščina High school, Matije Gupca 5, 49282 Konjščina, Croatia	Yes (electricity, fuel and water consumption, hourly, 2021), EPC, refurbishment documentation	Building refurbished in 2020. Smart metering system installed in 2020
2	Educational	3766	1957	Bedekovčina High school, Gajeva 1, 49221 Bedekovčina, Croatia	Yes (electricity, fuel and water consumption, hourly, 2021), EPC, refurbishment documentation	Building refurbished in 2020. Smart metering system installed in 2020
3	Educational	2655	1977	Gornja Stubica Elementary school, Matije Gupca 2, 49245 Gornja Stubica, Croatia	Yes (electricity, fuel and water consumption monthly 2021), EPC, refurbishment documentation	Building refurbished in 2020. Ventilation with heat recovery installed in 2020
4	Educational	3252	1956	Kumrovec Elementary school, Antuna Mihanovića 8, 49295 Kumrovec, Croatia	Yes (electricity, fuel and water consumption monthly 2021), EPC, refurbishment documentation	Building refurbished in 2020.
5	Educational	2200	1980	Đurmanec Elementary school, Đurmanec 49, 49225 Đurmanec, Croatia	Yes (electricity, fuel and water consumption monthly 2021), EPC, refurbishment documentation	Building refurbished in 2020.
6	Educational	2850	1959	Konjščina Elementary school, Matije Gupca 6, 49282 Konjščina, Croatia	Yes (electricity, fuel and water consumption monthly 2021), EPC, refurbishment documentation	Building refurbished in 2020.
7	Sports hall	822	1977	Gornja Stubica Elementary school, Matije Gupca 2, 49245 Gornja Stubica, Croatia	Yes (electricity, fuel and water consumption monthly 2021), EPC, refurbishment documentation	Building refurbished in 2020. Ventilation with heat recovery installed in 2020
8	Community/F	305	2020	Grabrina Public assembly building, Milekovo Selo 43, 49240 Donja Stubica, Croatia	Yes (electricity, fuel and water consumption monthly 2021), EPC, documentation	
9	Community/F	260	1980	Hruševac Public assembly building, 49240 Donja Stubica, Croatia	Yes (electricity, fuel and water consumption monthly 2021), EPC, documentation	Building refurbished in 2020.
10	Community/F	221	1980	Gornji Matenci Public assembly building, 49240 Donja Stubica, Croatia	Yes (electricity, fuel and water consumption monthly 2021), EPC, documentation	Building refurbished in 2020.
11	Educational		1957	Natural sciences school Karlovac, Stjepana Mihalića 43, 47000 Karlovac, Croatia	Yes (electricity, fuel and water consumption, air quality, comfort level, hourly, 2021), EPC, refurbishment documentation	
12	Educational		1980	Forestry school Karlovac, Vatrogasna cesta 5, 47000 Karlovac, Croatia	Yes (electricity, fuel and water consumption, air quality, comfort level, hourly, 2021), EPC, refurbishment documentation	
13	Educational	3000	1967	Švarča Elementary school, Baščinska cesta 20, 47000 Karlovac, Croatia	Yes (electricity, fuel and water consumption, hourly, 2021), EPC, documentation	Wood pellets heating
14	Educational	2497	1979	Dubovac Elementary school, Primorska 9, 47000 Karlovac, Croatia	Yes (electricity, fuel and water consumption, hourly, 2021), EPC, documentation	
15	Educational	1981	1893	Braća Seljan Elementary school, Vladimira Nazora 1, 47000 Karlovac, Croatia	Yes (electricity, fuel and water consumption, hourly, 2021), EPC, documentation	Building refurbished in 2005 (windows) and 2010 (roof)
16	Educational	973	1966	Mahično Elementary school, Mahično 122, 47000 Karlovac, Croatia	Yes (electricity, fuel and water consumption, hourly, 2021), EPC, documentation	Building refurbished in 2013
17	Educational	931	1964	Rečica Elementary school, Rečica 33a, 47000 Karlovac, Croatia	Yes (electricity, fuel and water consumption, hourly, 2021), EPC, documentation	Building refurbished in 2008 (windows)
18	Healthcare b	1792	1859	Ogulin Medical centre, Bernardina Frankopana 14, 47300 Ogulin, Croatia	Yes (electricity, fuel and water consumption monthly 2021), EPC, documentation	Building refurbished in 1998, 2016 (roof)
19	Healthcare b	148	1984	Žakanje ambulance, Žakanje 59, 47276 Žakanje, Croatia	Yes (electricity, fuel and water consumption monthly 2021), EPC, documentation	
20	Healthcare b	888	1950	Duga Resa Medical centre, Bana Josipa Jelačića 4, 47250 Duga Resa, Croatia	Yes (electricity, fuel and water consumption monthly 2021), EPC, documentation	Building refurbished in 2017
21	Sports hall	2325	2010	Dubovac Elementary school sports hall, Petra Kružića bb, 47000 Karlovac, Croatia	Yes (electricity, fuel and water consumption monthly 2021), EPC, documentation	
22	Sports hall	2332	2008	Karlovac School of economic and tourism sports hall, Frana Kurelca 2, 47000 Karlovac, Croatia	Yes (electricity, fuel and water consumption monthly 2021), EPC, documentation	Building refurbished in 2013

4.7 Malta

	Typology	Surface area, m2	Construction year	Building identificacion (eg address) and description	Data available?	Other comments
1	Single family	120	2009	423, Vjal l-Indipendenza, Zurrieq, Malta	Yes (floor plans, monthly electricity consumption kWh since 2018)	Ground floor maisonette
2	Single family	115	2018	Waterfront Block A, Flat 1, Triq il-Marfa, Mellieha, Malta	Yes (floor plans, electricity consumption kWh since 2019)	Ground floor apartment
3	Terraced hou		1980s	Richmond Foundation - Qormi Residence	Yes (floor plans, building material data)	Has PV installation
4	Terraced hou		1960s	Richmond Foundation - Paola Residence	Yes (floor plans, building material data)	Has PV installation
5	Educational	2884	1930	St George Primary School - Qormi	Yes (floor plans, monthly electricity consumption kWh)	Primary school - two storeys
6	Educational	3900	1997	St Thomas More College – Secondary School Santa Lucija	Yes (floor plans, monthly electricity consumption kWh)	Secondary school - three storeys
7	Office		1990s	Richmond Foundation Head office, Qormi	Yes (floor plans)	
8	Office		1990s	Richmond Service Centre	Yes (floor plans)	
9	Office		2008	Gozo Regional Council Offices	Yes (floor plans, electricity consumption)	Ground floor level office
10	Office	352		Isla Local Council, 2, St. Joseph Street, Isla	Yes (floor plans)	
11	Community/F			San Lawrenz Community Hall	Yes (floor plans)	
12	Community/F	1708	1980s	Local Councils Association, Triq il-Gvern Lokali, Marsa	Yes (floor plans)	2 levels, comprising offices and halls

4.8 Poland

	Typology	Surface area, m2	Construction year	Building identificacion (eg address) and description	Data available?
1	Educational	980.50	2018	Nowy Rynek 14, 98-170 Widawa	EPC; Real consumption data
2	Office	999.77	2019	Krakowska 289, 35-213 Rzeszów	EPC; Real consumption data
3	Educational	1437.59	2017	Wyszków, ul. Meliorantów	EPC; Real consumption data
4	Sports hall	589.83	2017	Biesiadki 58, 32-864 Biesiadki	EPC
5	Educational	1038.15	2017	Mińsk Mazowiecki, ul. Konstytucji 3-go Maja 11	EPC
6	Educational	1462.44	2017	Zielonka, ul. Staszica 16	EPC; Real consumption data
7	Single family	199.2	2003	Ostrów Mazowiecka, ul. Macieja Rataja	EPC, without energy consumption data
8	Single family	141.89	2013	Węgrce Panieńskie, gmina Obrazów, powiat sandomierski, województwo świętokrzyskie	Energy Performance Characteristic, gas consumption data
9	Single family	186.57	2015	Zielonka Wieś, k/Warszawy	Energy Performance Characteristic, electricty consumption data
10	Single family	177.76	2017	18-300 Zambrów	EPC
11	Single family	202.9	2004	Podkonice Miejskie 2, 97-216 Czerniewice	EPC
12	Educational	770.3	2003 (significant modernisation)	Warszawa, Nowoursynowska 164, building 19	EPC
13	Multi-apartme	1,576.40	2001	Warszawa, Pułtuska and Osowska streets corner	Energy Performance Characteristic
14	Single family	150.4	1976	09-400 Płock, ul. Judyma 20	EPC
15	Single family	245.07	2017	Puznówka, ul. Słoneczna	EPC

