crossCert
Next-generation of Energy Performance Assessment and Certification

D3.2 Performance gap causation

Task 3.1 Performance gap assessment

WP3 Deriving technical Guidelines for EPCs

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Date: 03/08/2023

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	**Performance gap causation**
Deliverable	D3.2
Responsible Partner	Heriot-Watt University
Contributors	
Reviewers	UNIZAR
Work Package	WP3
Task	3.1
Version	2.4
Version date	03/08/2023
Type of deliverable	R/DEC/ORDP

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

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EXECUTIVE SUMMARY

This report takes the Energy Performance Certificate (EPC) methodologies of nine different European countries, across 65 tested buildings, to investigate how the modelled energy consumption compares with real, measured energy consumption of those same buildings. Each individual building is modelled with the local EPC methodology and compared with metered energy consumption, converting the EPC output to a parameter that allows for this comparison where required.

The study demonstrates the challenges in comparing different methodologies, with different metrics and frameworks, particularly across relatively small samples of buildings. However, the 65 case-study buildings do indicate how previously discussed differences in methodologies can be seen when those methodologies are applied to real buildings.

Using real energy consumption values as an effective target for those methodologies – and therefore calculating a Performance Gap for each building – is an approximation of "success" for those different approaches of generating an EPC. However, as discussed in the report, this Performance Gap should not be seen as an absolute measurement for EPC effectiveness, with EPCs not designed to account for meaningful occupancy behaviour in individual buildings. Conclusions must therefore be guided by contextual data and further modelling results, as being explored in the crossCert project.

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1 Introduction

The Performance Gap (Bordass, 2013) is a well-used term in building modelling to describe the difference between the modelled and measured energy consumption of a building, usually based on a year of final energy consumption data (kWh/yr). It is used across many different forms of building modelling as a measure of accuracy or effectiveness of that model, and whether it is describing a building appropriately.

Although a seemingly obvious way of judging the suitability of a modelling method (i.e. how close to reality it is), the Performance Gap can be problematic when used as a test of energy compliance methods. Building modelling approaches with a high degree of standardisation, particularly around inputs such as occupancy and weather data, are intentionally not attempting to model a building under conditions that match those experienced during a specific year of measured energy consumption data. However, when carrying out a comparison of EPC methods across Europe, it could be argued that variations in Performance Gap, combined with a knowledge of factors that might cause such a gap, is a useful part of such a comparison providing it is qualified with limitations of such an analysis.

The crossCert project is attempting to understand how EPC methods differ across chosen European countries, what causes these differences, and whether this has implications for designing new innovations for next-generation EPCs. Informed by a previous crossCert report (Sayfikar and Jenkins, 2022) that documents these differences and building data provided by crossCert project partners, this report uses Performance Gap calculations to illustrate numerical differences that come from selected EPC methodologies. Furthermore, the report documents the difficulties in comparing measured and modelled energy consumption data in a fair and appropriate way – particularly when attempting to do so consistently for different buildings, different EPC methodologies, and different approaches to measuring energy consumption.

Following an overview of already noted differences in how crossCert project partner countries conduct and calculate EPCs, the numerical Performance Gap calculations of a small sample of buildings are presented. An analysis is then provided that discusses whether there are tangible links between these known differences in EPC approaches and how the different methods perform when compared with measured energy consumption data.

2 Methodology

2.1 Data collection

In order to study the performance gap, the information provided by the partners in the local ensemble (referred to as "L-buildings" in the crossCert project) are used. For L-buildings, the EPC certificate as well as any available measured energy data is provided by the relevant partner country and these values are compared against each other. The results of these comparisons are recounted in reports which form the basis of this deliverable. In addition to these reports, all partners were asked to provide a list of all of their buildings where measured energy data was available (regardless of building categories). For consistency purposes, the partners were asked to provide final energy consumption values in addition to the primary energy values provided in the L-building reports.

When comparing actual energy consumption to EPC results, it is important to note the differences in the metrics used on the EPC certificate in each country. Comparing the EPC certificates of different partner counties (Table 8) shows different metrics are used for reporting EPC calculation results. While some countries only provide the primary energy consumption, or carbon emission values, others provide more detailed information including total final energy consumption and carbon emissions as well as consumption values for various building services such as heating, cooling, and lighting. For countries where final energy values are provided on EPC certificates, it is possible to make direct comparisons against measured data, however for countries where only primary energy consumption or carbon emissions are reported, the comparison is less accurate. Although it is possible to calculate the primary energy consumption and carbon emissions from the measured values using primary energy and emission factors for each country, care must be taken to use the same values which were employed in the EPC calculations. These values usually tend to change over time due to decarbonization efforts in each country's energy infrastructure. For example, in the UK, the primary energy and emission factors provided in the National Calculation Methodology (NCM) in the 2015 version was 1.22 kWhPE(Primary Energy)/kWh and 0.216 kg CO2/kWh for natural gas and 3.07 kWhPE/kWh and 0.519 kg CO2/kWh for grid supplied electricity, respectively (NCM, 2015). However, these values were changed in the 2021 version to 1.126 kWhPE/kWh and 0.210 kg CO2/kWh for natural gas and an average value of 1.513 kWhPE/kWh and 0.138 CO2/kWh for grid supplied electricity, respectively (NCM, 2021).