4.9 Slovenia

	Typology	Surface area, m2	Construction year	Building identificacion (eg address) and description	Data available?	Other comments
1	Educational	7831	2013	Faculty of Computer and Information Science, Večna pot 113	All in Ljubljana; buildings of UL. IRI UL is the official energy manager for UL, as such has prepared and monitors the implementation of the University Sustainable Energy Action Plan (SEAP), and established an Energy Management system for UL public buildings. We have access to all its facilities and energy-related data, including: The energy information system covering the entire UL (300.000+ m2 of buildings), Local energy information systems for some UL faculties with detailed energy monitoring of all energy vectors (electricity, heat, cold, water, hot water) and IEQ parameters (e.g. a building with ~500 rooms monitored for temperature, thermostat interactions, window opening, and access to each of the rooms).	FRI, EIS available = L
2	Educational	17470	1976	School of Economics and Business, Kardeljeva ploščad 17		EF, EIS available, 100+ kW PV, 400 kW HP, retrofited
3	Educational	13407	1960	Faculty of Arts, Aškerčeva 2		FF, EIS available, retrofited = P
4	Educational	10421	1963	Faculty of Sport, Gortanova 22		FŠ = L
5	Educational	7116	2000	Faculty of Administration, Gosarjeva 5		FU, ~80 kW PV
6	Educational	4643	1895	Faculty of Architecture, Zoisova 12		FA
7	Educational	24974	1999	Faculty of Social Sciences, Kardeljeva Ploščad 5		FDV
8	Educational	12170	1981	Faculty of Education, Kardeljeva ploščad 16		PeF
9	Educational	15436	1973	Faculty of Medicine, Korytkova 2		MF, EIS available
10	Sports hall	2009	1973	University's multi-purpose sports hall, Svetčeva 11		UŠD

4.10 United Kingdom

	Typology	Surface area, m2	Construction year	Building identificacion (eg address) and description	Data available?	Other comments
1	Educational	c 2500m2 TFA	2008	Post Graduate Centre Building, Heriot-Watt University, Edinburgh, UK EH14 4AS	Building data (e.g. CAD), metered electricity and gas consumption (half-hourly) for multiple recent years	Hypostyle Architects | Glasgow | Projects | Educati
2	Educational	5200m2 TFA	2019	GRID Building, Heriot-Watt University, Edinburgh, UK EH14 4AS	Building data (e.g. CAD), metered electricity and gas consumption (half-hourly) for 2020	Heriot-Watt University GRID - Architecture - Shepp
3	Educational	6229m2 TFA	1974	Cameron Smail Library, Heriot-Watt University, Edinburgh, UK EH14 4AS	Building data available but no half-hourly metered energy data available. Annual or quarterly kWh may be obtainable upon request	Underwent 2019 refurbishment https://www.urbanre
4	Single family	146	1981-2016	Building Postcode - PL12; Building ID (NEWSITE) - 7	(e.g. EV, electric heating, electric shower) 3. minutely PV generation (including self-consumed and exported) 4. minutely behind meter battery charge (grid and PV) and discharge (consumed and exported) data Climate data (for 18 months) 1. half hourly weather data (for nearby location - within 50km) for 18 months EPC Input data including 1. heating demand & hot water demand 2. Heating controls 3. Billing information 4. Household income 5. Occupancy & demographics 6. appliance ownership 7. EV ownership 8. Orientation (Front door and roof) 9. Heating Type and fuel 10. Size of PV system 11. Glazing type 12. wall construction 13. roof insulation level 14. dwelling type	1. Addresses are redacted; All dwellings are located in the county of Cornwall in SW England; Homeowners are non-contactable 2. Property information is associated with the NEWSITE ID 3. All these dwellings are electrically heated - mixtue of ASHP, GSHP, storage 4. Weather file can be accessed using the Post Code 5. A further 81 dellings are also available in the dataset - all with the same monitored data and similar quality of EPC input data. heating fuel for these dwellings is non-electric (mixture of LPG, oil, coal, biomass). No metering of heating or hot water demand is available for these - the only heating demand info is provided by EPC input estimates 6. All dwellings have roof top PV (1 - 5kW size); All dwellings have behind the meter battery (Sonnen - 5, 7.5 or 10kWh)
5	Single family	181	pre-1945	Building Postcode - TR12; Building ID (NEWSITE) - 8		
6	Single family	48	pre-1945	Building Postcode - TR27; Building ID (NEWSITE) - 9		
7	Single family	145	1981-2016	Building Postcode - TR8; Building ID (NEWSITE) - 22		
8	Single family	124	1981-2016	Building Postcode - PL30; Building ID (NEWSITE) - 26		
9	Single family	146	1945-1980	Building Postcode - PL26; Building ID (NEWSITE) - 29		
10	Single family	94	1945-1980	Building Postcode - PL27; Building ID (NEWSITE) - 30		
11	Single family	423	1981-2016	Building Postcode - TR9; Building ID (NEWSITE) - 34		
12	Single family	113	pre-1945	Building Postcode - PL26; Building ID (NEWSITE) - 46		
13	Single family	69	??	Building Postcode - TR11; Building ID (NEWSITE) - 51		
14	Single family	41	1945-1980	Building Postcode - TR1; Building ID (NEWSITE) - 53		
15	Single family	94	1981-2016	Building Postcode - TR3; Building ID (NEWSITE) - 64		
16	Single family	98	1981-2016	Building Postcode - TR9; Building ID (NEWSITE) - 65		
17	Single family	141	??	Building Postcode - TR15; Building ID (NEWSITE) - 70		
18	Single family	86	1945-1980	Building Postcode - TR5; Building ID (NEWSITE) - 71		
19	Single family	71	1981-2016	Building Postcode - TR3; Building ID (NEWSITE) - 81		
20	Single family	93	1945-1980	Building Postcode - TR14; Building ID (NEWSITE) - 85		
21	Single family	73	??	Building Postcode - TR5; Building ID (NEWSITE) - 86		
22	Single family	99	2015	Findhorn Ecovillage, Moray, Scotland, IV36	Floor plans and elevations; HVAC; some metered energy consumption; full EPC and related info uploaded to Google Drive	https://www.ecovillagefindhorn.com/
23	Single family	63	2002	Findhorn Ecovillage, Moray, Scotland, IV36		https://www.ecovillagefindhorn.com/
24	Healthcare b	4342	2009	Adelaide Health Centre, Western Community Hospital, Southampton, SO16 4XE	EPC; DEC; Floor plans and elevations; inputs from A/C inspection certificate	

5 Cross-testing procedure

5.1 Challenges

The background to the cross testing exercise, as set out in the crossCert contract, has been summarised above in the introductory section of this deliverable.

In designing a cross-testing procedure, we have encountered the following main challenges:

- The first one is the climate differences among our target countries. Climate differences limit the extent of the cross testing exercise, since we have found that different EPC methods in different countries cannot test a building under the same climate conditions: research conducting under WP2 in preparation for cross testing has revealed that the EPC software used in each country restricts, for most crossCert countries, the climate options to those prevailing in the country. We will below indicate how we have addressed this difficulty.
- The second obstacle is the language of the EPC software in each country, which limits meaningful access from project partners from alternative countries.
- A third obstacle is that the data required may be very different among countries, and the cross testing activity in crossCert brings this diversity to the forefront. We are partially addressing this obstacle by creating a Neutral Data Inventory for reporting input data.
- A fourth obstacle is the duration of the COVID-19 pandemic. While the pandemic was already a major disruption to normal business activities at the time of writing the proposal, it was unlikely that it would still hamper travel at the time of the cross-testing activities, almost two years after its onset. Successive waves have however continued to bring disruption and inconveniences to international travel and to large meeting gatherings. The cross-testing protocol has had to be designed around these restrictions, which could severely affect an exercise that was eminently based on the in-person interaction among partners from different countries. Details of the adaptation of the testing procedure to this unlikely reality are provided below.

5.2 Building ensembles

To circumvent the challenges indicated above, the crossCert test buildings indicated in Table 3 have been grouped into three testing ensembles:

- Project-wide ensemble, the buildings of which will be termed P-buildings.
- Climate clusters, the buildings of which will be termed C-buildings.
- Partner local building ensemble, the buildings of which will be termed L-buildings.

The rationale behind these ensembles, and a summary of their purpose in the cross-testing exercise, are summarised below. A later subsection specifies the testing procedure for each ensemble

5.2.1 The project-wide ensemble (P-buildings)

The P-building ensemble consists of typically one building in each major building typology in the crossCert building portfolio, totalling seven buildings in all.

These seven buildings are tested project-wide in each testing country, in the same climate conditions as the original building or in a climate as similar as possible within the country EPC climate set.

To make the building portable across climates, a detailed energy model (or dynamic model) for each of these seven buildings will be created by HWU with assistance from UNIZAR.

These detailed models will have the added benefit of allowing a determination of the certificate performance gap with respect to a theoretical, but highly detailed, model.

The goal of P-building testing is to have a project-wide set of common buildings from which each partner can derive both quantitative and qualitative indicators of the national EPC performance, thus enabling a robust cross-testing exercise.

To facilitate the exchange of data and results among partners in different countries, a country-neutral data and result inventory have been developed by UNIZAR. The partner contributing with the building will provide the building data in this country-neutral format, to facilitate the communication of the data among countries using different EPC methodologies but also different languages.

The buildings selected for the P-ensemble are the following:

1. A retail building: The stand-alone grocery store in St. Veit in Carinthia (Austria), from AEA
2. An office building: Office building in Sofia (Bulgaria), from ENEFFECT
3. A multi-apartment building: Herning Kommune, in Herning (Denmark), from ECNET
4. A public assembly building: the Grabrina Public assembly building (Croatia), from REGEA
5. An educational building: The Faculty of arts of the University of Ljubljana (Slovenia), from IRI-UL
6. A sports hall centre: The University's multi-purpose sports hall of Ljubljana (Slovenia), from IRI-UL
7. A single-family house: located Findhorn Ecovillage, Moray, Scotland (UK), from HWU

5.2.2 Climate-cluster ensembles (C-buildings)

Climate-cluster ensembles (C-buildings) are the basis for comparative testing among crossCert testing partners, and shared testing experiences.

Buildings in a cluster are chosen based on the similarity of the climate at the building location, and paired across countries. Thus a building originally located in country C1 is tested using the EPC method of another country C2 with a similar climate. The testing is done in a joint workshop of a partner in C1, who contributes the building (the "visitor" team), and a partner in C2, who has knowledge of the EPC method in the new country (the "home" team).

In this way, language and climate barriers are minimised, and testing experiences across countries can be compared. The aim of C-building testing is therefore:

- To compare qualitative indicators among countries (such as robustness, user experience, building improvements suggested by the EPC);
- To compare quantitative results (insofar as the climate pairs are similar enough);
- To compare the shared certification experiences (what country C1 can learn from the EPC procedures in country C2).

To facilitate the exchange of data and results among partners in different countries, a country-neutral data and result inventory have been developed by UNIZAR. The partner contributing the building will provide the building data in this country-neutral format, to facilitate the communication of the data among countries using different EPC methodologies but also different languages.

To pair the project buildings under similar climatic conditions to form C-clusters, we use climate information at the building location; specifically, the pairing is carried out on the basis of the following indicators at the building location:

- Heating Degree Days (HDDs)
- Cooling Degree Days (CDDs)
- Global horizontal irradiation
- Annual average ambient temperature

The procedure for determining these parameters for all the buildings has been created, and is reported in Appendix A.

With the above climate information, the buildings are classified into 5 different clusters, 0 to 4, created using an algorithm (K means). The results of this clustering are shown in Figure 2.

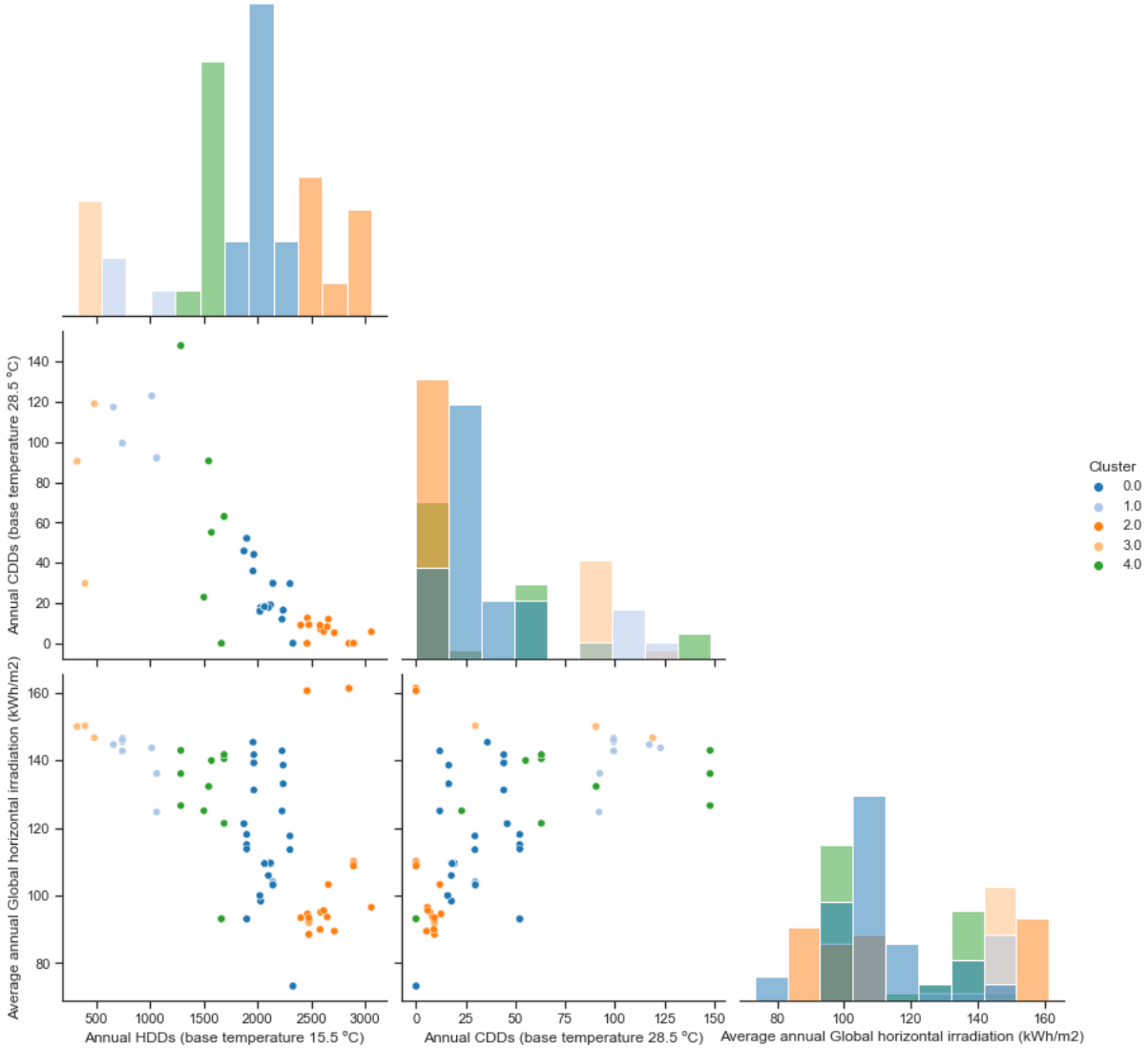


Figure 2. Buildings clustering according to the Heating Degree Days, Cooling Degree Days and annual global horizontal irradiation.

The buildings from country C1 are then paired with another country C2 with similar Heating Degree Days and Cooling Degree Days, that is, buildings close to each other in Figure 3 are paired. For instance, buildings from a specific region of Spain (ES-EREN) have similar Heating Degree Days (around 1600) and Cooling Degree Days (less than 70) as buildings from part of the UK (UK-HWU), so these buildings are paired.

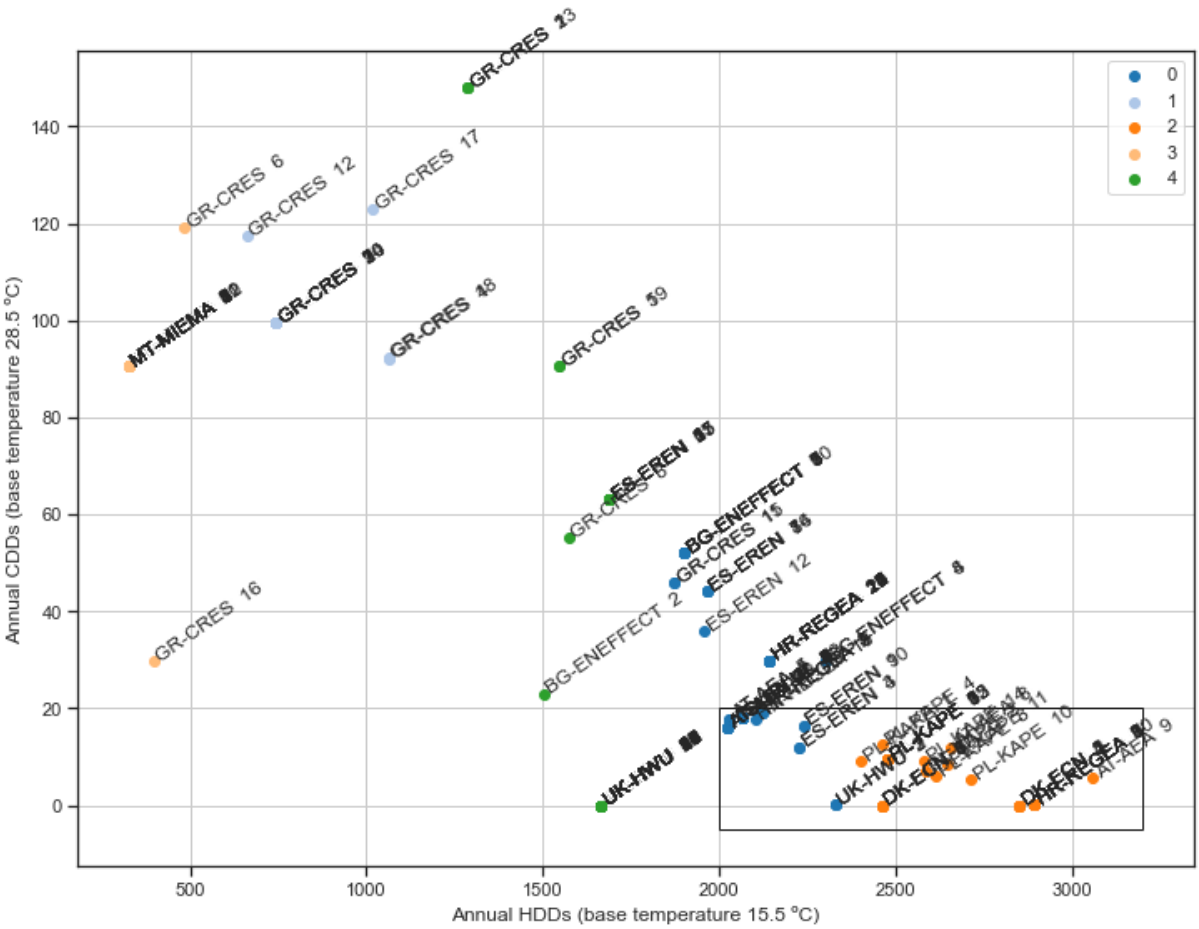


Figure 3. HDDs vs. CDDs for the different crossCert buildings. The first two letters (e.g. GR) refer to the country where the building is located, the second acronym refers to the partner (e.g. CRES) and the number refers to the building number as shown in Section 3.