As can be seen from Table 1 and Appendix A, most countries provide final energy values on their EPCs, making direct comparison possible. However, the EPC certificates in Scotland only include the primary energy consumption, non-residential EPCs in England and Wales only include the annual CO2 emissions value, and EPCs in Malta only include primary energy consumption and CO2 emissions. In order to study the performance gap for the non-residential L-buildings in England, the measured energy consumption values were converted to carbon emissions using the emission factors provided in NCM 2015 (NCM, 2015). For Maltese buildings, the detailed calculation results (not included in the certificate) which included the final energy values were provided by the partners which were used in comparisons against measured energy consumption. For the Danish L-buildings, only the measured energy consumption for heating was available. These values were compared against the corresponding values on the EPC certificates.

Table 1- Metrics provided in each country's EPC.

Austria residential	Final energy consumption for heating and hot water demand, total final energy, total primary energy, CO2 emissions
Austria non-residential	Final energy consumption for heating, cooling demand, hot water demand, lighting, and humidification, total final energy, total primary energy, CO2 emissions
Bulgaria	Final energy consumption for heating, ventilation, cooling, hot water, lighting, and auxiliary electricity, total final energy, primary energy, CO2 emissions
Croatia	Final energy consumption for heating and cooling, total primary and final energy consumption, CO2 emissions
Denmark	Final energy consumption for heating, and electricity for building operation
Greece	Final energy consumption for heating, cooling demand, hot water demand, and lighting, total final and primary energy disaggregated by fuel type, CO2 emissions
Malta	Primary energy consumption, CO2 emissions
Poland	Final energy consumption for heating, cooling demand, hot water demand, and lighting, total final energy, total primary energy, CO2 emissions
Slovenia	Final energy consumption for heating, ventilation, cooling, hot water, lighting, and auxiliary electricity, total final energy, primary energy, CO2 emissions
Spain	Primary energy consumption and CO2 emissions for heating, cooling demand, hot water demand, and lighting, Final energy for heating and cooling, total primary energy and CO2 emissions
UK non-residential (Scotland)	Primary and final energy consumption, CO2 emissions
UK residential (Scotland)	Primary energy consumption, annual cost rating

Rest of the UK non-Residential	CO2 emissions
Rest of the UK Residential	annual cost rating, Final energy consumption for heating and hot water

3 Sources of the performance gap

When comparing EPCs to measured energy data, it is important to note that the main objective of EPCs is to use normative metrics for facilitating comparison between different buildings rather than accurately reflecting the actual building (Summerfield et al., 2019). To achieve this goal, many aspects of building operation are simplified or standardized during an EPC calculation. Therefore, when comparing performance gaps between different countries, taking into account the differences between countries approaches to such inputs, as well as other differences such as the energy categories considered in calculations is crucial. These differences are highlighted in detail in other project deliverables D2.4 (Fueyo and Herrando, 2022), D3.1 (Sayfikar and Jenkins, 2022) and D2.5 (Gómez, 2022). A summary of the important aspects that could impact the performance gap are included in this section. Understanding these differences are important for placing the results of Section 4 into a wider context, and as a reminder that the EPC approaches across countries can be fundamentally different.

3.1 Energy categories

When comparing the EPC energy consumption values to measured data, it is important to note that the categories of energy consumption included in the calculation of EPCs are not similar in all countries. The Annex I of the revised EPBD published in 2018 (EPBD, 2018) states that the energy performance of a building "shall reflect typical energy use for space heating, space cooling, domestic hot water, ventilation, built-in lighting and other technical building systems", where "technical building systems" refers to any technical equipment used for the purposes of space heating, space cooling, ventilation, domestic hot water, built-in lighting, building automation and control, or on-site electricity generation. However, comparison between the studied methodologies shows some differences in countries' approaches. While all the studied countries include heating, domestic hot water (DHW) and ventilation in their EPC calculation, inclusion of cooling and lighting energy consumption tends to vary. In addition, none of the crossCert countries (except for Bulgaria) include energy consumption of electrical equipment in their calculations, whereas these values are included in the measured energy data unless a building is equipped with submetering equipment.

Lighting is included in EPC calculation of non-residential buildings in all countries. But for residential building assessments, it is not included in Polish and Spanish methodologies, and for Danish buildings only the lighting in communal spaces in multi-family residential buildings is included in calculations. For cooling energy consumption, the approach is similar to lighting, where it is included in non-residential buildings' calculations in all of the studied methodologies. However, for residential buildings cooling is not included in calculations in UK and Austrian methodologies.

3.2 Building zones

The ability to use zoning in the EPC software is an indicator of the level of details required during the assessment and provides insight into the overall approach of a methodology. Dividing a building into multiple zones allows for a more detailed and accurate analysis, which is closer to the actual building usage. On the other hand, it increases the number of inputs which can make the EPC issuing process more time consuming and increase the potential of human errors which could be a source of the performance gap.

Criteria used by different methodologies for dividing the building into various zones include temperature set points, HVAC systems, type of activity, and significant differences in heat loss or heat gains (e.g., south facing rooms). Comparing the methodologies in different countries shows that all countries allow zoning for non-residential buildings, whilst treating residential buildings as single zone spaces. However, EPC methodologies of Greece, Spain, Poland and Bulgaria allow the assessor to divide residential buildings into multiple zones as well, which is an option rarely used by the assessors.