Most of the buildings are located in the lower part of Figure 3 (marked in a box), so Figure 4 shows a zoom of this area.

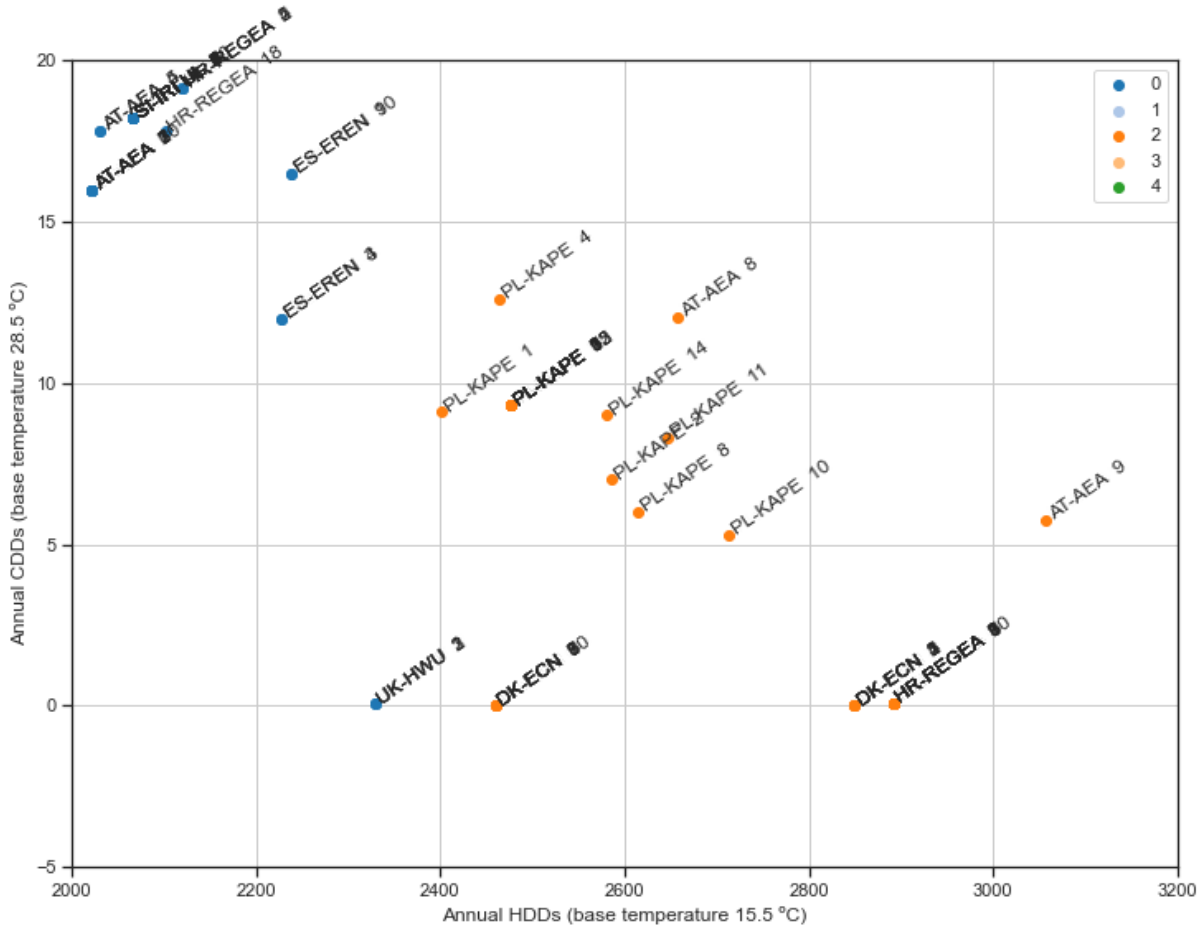


Figure 4. Zoom of HDDs vs. CDDs for the different crossCert buildings.

When a building from a country does not have a close building from another country (e.g. with similar HDDs and CDDs), the pairing is selected based on the HDDs and Global horizontal irradiation (see Figure 5). For instance, buildings from Malta (MT-MIEMA) are paired with buildings from Greece (e.g. GR-CRES 6, GR-CRES 16). In some cases, the CDDs vs. Global horizontal irradiation is also checked to decide some pairings (see Figures 6 and 7)

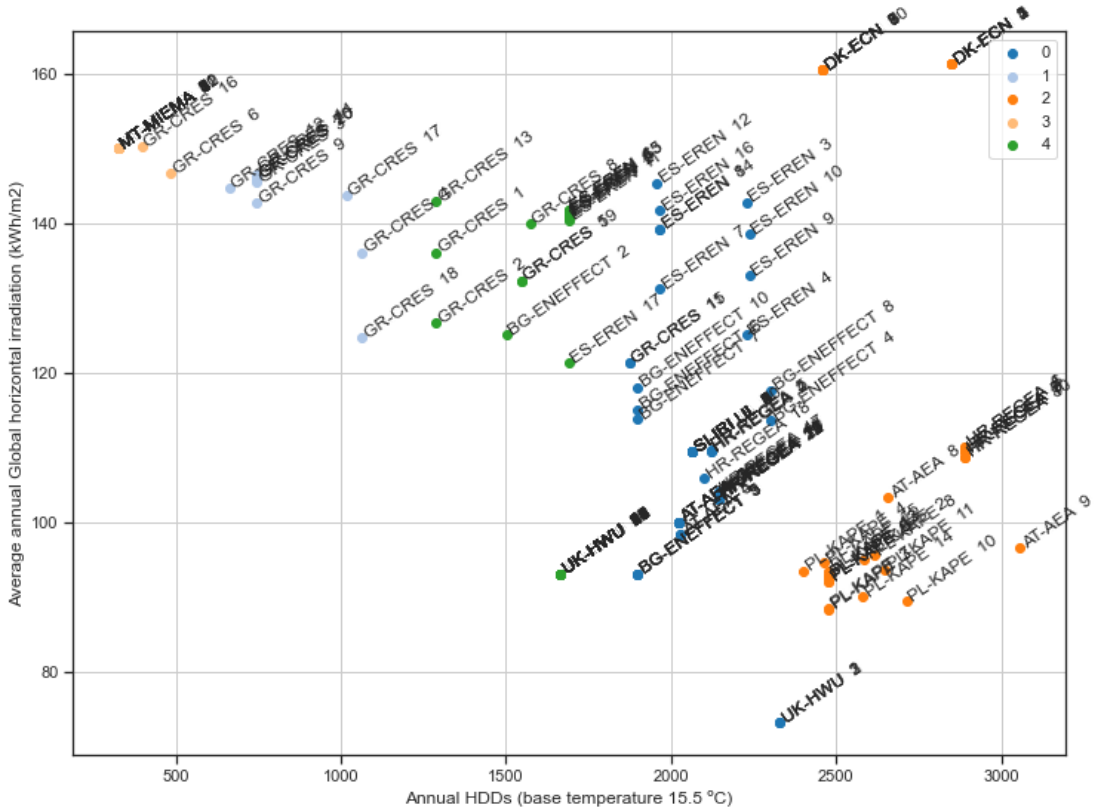


Figure 5. HDDs vs. Global horizontal irradiation for the different crossCert buildings.

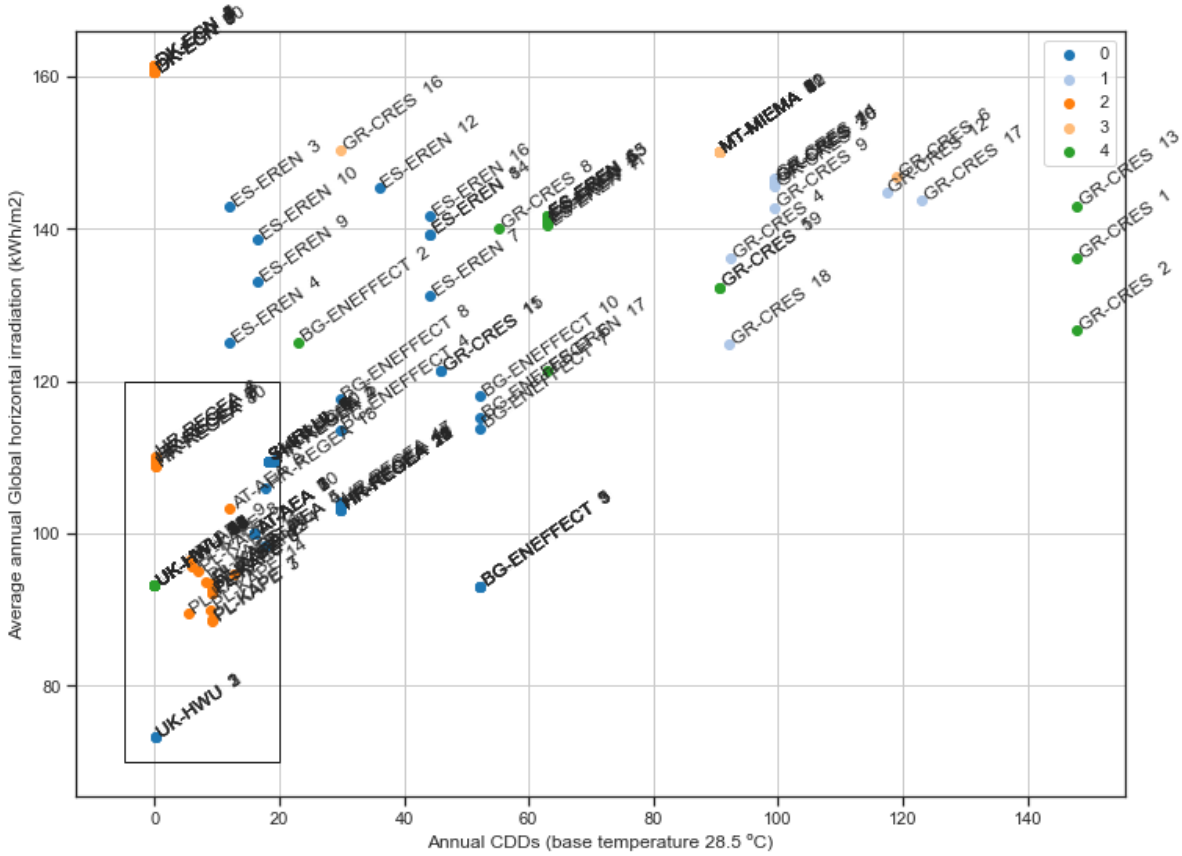


Figure 6. CDDs vs. Global horizontal irradiation for the different crossCert buildings.

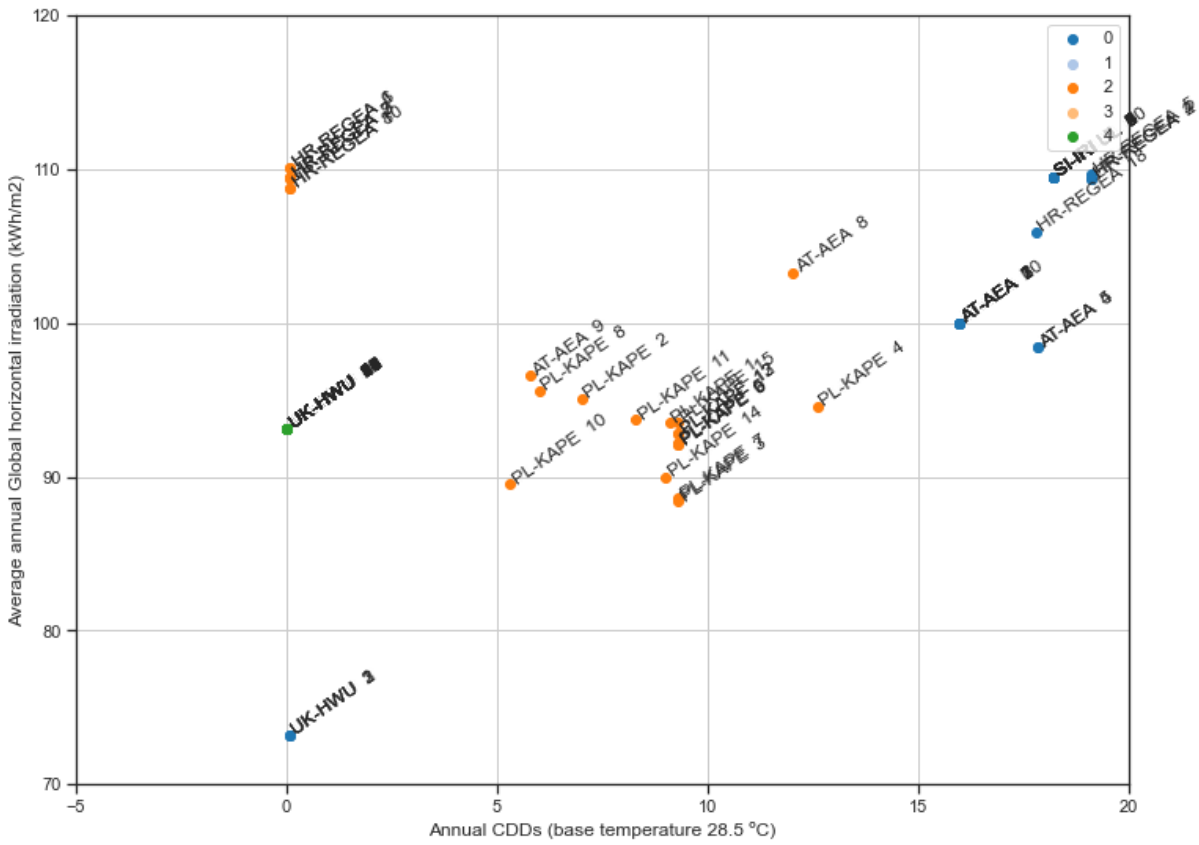


Figure 7. Zoom of CDDs vs. Global horizontal irradiation for the different crossCert buildings.

Overall, 65 unique buildings are selected among the 10 partner countries. Each partner from country C1 is paired with at least 2 different countries to enhance the cross-testing experience (see Table 4).

Table 4. Climate-cluster pairing.

"away" team->		AT	BG	DK	ES	GR	HR	MT	PL	SI	UK	No countries
"Home" team	AT						HR		PL	SI		3
	BG				ES	GR					UK	3
	DK						HR		PL			2
	ES		BG			GR					UK	3
	GR		BG		ES			MT				3
	HR	AT		DK						SI		3
	MT					GR						1
	PL			DK							UK	2
	SI	AT					HR					2
	UK		BG		ES				PL			3
No buildings to be tested "away"		7	7	7	7	10	7	4	6	4	6	65

Table 5 shows the matrix of the Climate-cluster pairing. Each row shows the buildings from the "visitor" team that should be tested by the "Home" team.

Table 5. Matrix of the climate-cluster pairing.

		1	2	3	4	5	6	7
"Home" team	**AT-AEA**	PL-11	HR-18	HR-5	SI-1,2	SI-4,8,6,7,8,9	SI-4,8,6,7,8,9	SI-4,8,6,7,8,9
		Single family hou	Healthcare buildings	Educational	Educational	Educational	Educational	Educational
	BG-ENEFFECT	ES-7, 8	ES-13, 15	GR-11	GR-15	UK-1	UK-2	UK-3
		Others	Office	Educational	Educational	Educational	Educational	Educational
	DK-ECN	HR-1	HR-7	HR-9	PL-7,9,15	PL-3,5,6,12	PL-3,5,6,12	PL-13
		Educational	Sports hall	Public assemby	Single family house	Educational	Educational	Multi-apartmer
	ES-EREN	BG-5	BG-6	BG-9	GR-8	UK-4-22	UK-4-22	UK-4-22
		Public entertainr	Office	Educational	Multi-apartment Building	Single family house	Single family h	Single family h
	GR-CRES	BG-1	BG-7	MT-1,2	MT-3,4	MT-5,6	ES-11	MT-11,12
		Multi-apartment	Office	Single family house	Terraced house	Educational	Social housing	Community/Pu
	HR-REGEA	AT-1-3	AT-6	DK-1	DK-4,5	SI-1,2	SI-4,8,6,7,8,9	SI-4,8,6,7,8,9
		Single family hou	Multi-apartment Buil	Single family house	Terraced house	Educational	Educational	Educational
	MT-MIEMA	GR-16	GR-6	GR-12	GR-3	GR-20	GR-7, 9, 10	GR-14
		Office	Multi-apartment B	Educational	Single family house	Sports hall	Multi-apartm	Educational
	PL-KAPE	DK-6	DK-7	DK-8	DK-9	DK-10	UK-1	UK-2
		Multi-apartment	Multi-apartment Buil	Multi-apartment Buildi	Office	Office	Educational	Educational
	SI-IRI UL	HR-4	HR-2	AT--4	AT--5	AT-1-3	AT-7	AT-10
		Educational	Educational	Multi-apartment Buildi	Multi-apartment Building	Single family house	Office	Educational
	UK-HWU	BG-4	BG-8	ES-9	ES-3	ES-4	ES-10	PL-1
		Single family hou	Office	Others	Office	Office	Healthcare bui	Educational

5.2.3 Partner local building ensemble (L-buildings)

In the L-building ensemble, each partner tests the remaining buildings in their own country.

The main goal of testing the L-building ensemble is to draw quantitative conclusions about the EPC, such as the performance gap, that can be later compared among countries; other qualitative indicators, such as robustness against user input error, will be assessed.

In addition, in countries where EPC databases are available and accessible, crossCert testing partners will compare database statistics.

5.3 Cross-testing protocol

This section describes the cross-testing protocol for each of the building ensembles presented above.

5.3.1 Testing protocol for buildings in the project-wide ensemble (P-buildings)

The procedure for the testing of P-buildings is as follows:

1. UNIZAR, in agreement with the cross-testing partners, will select the P-buildings, with the following criteria: about seven buildings in all; one building in each of the main typologies; no more than one building per country; preferably, buildings with available energy-consumption data. Section 5.2.1 lists the buildings selected for the P-ensemble.
2. The cross-testing partner that contributes the building provides:
    a. The *Country Neutral Data Inventory* for the building (see the template in Appendix B)
    b. Building drawings, or a similar description of the building layout
    c. The *Country Neutral Result Report* (see the template in Appendix C)
    d. The national EPC for the building, including any meta data produced by the EPC software
3. Each cross-testing partner chooses a target location for the P-building in their country. The location will be chosen, if possible, in an area with a climate similar to that of the P-building, or as close as possible. The partner provides climate data for the target location.
4. HWU, with assistance from UNIZAR, creates a dynamic or detailed model for the building, and runs the model for all the target climates. The model results are reported at each location in the format of the *Country Neutral Result Report*.
5. Each cross-testing partner tests the building with their national EPC, and provides:

   a. The resulting EPC.
   b. The *Country Neutral Result Report* (see the template in Appendix C)
   c. A report on the theoretical performance gap, that is, the differences between the results from the detailed model and the results from the EPC.
6. The consortium discusses the result of the P-building testing in a workshop.