3.3 Calculation inputs

One of the possible causes of the performance gap is the level of simplification of EPC calculation inputs. In some countries, in order to facilitate the process of issuing EPCs, databases of default values for various parameters such as thermal bridges, building envelope U-values, infiltration and ventilation rates, system efficiencies, etc. are provided and are commonly used by assessors. Using default values instead of performing measurements on-site or using manufacturer documents can lead to EPC results which don't reflect the actual building accurately.

In addition, input parameters such as occupancy, equipment/lighting and HVAC schedules, and temperature setpoints are treated differently in each methodology. Some countries use standardised representations for these parameters whereas others use values closer to the actual building operation. These inputs are highly dependent on occupants and can have considerable impacts on the EPC assessment results. Using standardised inputs for such parameters can serve the comparative purposes of EPCs, as well as harmonizing the results of different assessments of the same building, while potentially creating larger performance gaps.

This section summarizes the differences in how crossCert partner countries approach the calculation inputs and categorises country methodologies.

3.3.1 Building envelope U-values

Thermal transmittance of materials (i.e., U-values) and other similar characteristics of building fabric are usually either calculated by the EPC software using a library of commonly used materials or taken from databases of default values for common structure types in a country. It is worth noting that these libraries and databases are specific to each country, therefore identical material might have different values in each country. In most of the partner countries, if enough data is available, the assessor uses the software to calculate these values based on the information they collected during a site visit, using building drawings, or other documents such as wall construction certificates (in the case of Denmark).

For most countries, a database of commonly used wall, roof and floor constructions as well as U-values and G-values for windows is implemented in the calculation software. Exceptions are Bulgaria and the methodology for residential buildings in Malta, for which there is no database implemented in the national software and assessors must calculate U-values separately using information from other official resources and enter the results into the software.

Some countries also allow estimating the thermal transmittance of the building envelope using general information about the building, such as building age or use-type. Spain and UK use such a feature for existing buildings, which infers values based on the building sector, climate zone and the building regulations that were in use at the time of construction.

Table 2- Countries' approaches to U-values

U values	
No default values, only calculated based on the actual building fabric	Malta (residential)
	Bulgaria
Default values based on construction type or inferred using building characteristics	Austria
	Croatia
	Denmark
	Greece
	Malta (non-residential)
	Poland
	Slovenia
	Spain
	UK

3.3.2 Infiltration and ventilation rates

Infiltration rate is also an important input which could affect the performance gap in EPC models and is linked to the building fabric and opening types. The EPC methodologies of most countries require the assessors to perform a pressure test at 50 Pa to measure the infiltration rate (Austrian Standards, 2019, Dansk Standardiseringsrad (DS), 2020, PIS, 2014, Official Gazette of the Republic of Slovenia, 2019, BRE, 2020, BRE, 2012a, BRE, 2012b). Similar to the U-values, in the absence of a measured value, some methodologies provide default values based on certain building characteristics. For example, the default infiltration rates in the Austrian methodology depend on the building type, whereas in the Danish methodology they depend on the level of weatherproofing of the building (The Danish Energy Agency, 2021). The Polish methodology determines the default infiltration value depending on whether a building was built before or after 1995. In some countries it is possible to infer infiltration rates from building age. Greece, Malta, Spain and UK methodologies provide default values based on building age. For the UK, this only applies to existing buildings, and it is mandatory for the assessor to measure the infiltration rate on-site for new buildings. In the Bulgarian methodology, assessors use infiltration rate values based on their experience, and adjust these values by calibrating the model against actual energy consumption data.

Comparing countries' approaches to ventilation rates shows that most countries provide databases in their software with default minimum values for different activity types. Bulgaria, however, doesn't provide default values for ventilation rates and requires the assessor to use system design values or measure the ventilation rates on-site using a thermo-anemometer. Although, this is usually not the case in practice, mostly due to the low cost of EPC assessments, and similar to infiltration rates, most assessors use values based on their experience and make the necessary adjustments during the calibration step.

Table 3- Countries' approaches to Infiltration rates

Infiltration rate	
No default values/ or only measured values allowed	UK (new buildings)
	Bulgaria
default values	Austria
	Croatia
	Denmark
	Greece
	Malta
	Poland
	Slovenia
	Spain
	UK

3.3.3 Temperature setpoints

Temperature setpoints have a direct impact on the energy consumption results, and in turn the performance gap. All of the studied countries apart from Bulgaria use default temperature setpoints for EPC calculations. However, these setpoints are different across different countries, mostly due to the country specific norms of temperature settings in buildings. Default temperature setpoints are generally defined in a static way; and for some countries don't change between cooling or heating seasons. In Bulgaria, although the official EPC methodology doesn't include default setpoints, there are reference values provided for various building use-types in national ordinances that are commonly used by assessors.

For non-residential buildings, it is common to link the setpoints to activity types, which is the case for Greece, Malta, Poland, Slovenia and UK. Greece sets the default values based on the building use-type. Slovenia, Malta, and the UK define different setpoints for each zone activity type such as offices, circulation areas, etc. Poland uses a similar approach, but instead of specific activity type, the default values are based on the level of physical activity (seated, standing, walking) and clothing type. Denmark uses a different approach where temperature setpoints are linked to building controls instead of activity type, and Spain and Austria use fixed heating and cooling setpoints regardless of activity. Bulgaria doesn't provide default values in the EPC methodology and leaves it to the assessor's discretion, however there are national ordinances for reference temperature settings in buildings such as workplaces that are commonly used by assessors in calculations.