File repositories: The files indicated above must be placed in the following folders on the project file system, under `02 WP2 Cross Assessing EPC paradigms`:

- Files in 2.a and 2.b to be placed under:
  `crossCert Buildings > _ P-Buildings -- data for modelling`
- Files in 2.b and 2.c to be placed under:
  `crossCert Buildings > [country]-[partner] buildings > _ P-building results`
- Files in 4 to be placed under:
  `crossCert Buildings > [country]-[partner] buildings > _ P-building results`
- Files in 5 to be placed under:
  `crossCert Buildings > [country]-[partner] buildings > _ P-building results`

5.3.2 Testing protocol for buildings in the climate-clusters ensemble (C-buildings)

The protocol for the testing of C-buildings is detailed below. In the description, the "visiting partner" refers to a partner testing their building using the EPC procedure of the country of a "home partner":

1. UNIZAR, in agreement with each cross-testing partner, selects the building and country pairs for cross-testing among the project buildings to create the C-buildings ensemble. The main criteria for the selection will be the similarity of climates between the actual building location and the target country. See section 5.2.2 for the climate-cluster pairing
2. The partner contributing the building (the visiting partner) provides:
   a. The *Country Neutral Data Inventory* for the building (see the template in Appendix B)
   b. The EPC for the building in their country, including any metadata produced by the EPC software
   c. The Country Neutral Result Report for their country (see the template in Appendix C)
3. The partner contributing the building assesses the robustness of the EPC method on the building. Appendix D provides some suggestions for this assessment.
4. The visiting partner and the home partner agree on a date for a joint workshop, in which the home partner performs the home country EPC on the visiting partner's building with assistance from the visiting partner. As a result, the following results are provided:
   a. The EPC for the building in the country.
   b. The *Country Neutral Result Report* (see the template in Appendix C).
   c. A short report by the visiting partner comparing the experience in generating the EPCs in both countries. Appendix D lists some suggested items to attend to in this *EPC Generator Experience Report*.

File repositories: The files indicated above must be placed in the following folders on the project file system, under `02 WP2 Cross Assessing EPC paradigms`:

- Files in 2.a and 2.b to be placed under:
  `crossCert Buildings > [country]-[partner] buildings > _ C-building data for home buildings`

- Files 2.c to be placed under:
  `crossCert Buildings > [country]-[partner] buildings > _ C-building results for home buildings at home`
- Files 3 to be placed under:
  `crossCert Buildings > [country]-[partner] buildings > _ C-building results for home buildings at home`
- Files in 4 to be placed under:
  `crossCert Buildings > [country]-[partner] buildings > _ C-building results for home buildings as a visitor`

5.3.3 Testing protocol for buildings in the local ensemble (L-buildings)

The procedure for the testing of L-buildings is as follows:

1. The partner tests any buildings in their country's list that will not be tested locally as a part of the P-ensemble or C-ensemble.
2. The partner testing the building provides:
   a. The EPC for the building in their country, including any metadata produced by the EPC software.
   b. The *Country Neutral Result Report* for the building (see the template in Appendix C).
   c. A short *L-Building Test Report*, including:
      i. A quantitative assessment of the performance gap, where measure data are available for the building
      ii. A (mainly qualitative) assessment of the EPC robustness. See Appendix D (Robustness paragraph) for suggestions. Additionally, test robustness by introducing out-of-bounds or contradictory data, and assessing their effect on the EPC.
      iii.

File repositories: The files indicated above must be placed in the following folders on the project file system, under `02 WP2 Cross Assessing EPC paradigms`:

- Files in 2 to be placed under:
  `crossCert Buildings > [country]-[partner] buildings > _ L-building data and results`

6 Cross-testing rounds

The cross testing to be conducted under WP2 is organised in three rounds:

1. The first cross-testing round focuses on the current EPC regulatory framework and practices across partner countries. The protocols and guidelines for this cross testing round are those described above.

2. The second cross-testing round, which will take place in project months M11-M15, will consist of the cross-assessment of new EPC approaches available at that time, such as the methodologies and procedures developed in the finished projects in previous H2020 calls related to next-generation EPCs (U-CERT, QualDeEPC, X-tendo) and other new EPCs developed under the framework of other projects (European, national or regional).

3. The third cross-testing round will evaluate the EPC approaches developed in the latest H2020 calls related to the next generation of EPCs (ePANACEA, E-DYCE, D^2EPC, EPC RECAST) and other new EPCs developed under the framework of other projects (European, national or regional). This final campaign will be carried out in project months M16-M20.

For the second and third rounds, the focus will be on assessing the extent to which the proposed new procedures will redress the deficiencies encountered in the current generation of EPC procedures already tested under the first round of WP2. The testing in rounds two and three will be based on the new EPC software available at the time of testing. Additionally, and certainly for those proposals for which no EPC software is available, we will evaluate how the proposed developments will impact the following aspects of current EPCs as applied to the crossCert building ensemble:

i. The likelihood that the new proposals will improve the performance gap and increase the robustness of existing EPCs.
ii. The new Key Performance Indicators introduced by the next generation certificates, and how they will increase the functionality of EPCs and facilitate the embodying of added value services (investor needs, energy audits, logbooks, building renovation passports, one-stop-shops).
iii. The improvement of the user experience for all types of users (building owners and tenants, buyers, sellers, facility managers, architects, real estate brokers, EPC issuers).
iv. The harmonization of EPCs across Europe, including that of regulations, input and output parameters, EPC verification, EPC databases, and training.

7 References

Androutsopoulos A., Bololia M, Polychroni E., Urbanz T., Maia I. (2021): Energy Performance Certificates (EPCs) potential linkage with Digital Building Logbooks and Building Renovation Passports. ePANACEA H2020 project. https://epanacea.eu/results/

Abela A., Hoxley M., McGrath P., Goodhew S. (2016): An investigation of the appropriateness of current methodologies for energy certification of Mediterranean housing. Energy and Buildings, 130, 210-218

Arcipowska A., Anagnostopoulos F., Mariottini F., Kunkel S. (2014): Energy Performance Certificates across the EU – A mapping of national approaches. BPIE

D^2EPC (2020-2023): Next-generation Dynamic Digital EPCs for Enhanced Quality and User Awareness. https://www.d2epc.eu/en

E-DYCE (2020-2023): Energy flexible DYnamic building CErtification. https://edyce.eu/

ePANACEA (2020-2023): Smart European Energy Performance Assessment and Certification. https://epanacea.eu/

EPC RECAST (2020-2023): Energy Performance Certificate Recast. https://epc-recast.eu/

EUB Superhub (2021-2024): European Building Sustainability performance and energy certification Hub. https://eubsuperhub.eu/

Gokarakonda S., Venjakob M., Thomas S., Kostova D. (2020): D2.1 Report on local EPC situation and cross-country comparison matrix. QualDeEPC H2020 project. https://qualdeepc.eu/public-project-deliverables

Gokarakonda S., Venjakob M., Thomas S. Kostova D. (2020): D2.3 Report on EPC short-comings and national priority approaches to their resolution. QualDeEPC H2020 project. https://qualdeepc.eu/public-project-deliverables

iBRoad2EPC (2021-2024): Integrating Building Renovation Passports into Energy Performance Certification schemes for a decarbonised building stock. https://ibroad2epc.eu/

IRI-UL and U-CERT project partners (2021): U-CERT - D2.3 Report on users' perception about EPC scheme in U- CERT partner countries.

Jenkins D., Simpson S., Peacock A. (2017): Investigating the consistency and quality of EPC ratings and assessments, Energy, Volume 138, Pages 480-489, ISSN 0360-5442, https://doi.org/10.1016/j.energy.2017.07.105

Kostova D., Gokarakonda S., Venjakob M., Thomas S. (2020): D2.2 Report on EPC best practices. QualDeEPC H2020 project. https://qualdeepc.eu/public-project-deliverables

Li Y., Kubicki S., Guerriero A., Rezgui Y. (2019): Review of building energy performance certification schemes towards future improvement. Renewable and Sustainable Energy Reviews, 113 109244

Maia I., Johannes N., Kranzl L. (2021): Description of current Energy Performance Certificates (EPCs) related policy framework in implementing countries. ePANACEA H2020 project. https://epanacea.eu/results/

Morsink-Georgali, P., Fokaides P., Radchuk O., Wagmeister S., Grün K., Altmann N., Nicole H., (2020): D1.1: Comparative assessment of current EPC schemes and relevant emerging performance paradigms v1. D2EPC H2020 project. https://www.d2epc.eu/en/project-results

Muhr L. (2021): Insights on user perceptions and needs regarding the Energy Performance Certificate (EPC). ePANACEA H2020 project. https://epanacea.eu/results/

Muhr L. (2022): Assessing user-friendliness of proposals for a new Energy Performance Certificate (EPC). ePANACEA H2020 project. https://epanacea.eu/results/

Panteli C., Duri M., Olschewski D., Klumbyte E., Delft A. (2021): D1.2: Next-generation EPC's user and stakeholder requirements & market needs v1. D2EPC H2020 project. https://www.d2epc.eu/en/project-results

Pasichnyi O., Wallin J., Levihn F., Shahrokni H., Kordas O. (2019): Energy performance certificates – New opportunities for data-enabled urban energy policy instruments. Energy Policy, 127, 486-499

Pomianowski M. (2020): EPC regional report. E-DYCE H2020 project. https://edyce.eu/wp-content/uploads/2021/01/E-DYCE_D1.1_EPC_regional_report_18.12.2020_Final.pdf

QualDeEPC (2019-2023). High-quality Energy Performance Assessment and Certification in Europe Accelerating Deep Energy Renovation. https://qualdeepc.eu/

REHVA and U-CERT project partners (2021): U-CERT - D2.1 Report on implementation of EPC schemes in U-CERT partner countries.

Schmatzberger S., Zuhaib S. (2020): D2.4: Understanding end-user needs and expectations of the Next-Generation Energy Performance Certificates scheme. X-tendo H2020 project. https://x-tendo.eu/toolbox/background-material/

Semple S., Jenkins D. (2020): Variations of energy performance certificate assessments in the European Union. Energy Policy 137, 111127

TIMEPAC (2021-2024): Towards innovative methods for energy performance assessment and certification of buildings. https://timepac.eu/

Tronchin L., Fabbri K. (2010): A Round Robin Test for building energy performance in Italy. Energy and Buildings 42 (2010) 1862-1877

Tronchin L., Fabbri K. (2012): Energy Performance Certificate of building and confidence interval in assessment: An Italian case study. Energy Policy 48, 176-184

U-CERT (2019-2022): Towards a new generation of user-centred Energy Performance Assessment and Certification; facilitated and empowered by the EPB Center. https://u-certproject.eu/

Volt J., Zuhaib S., Schmatzberger S., Toth Z. (2020): D2.1 Energy Performance Certificates: Assessing their Status and Potential. X-tendo H2020 project. https://x-tendo.eu/toolbox/background-material/

X-tendo (2019-2022): eXTENDing the energy performance assessment and certification schemes via a mOdular approach. https://x-tendo.eu/

X-tendo toolbox (2022): https://x-tendo.eu/toolbox/

Appendixes

Appendix A: Identification of the building climatic conditions

A.1 Climate data

To pair the project buildings under similar climatic conditions, we need to following information for each of your crossCert buildings:

- Heating Degree Days (HDDs) and Cooling Degree Days (CDDs) in the building location
- Global horizontal irradiation
- Annual average ambient temperature

This information should be included, for each of the crossCert buildings, in the corresponding columns of the shared gsheet, in the tab for your country:

https://docs.google.com/spreadsheets/d/1dzUmr9QKNz8bfPD-jDgwSz1dnrnKD5CNgOC4F-e4pg8/edit?usp=sharing

	Typology	Surface area, m2	Construction year	Building identificacion (eg address) and description	Data available?	Other comments	Annual HDDs	Annual CDDs	Weather station ID (used for HDDs/CDDs)	Average annual Global horizontal irradiation (kWh/m2)	Total annual Global horizontal irradiation (kWh/m2)	Average annual ambient temperature
0	Office	250	1927	City council, Mayorga de Campos	Yes (electricity and fuel consumption, hourly, 2019)	Building refurbished 2010. Solar panels installed 2019						
1												
2												

Also, please create a new subfolder of "Climate Data" inside your country folder in the shared folder:

02 WP2 Cross Assessing EPC Paradigms > crossCert Buildings

and include there the files that you will download from the webpages where the weather information is gathered (see instructions below).

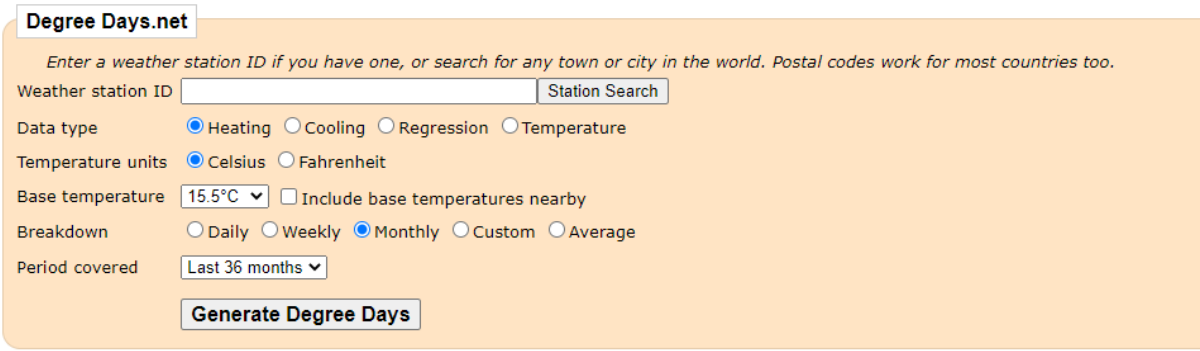
If more then one building is located in the same city/municipality, you only have to do it once per city/municipality

https://drive.google.com/drive/folders/13q0XUYFhpKuNVviGAnqrzxDujn4fCZqy?usp=sharing

For the weather data, if the data at the building location and the data that the EPC uses or would use are different (for instance, because your EPC procedure uses just a few standardised climates for the whole country), then please report both the climate data at the building site and data that the EPC uses or would use; you can duplicate the columns in the excel file. (This applies in particular to the UK.)

A.2 How to obtain HDDs and CDDs

For HDDs y CDDs, visit the website: https://www.degreedays.net/#

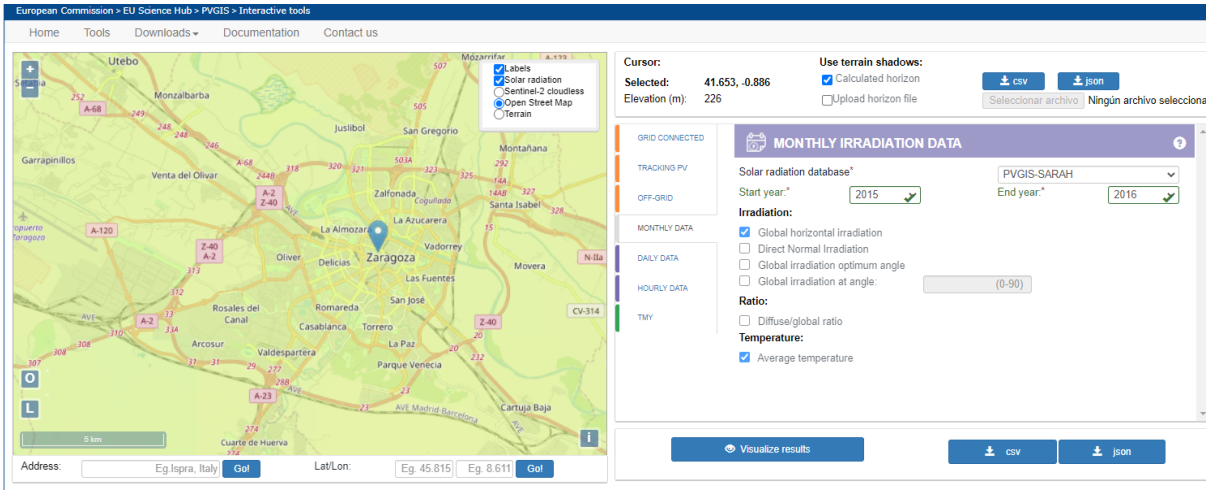


1. Select the weather station closer to the municipality where the building is located
2. Data type: heating for HDD and cooling for CDD
3. Temperature units: Celsius

4. Base temperature: 15.5ºC for heating degree days/ 28.5 ºC for cooling degree days
5. Breakdown > Monthly: This will calculate the accumulated HDD and CDD for each month
6. Period covered: Last 36 months: This will obtain the monthly total indicated above for the last 36 months
7. Generate Degree Days - an Excel file will be created - please upload it in the "Climate Data" folder
8. Then add up all the 36 months and divide by 3 to obtain the average HDDs/CDDs per year
9. Report this in the buildings gsheet

A.3 How to obtain solar irradiance levels

For solar irradiance levels, visit: https://re.jrc.ec.europa.eu/pvg_tools/en/#MR



1. Select the municipality where the building is located
2. Select Monthly data - PVGIS-SARAH
3. Start year 2015 ; End year 2016
4. Irradiation: Global horizontal irradiation
5. Temperature: Average temperature
6. Download results and provide in the buildings gsheet:
   a. Average annual ambient temperature (average of all months) (ºC) - you will obtain data for 2 years, do average of all
   b. Average annual Global horizontal irradiation (average of all months) (kWh/m2) - you will obtain data for 2 years, do average of all
   c. Total annual Global horizontal irradiation (adding up months in a year)(kWh/m2) - you will obtain data for 2 years, you will have add the months of each year and then do the average of both years
7. Please upload the downloaded files in the "Climate Data" folder

Appendix B: Country Neutral Data Inventory

Partner providing this data inventory		
Organisation	UNIZAR	
Person(s) filling the data inventory	Maria Herrando	
Date of last edit	03-mar-22	

IDENTIFICATION OF THE BUILDING OR PART OF THE BUILDING CERTIFIED		
		Notes
Name or identification label of the building	(ES) Music School	[Use a unique name or identifying label]
Address	Street ...	[If confidential, do not include here]
Postcode	50016	[If confidential, do not include here]
Municipality		
Province (if applicable)	Zaragoza	
Country	Spain	
Heating Degree Days (HDD)		
Cooling Degree Days (CDD)		

DESCRIPTION OF THE BUILDING ENERGY FEATURES		
Construction year	2005	
Type of building or part of the building that is certified:		
Habitable area [m2]	512.74	
Conditioned area [m2]	512.74	