For residential buildings, some countries use a fixed value for all seasons (Austria and Denmark) which could contribute to higher performance gaps compared to others which use different setpoints for cooling and heating seasons (Greece, Malta, Poland, Slovenia, Spain, UK).

Table 4- countries' approaches to temperature setpoints

<table>
<tr><th colspan="2">Non residential</th><th colspan="2">Residential</th></tr>
<tr><td>No default values</td><td>Bulgaria</td><td>No default values</td><td>Bulgaria</td></tr>
<tr><td rowspan="3">Default values, less detailed</td><td>Spain</td><td rowspan="3">Default values fixed all year</td><td>Austria</td></tr>
<tr><td>Denmark</td><td rowspan="2">Denmark</td></tr>
<tr><td>Austria</td></tr>
<tr><td rowspan="6">Default values based on activity type</td><td rowspan="2">Greece</td><td rowspan="6">Default values different for cooling/heating season</td><td>Greece</td></tr>
<tr><td>Malta</td></tr>
<tr><td>Malta</td><td>Poland</td></tr>
<tr><td>Poland</td><td>Slovenia</td></tr>
<tr><td>Slovenia</td><td>Spain</td></tr>
<tr><td>UK</td><td>UK</td></tr>
</table>

3.3.4 Occupancy schedules

Internal heat gain is an important factor in calculating heating and cooling demands which can affect the EPC rating of a building. Therefore, comparing how internal heat gains (i.e., occupancy, lighting, and electrical appliances) are defined in each methodology can provide valuable insights for studying the performance gap. In addition to affecting the internal heat gains, HVAC and lighting operation profiles can directly change the energy consumption results of the model and should be considered in any comparison of EPC methodologies. It is here that the fundamental difference between a standardised model (intentionally simplifying building occupancy) and real building energy consumption (betraying real choices by individual occupants in a specific building) is particularly apparent.

Most of the studied countries use pre-defined profiles in their EPC calculation methodologies in order to standardize and facilitate better comparison between buildings. Assessors must use these profiles in order for the EPC to be valid. Exceptions to this approach are Bulgaria, Poland and Slovenia. Bulgaria and Poland don't provide standard profiles and leave it up to the assessor to collect the necessary information during site-visits or use their own professional judgement, whereas Slovenia provides default schedules for various activities but allows the assessor to override these and use customized profiles based on the actual building activity. Spain also allows the assessor to use tailored schedules for HVAC operation, but only for non-residential buildings. Even though such approaches could lead to results closer to the actual building operation, hence a smaller performance gap, they might also lead to variations in assessment results even for the same building when assessed by different assessors or during different times, rendering EPCs less consistent and standardised for that country.

Since the calculation methodologies of most of the studied countries are steady state, the exact timing of occupancy or system operation does not directly affect the results. Therefore, in most methodologies, occupancy and system operation profiles are defined in terms of a fixed number of hours in a typical day (sometimes different between weekdays and weekends, and heating and cooling season). These numbers vary across different countries as well which affects the results, leading to difference in performance gaps. For example, public buildings are assumed to be occupied for 8 hours per day in Poland, whereas in Denmark this value is 9 hours. Another example is the variations of the HVAC operation profiles for residential buildings across different countries. In the Spanish methodology, the HVAC system operates from 7 AM to 11 PM from October to May and from 3 PM to 11 PM from June to September. Whereas Malta assumes the HVAC system to run from 6 to 8 AM and 5 to 11 PM. The UK methodology assumes the heating schedule to be between 7 to 9 AM and 4 to 11 PM on weekdays and 7AM to 11PM for weekends and a uses a standard cooling schedule of 6 hours/day. Slovenia and Denmark both assume 24-hour HVAC operation all year round.

Some countries provide more detailed profiles for non-residential buildings which are also suitable for using in dynamic simulation. This is the case for the UK and Spanish methodologies which have dynamic simulation options in their methodologies. The UK's National Calculation Methodology (NCM) (BRE, 2020) provides different hourly profiles for occupancy, lighting, HVAC operation and electrical equipment operation based on zone activity type for non-residential buildings. The Spanish methodology divides all building types into 8hr, 12hr, 16hr and 24hr operation times and provides the default profiles for each type. It is worth mentioning that in the Spanish methodology, it is not possible to define different profiles for each zone separately, and the operation profiles apply to all zones in the building.

Table 5- Countries' approaches to schedules

Type of schedules	
No standard schedules	Bulgaria
	Poland
Standard schedules-not mandatory	Spain
	Slovenia
Standard schedules- mandatory	Austria
	Croatia
	Denmark
	Greece
	Malta
	UK

3.3.5 HVAC systems

For defining HVAC equipment, most countries take a similar approach by requiring the assessor to collect information regarding system efficiency parameters such as the Coefficients of Performance (COP), EER (Energy Efficiency Ratio), and SEER (Seasonal Energy Efficiency Ratio) using manufacturer documents or equipment nameplates. Some countries require more detailed inputs, for example for defining boilers, in addition to the system efficiency; Slovenia requires the heating power at 30% operation, the efficiency at 30% operation, and the heat loss in standby mode.