ENVELOPE - WALLS, ROOF AND FLOOR

Name of the wall	Type	Area [m2]	Total or net wall area	Thermal transmittance (U-value) [W/m2·K]	Orientation	How data was
Cubierta Plana	Roof	64.95	Total wall area	0.51		
Muro enterrado Planta Sótano Norte	Wall	31.48	Total wall area	0.52		
Muro enterrado Planta Sótano Este	Wall	27.68	Total wall area	0.52		
Muro enterrado Planta Sótano Oeste	Wall	20.41	Total wall area	0.52		
Muro de fachada Planta Baja Este	Wall	39.96	Total wall area	0.47		
Medianería Planta Baja	Wall	95.03	Total wall area	0.00		
Muro de fachada Planta Primera Este	Wall	36.54	Total wall area	0.47		
Muro de fachada Planta Primera Oeste	Wall	31.03	Total wall area	0.47		
Medianería Planta Primera	Wall	68.96	Total wall area	0.00		
Muro de fachada Planta Segunda Este	Wall	36.54	Total wall area	0.47		
Muro de fachada Planta Segunda Oeste	Wall	31.03	Total wall area	0.47		
Muro de fachada Planta Segunda Norte	Wall	31.73	Total wall area	0.47		
Medianería Planta Segunda	Inner Partition	37.24	Total wall area	0.00		
Partición vertical Planta Sótano	Inner Partition	43.79	Total wall area	1.44		
Partición vertical Planta Baja	Inner Partition	9.28	Total wall area	1.44		
Partición vertical Planta Primera	Inner Partition	9.28	Total wall area	1.44		
Partición vertical Planta Segunda	Inner Partition	9.28	Total wall area	1.44		
Suelo con terreno	Floor	119.35	Total wall area	0.32		

Notes

Some EPC methods might ask for wall area with window area already subtracted, while other methods might just want the "width x height" area of the wall, and then subtra

Please specify whether:

- the wall area state includes windows area --> select total wall area
- the wall area state DOES NOT include windows area --> select net wall area

HVAC SYSTEMS

Name	Demand satisfied	Type of system	Nominal power [kW]	SCOP (Seasonal Coefficient Of Performance [-]	Energy source	How data was obtained	Comments
Heating and DHW system	Heating and DHW system	Standard Boiler	58.2	0.644	Natural gas	Estimated	
Air conditioning ssytem	Cooling-only system	Air Conditioning	126.6	1.27	Electricity	Estimated	
	Heating-only system						
	DHW system						
	Heating-only system						

VENTILATION AND PUMPING

Name	Type of system	Associated	Energy consumption [kWh/year]	How data was obtained	Comments
VENTILADORES CALEFACCION - 16 CLIMATIZADORES	Constant flow-rate ventilation	Heating	42788.9	Known	
VENTILADORES REFRIGERACION - 16 CLIMATIZADOR	Variable speed pump	Cooling	50346.4	Known	
2 BOMBAS CALEFACCION SALA CALDERAS	Constant flow-rate pump	Heating	5436	Known	
2 BOMBAS REFRIGERACION AZOTEA	Variable speed pump	Cooling	15408	Known	

Others

Domestic Hot Water (DHW) demand (litres/day)	120
Ventilation and infiltrations (renewals/hour)	0.08

Notes

SCOP not needed for ventilation services

Type of system not needed in ventilation if not in the list

Log and notes | General info | Envelope - walls, roof, floor | Envelope - windows, thermal bri | HVAC systems; DHW, infiltration | Lighting System | In ...

LIGHTING SYSTEM

Name	Installed power [W/m2]	VEEI [W/m2·100lux] (value of energy efficiency in installations)	Average maintained illuminance [lux]	How data was obtained
Edificio Objeto	8.89	5.56	160.00	Estimated

INTERNAL HEAT GAINS/ INTERNAL LOADS

Room/area	Area [m2]	Internal heat gain [W/m2]
Edificio	512.74	6

Notes

Internal heat gain refer to heat released due to occupants and equipment

Please let us know if internal heat gains are introduced differently, for example, working hours per day, etc. (mherrando@unizar.es)

RENEWABLE ENERGIES

Thermal energy

Name	Final Energy Consumption covered for each energy demand [%]			Comments
	Heating	Cooling	DHW	
Solar thermal				
Biomass boiler				
TOTAL				

Electricity

Name	Final Energy Consumption covered [%]	Comments
PV panels		
TOTAL		

Notes

Please let us know if renewable energies are introduced differently (mherrando@unizar.es)

Appendix C: Country Neutral Result Report

IDENTIFICATION OF THE BUILDING OR PART OF THE BUILDING BEING CERTIFIED			
Uniue name of the building	(ES) School of music		[Same name as in Neutral Data Inventory]
Type of building or part of the building that is certified:			
BUILDING ENERGY LABEL IN PRIMARY ENERGY			
Primary energy consumption	[kWh/m2·year]	Energy label	
TOTAL	315.03	F	
Breakdown of primary energy per use	[kWh/m2·year]	Energy label	
- Heating	144.06	F	
- Cooling	112.26	G	
- Domestic hot water (DHW)	0.62	D	
- Lighting	58.09	B	
BUILDING ENERGY LABEL IN CO2 EMISSIONS			
CO2 emissions	[kgCO2/m2·year]	Energy label	
TOTAL	71.63	D	
Breakdown of CO2 emissions	[kgCO2/m2·year]	Energy label	
- Heating	29.10	D	
- Cooling	27.91	G	
- Domestic hot water (DHW)	0.12	C	
- Lighting	14.5	B	
BUILDING ENERGY LABEL IN ENERGY DEMAND			
	[kWh/m2·year]	Energy label	
Heating demand	91.86	E	
Cooling demand	65.52	B	
DESCRIPTION OF THE BUILDING ENERGY FEATURES			
Habitable area [m2]	512.74		
Conditioned area [m2]	512.74		

General info ENERGY LABEL | Energy efficiency measures | DATABASE-DoNotTouch

RECOMMENDATIONS TO IMPROVE THE ENERGY EFFICIENCY

				After the application of the measure					
Description of the measure	Indicative costs (€)	Economic savings	Payback (years)	Total CO2 emissions [kgCO2/m2·year]	Total primary energy consumption [kWh/m2·year]	Heating Demand [kWh/m2·year]	Cooling Demand [kWh/m2·year]	New energy label [specify if based on Primary Energy or CO2 emissions]	Comments
Replacement of glass with solar control				35.29	300	95.28	45.63		

Appendix D: EPC Generator Experience Report - Suggested contents items

Note on terminology: "visitor" refers to the country/partner/team whose buildings are tested under the EPC protocols of another country. "Home" refers to this country/partner/team whose EPC protocols are being used on the buildings.

The EPC Generator Experience Report is a report issued by a visiting partner, that is, the partner who is testing its C-ensemble buildings under the EPC protocols of another crossCert country (the home country).

The report is therefore produced by the visiting partner, with the assistance as needed of the home partner, for instance in respect of language aspects. There is no need to supply a report for each building, unless the visiting partner prefers to do so; otherwise a single report covering all the experience in the home country suffices.

The report is largely qualitative in nature, with particular emphasis on people-centred aspects. Comparisons with EPC protocol in the partner's own country in respect of usability, robustness, clarity and quality of output are particularly welcome.

Below are some suggestions of items to consider for this report. The list is not exhaustive, and partners should include any additional relevant information.

Output comparison

1. Briefly compare the numerical results of the EPC for each building in the away country and in your own country. Do the figures make sense, considering the possible climate differences among both locations?
2. Briefly discuss the building energy improvement measures offered by the EPC. Does the EPC procedure/software suggest building energy improvement measures? If it does:
    a. Does the EPC provide a list of possible measures, tailored to the EPC results, or is it left to the EPC issuer to suggest possible measures?
    b. Does the EPC protocol/software provide the modified performance results if the measure is applied (for instance, new energy consumption, new CO2 emissions, new energy rating) if the measure is applied?
    c. Does it provide economic indicators, such as investment costs or payback period?
3. Does the EPC allow for the inclusion of contributions from renewable sources (RES)?

People-centred aspects

4. How easy-to-use is the EPC procedure/software in your visiting country compared to your own country, **for the person issuing the certificate**? Are there aspects that could be usefully imported to your country's EPC, or vice versa?
5. How people-centred is the EPC report in your visiting country compared to your own country, **for the building owner**? Is the information complete and easy to interpret by the building owner? Are there aspects that could be usefully imported to your country's EPC, or vice versa?
6. What is your perception of the EPC data-input requirements, compared to EPC procedures in your own country? For instance, is data input unduly demanding or tedious, e.g. because of redundancies? Are there meaningful default values where appropriate? Are there any significant input-data gaps that should be redressed?

Robustness

7. Did any significant doubts arise regarding data input, such as the precise meaning of an input parameter? If so, were they easily and unequivocally resolved? List any potential sources of loss of robustness. Some sources of uncertainty are (see Jenkins et al, 2017, for details): The efficiency ratings of roofs, windows, walls; the total floor area; the efficiency of lighting, heating, hot water systems.
8. Comment on your perception of the robustness of the home country EPC procedure, particularly compared with EPCs in your own country. To this aim, we can define robustness as the likelihood that two people performing the EPC from scratch, i.e. having to collect the data for the building, would get the same output results.

Convergence

9. Indicate other aspects from the home country's EPC procedure that could be usefully included in the EPC procedure for your country
10. Indicate other aspects from your country's EPC procedure that could be usefully included in the EPC procedure for the home country.