In the absence of the required information, different countries provide assessors with different options. Austria, Denmark, Greece (Technical chamber of Greece, 2012), Malta (only for non-residential buildings), Poland (Rozporządzenie Ministra Infrastruktury I Rozwoju, 2015), Slovenia, and the UK provide default values in the software or in a separate database which can be used in the calculations instead of the actual values. These values are selected based on system type, range of system power, or device manufacturing date. However, this is not the case in all countries. For Bulgaria, if manufacturer data isn't available, the assessor should use instruments to measure device performance on-site. It is also mandatory to perform on-site measurements for any equipment with capacities over 70 kW. Also, for the countries studied, only Spain allows using default parameters in cases where the installed HVAC system doesn't meet the necessary setpoint temperatures, for example in older buildings with no installed heating systems.

Table 6- Countries' approaches to HVAC system parameters

HVAC performance parameters	
No default values- only actual values allowed	Bulgaria
	Spain
Default values	Austria
	Croatia
	Denmark
	Greece
	Malta
	Poland
	Slovenia
	UK

4 Numerical analysis

Table 7 shows the performance gap calculated for 65 buildings (anonymised but associated with country-specific identifiers) for which measured annual energy data is available. As mentioned in previous sections, for Danish buildings, only the measured heating energy consumption is available which has been used for comparison. Also, since UK4 is certified using the UK methodology for England and Wales, only carbon emissions data is available on the EPC certificate, which was compared to the calculated carbon emissions using the measured energy data.

Based on the results in Table 7, the performance gap values range from 0.77% to 859%, showing a wide range of variation. Out of the 65 buildings, for 37 buildings (57%) the performance gap is negative, meaning that the EPC overestimates the energy consumption values, while for the rest of the buildings the EPC underestimates these values. *Figure* 1 clearly shows the variations of the performance gap for the case study buildings (where the level of standardisation of each method has been judged based on a previous review by the project (Sayfikar and Jenkins, 2022).

Table 7- Performance gap values

	Code	Building type	Measured total final energy consumption [kWh/m2/year]	EPC result final energy consumption [kWh/m2/year]	Gap (%)	Country
1	GR100	Educational	207.8	183.8	11.550	Greece
2	GR101	Single family house	170.4	124.5	26.937	Greece
3	GR102	Healthcare building	194.2	222.4	-14.521	Greece
4	GR103	Single family house	232	621.9	-168.060	Greece
5	GR104	Retail building	45.2	86.7	-91.814	Greece
6	GR105	Multi-Apartment building	67.4	40	40.653	Greece
7	GR106	Single family house	87	310.7	-257.126	Greece
8	GR107	Retail building	28.3	271.5	-859.364	Greece

9	GR108	Single family house	198.3	154.1	22.289	Greece
10	DK3[1]	Single family house	160.2252747	162.5	-1.420	Denmark
11	DK5[1]	Terraced house	68.94308943	88.61788618	-28.538	Denmark
12	DK11[1]	Multi-apartment Building	104.8389631	128.5938727	-22.658	Denmark
13	DK12[1]	Multi-apartment Building	97.45535714	122.7827381	-25.989	Denmark
14	DK13[1]	Public building for education	57.91638627	75.30114401	-30.017	Denmark
15	DK14[1]	Single family house with business area	114.1664089	74.45097433	34.787	Denmark
16	DK15[1]	Single family house with business area	120.4119241	119.5392954	0.725	Denmark
17	DK16[1]	Multi family building	85.53663571	134.9226006	-57.737	Denmark
18	DK17[1]	Public Community Hall	125.3578928	102.7702703	18.019	Denmark
19	DK18[1]	Public Community Hall	59.91570074	58.29293994	2.708	Denmark
20	DK201[1]	Single family building with business area	142.3684211	115.5789474	18.817	Denmark
21	DK21[1]	Single family building with business area	124.2095238	109.4603175	11.874	Denmark
22	DK22[1]	Single family building with business area	114.6245059	128.2806324	-11.914	Denmark
23	DK23[1]	Multifamily building with business area	92.32676056	140.7605634	-52.459	Denmark
24	DK24[1]	Commercial building	34.99835255	71.14332784	-103.276	Denmark
25	ES01	Educational	70.85	645.25	-810.78	Spain
26	ES02	Educational	31.17	42.29	-35.675	Spain
27	ES03	Office	132.4	162.28	-22.568	Spain
28	ES13	Sports hall	114.69	315.73	-175.290	Spain
29	ES15	office	65.5	109.82	-67.664	Spain
30	ES17	healthcare	8.03	30.6	-281.071	Spain
31	ESR2	Educational	74.22	134.08	-80.652	Spain
32	ESR3	Social Housing	152.57	439.24	-187.894	Spain
33	ESR4	Social Housing	170.29	443.73	-160.573	Spain
34	ESR5	Social Housing	189.59	395.92	-108.830	Spain
35	HR-3	Educational	103.83	55.54	46.509	Croatia
36	HR-6	Educational	72.6	77.29	-6.460	Croatia
37	HR-10	Community/Public assembly buildings	45.3	154.86	-241.854	Croatia

38	HR-11	Educational	86.78	49.21	43.293	Croatia
39	HR-12	Educational	147.98	192.4	-30.018	Croatia
40	HR-20	Healthcare buildings	183.08	80.34	56.118	Croatia
41	PL-2	Office	30.98	28	9.619	Poland
42	MT-01	Single family house	54.97	33.46	39.130	Malta
43	MT-10	Office	30.37	108.48	-257.195	Malta
44	MT-03	Terraced house	26.28	114.92	-337.291	Malta
45	MT-12	Non-residential	47.83	92.83	-94.083	Malta
46	SI-1	Educational	37	111	- 200.000	Slovenia
47	SI-2	Educational	145	305	-110.345	Slovenia
48	SI-3	Educational	133	116	12.782	Slovenia
49	SI-4	Educational	313	362	-15.655	Slovenia
50	SI-7	Educational	95	87	8.421	Slovenia
51	UK1	Educational	137	265.88	-94.073	UK
52	UK2	Educational	32	92.308	-188.463	UK
53	UK4[2]	Educational	51.41	19.92	61.253	UK
54	UK22[3]	Single family house	139.99	151	-7.865	UK
55	UK23[3]	Single family house	247.44	346	-39.832	UK
56	BG08	Office	187.01	147.21	21.282	Bulgaria
57	BG1	Multi-apartment Building	57.41	159.8	-178.349	Bulgaria
58	BG2	Multi-apartment Building	60.39	87.8	-45.388	Bulgaria
59	BG3	Multi-apartment Building	86.99	159.9	-83.814	Bulgaria
60	BG4	Single family house	321.95	131.69	59.096	Bulgaria
61	BG5	Public entertainment building	14.77	127.4	-762.559	Bulgaria
62	BG6	Administrative building	98.36	208.5	-111.976	Bulgaria
63	BG7	Administrative building	33.94	34.2	-0.766	Bulgaria
64	BG9	Educational building	64.85	83.9	-29.375	Bulgaria
65	BG10	Educational building	28.88	210.3	-628.186	Bulgaria

Lowest performance gap — Highest performance gap

[1] Heating energy consumption (kWh/m^{2}year)

[2] Carbon emissions (kgCO_2/m^{2}year)

[3] Primary energy (kWh/m^{2}year)

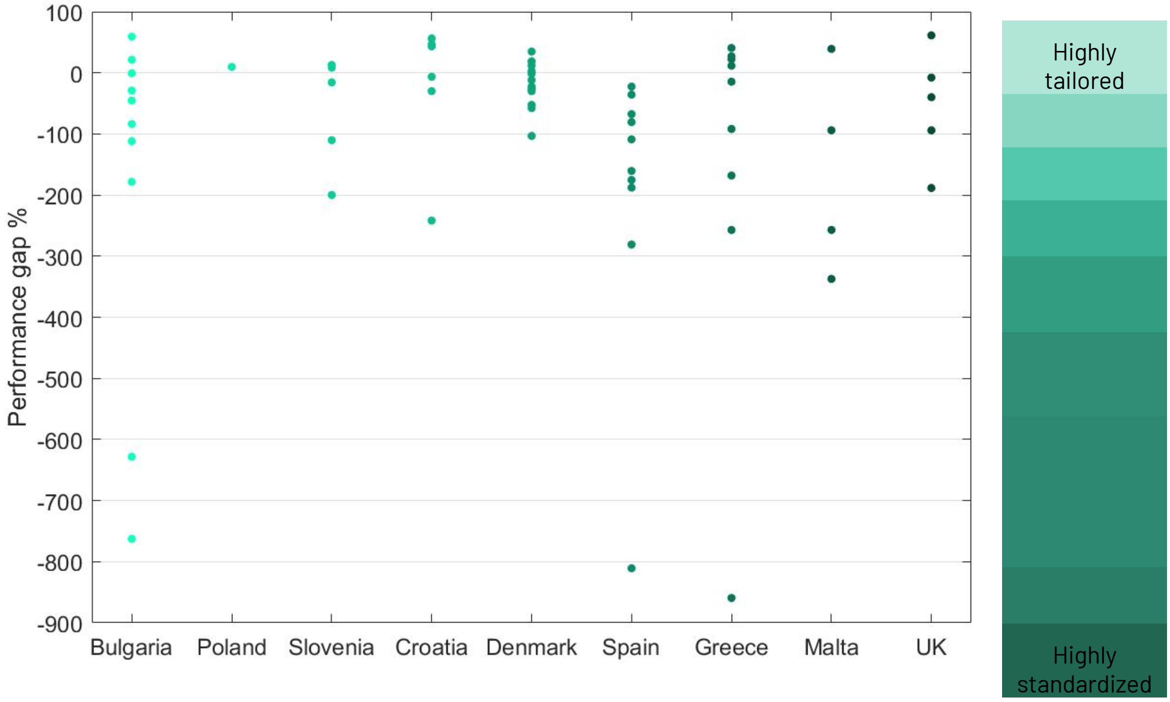

Figure 1- *Performance gap variations*

In order to compare the performance gap values across different countries, the coefficient of variation for the root mean square error (CV(RMSE)) for each country is calculated and presented in Figure 2.

$$CV(RMSE) = \frac{\sqrt{\sum_{i=1}^{n} (e_i - r_i)^2 / n}}{\bar{e}}$$

Based on these results, it appears that the performance gap is generally lower for more tailored methodologies compared to more standardized ones with Bulgaria as an exception. However, it is important to note that the sample sizes are not equal in all countries, and there is only one building included in this study for Poland which has a highly tailored methodology. In addition, it is important to note that categorising country methodologies accurately is not possible as a country's approach to treating one input can be completely different from its approach in treating other inputs. However, for the purpose of exploring possible links between the performance gap and the general type of the EPC methodology, different methodologies were assigned to different levels of standardization.

Figure 2 shows that amongst the standardized methodologies, the UK performance gap results are in the same range as the more tailored methodologies, even though the UK method is highly standardized. Another important point to note is that the lower value for Denmark buildings could be attributed to the fact that only the heating energy consumption values are compared against the relevant EPC values. For other countries, a large part of the performance gap is possibly caused by other energy consumption categories which are not accounted for in EPC calculation, such as lighting, cooling, and electrical equipment.

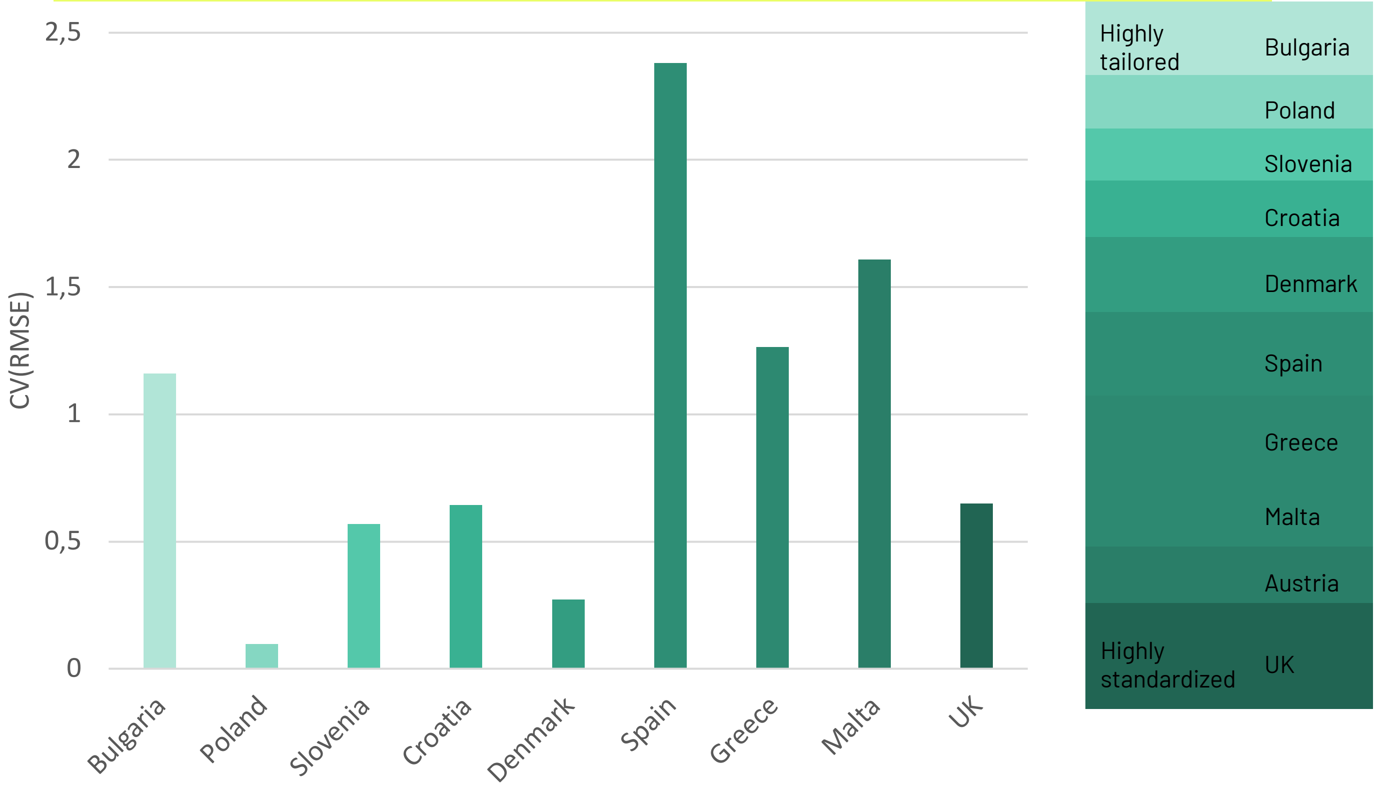

Figure 2- Comparison of the performance gap across crossCert countries

5 Conclusion

This study has demonstrated the variability of the Performance Gap when comparing EPC-predicted energy use with real energy consumption for a small sample of buildings. Due to this sample size, the methodological approach has been to understand the detail of the calculation procedures, identify potential causes of performance gaps from these descriptions (i.e., factors that cause a standardised representation of a building to be different to the real building), and then document whether such differences are found when applied to a set of case-study buildings. The results, as a whole, should therefore not be seen as numerically generalisable across wider stocks of buildings in the selected countries, but they do help demonstrate that:

- The Performance Gap between the measured and EPC-modelled energy consumption of a building is both significant and variable depending on building type and chosen EPC methodology. This study notes a calculated Performance Gap varying between 0.77% and 859%
- Using Performance Gap as a metric for EPC effectiveness must be placed in context of a) what EPCs are fundamentally trying to do with regards to standardisation of energy assessment, b) the lack of ability in most EPC methods to account for genuine occupant behaviour, and c) the chosen output metrics of a national EPC approach, which may not allow for ease of comparison with a Performance Gap
- Even with difficulties in quantifying (numerically) a Performance Gap for a given method and/or building stock, the list of causes of Performance Gaps (and why this may differ between countries) is a long one. It is suggested that this should be the starting point of any critique of an EPC method (i.e., is an assumption in the methodology justified when compared to approaches elsewhere), rather than making a judgement purely on numerical results.

As discussed in the report, a number of caveats must be understood when making these comparisons – and these, in turn, help illustrate just how different the EPC methodologies are that exist across Europe. In particular, categorising methodologies by a single factor (e.g., level of complexity or standardisation) does not account for the different layers of complexity (across different input parameters) within an approach. For example, Malta is standardized in many aspects but does not have default values for U-values for residential buildings. Likewise, in the UK where there is considerable standardisation of inputs, it is still mandatory to measure the infiltration rate for new buildings.

It has also been noted that the sample size is too small for detailed statistical analysis and, due to the need to select buildings with specific availability of data, countries are not represented equally in that sample; e.g. Poland only has one building, whereas Denmark has 14.

This broad discussion and comparison have encompassed case studies from different sectors, i.e., non-residential, and residential. In some countries these building types are treated differently in EPC calculations, and these intra-country variations may be as significant as those occurring between countries.

Finally, it may be surprising that, despite the guidance and boundaries provided by the Energy Performance of Buildings Directive, countries do not record the same categories of energy consumption on EPCs. Furthermore, for Performance Gap analysis, different buildings measure energy consumption in different ways (and this can also be country-specific). For example, except for Danish buildings, there is no sub-metered data available in the sample used in this study. Therefore, it was not possible to directly compare the EPC results to the measured values of the energy categories included in an EPC (even if such EPC categorisation was used). Therefore, electrical equipment, lighting and cooling energy consumption are included in the measured energy data whereas for some countries some or all of these are not calculated in EPCs. This is enough to cause large performance gaps regardless of methodology, particularly for non-residential buildings where a large part of energy consumption is due to electrical appliances and lighting.

The crossCert project will continue to explore these results in future reports, alongside other modelled outputs (such as applying EPC approaches from one country to those of another, and running detailed dynamic simulations of target buildings) that will help identify the causation of differences across EPC methodologies in Europe, and the consequences of this lack of harmonisation for next-generation EPCs.

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7 Appendix A

Table 8- Excerpts from crossCert countries' EPCs showing metrics provided in each country's certificate, usable in performance gap calculations.

Country	Metric	Value	Status	Indicator	Specific value
Austria non-residential	**REQUIREMENTS (reference climate)**				
	reference heat demand	68.5 kWh/m²a fulfilled		HWB Ref,RK	49.0 kWh/m²a
	Externally induced cooling demand	1.0 kWh/m³a fulfilled		KB* RK	0.0 kWh/m³a
	Final/delivery energy demand			E/LEB RK	136.7 kWh/m²a
	Overall Energy Efficiency Factor	0.85	Fulfills	f GEE	0.59
	Renewable portion	at least 5% of the fGEE requirement	Fulfills		
	HEAT AND ENERGY REQUIREMENTS (site climate)				
	reference heat demand	96,276 kWh/a		HWB Ref,SK	56.3 kWh/m²a
	heating demand	102,789 kWh/a		HWB SK	60.1 kWh/m²a
	hot water heat demand	9,489 kWh/a		WWWB	5.5 kWh/m²a
	heating energy demand	59,536 kWh/a		HEB SK	34.8 kWh/m²a
	Energy expenditure figure for heating			e AWZ,H	0.53
	cooling demand	43,399 kWh/a		KB SK	25.4 kWh/m²a
	cooling energy demand	21,623 kWh/a		KEB SK	12.6 kWh/m²a
	energy expenditure figure cooling			e AWZ,K	0.50
	humidification energy requirements			commandEB SK	
	lighting energy requirements	120,766 kWh/a		BelEB	70.6 kWh/m²a
	operating power requirements	42,144 kWh/a		BOD	24.6 kWh/m²a
	final energy demand	244,070 kWh/a		EEB SK	142.7 kWh/m²a
	primary energy demand	466,174 kWh/a		PEB SK	272.5 kWh/m²a
	Primary energy demand not renewable	322,172 kWh/a		PEB n.ern.,SK	188.3 kWh/m²a
	Primary energy demand renewable	144,001 kWh/a		PEB ern.,SK	84.2 kWh/m²a
	carbon emissions	67,363 kg/a		CO2 SK	39.4 kg/m²a
	Overall Energy Efficiency Factor			f GEE	0.59
	Photovoltaic export			PV Export,SK	

Austria residential

	Referenzklima zonenbezogen [kWh/a]	Referenzklima spezifisch [kWh/m²a]	Standortklima zonenbezogen [kWh/a]	Standortklima spezifisch [kWh/m²a]	Anforderungen ab 01.01.2010 [kWh/m²a]	
HWB	1.912	9,11	2.081	9,92	44,9	erfüllt
WWWB			2.680	12,78		
HTEB-RH			-32	-0,15		
HTEB-WW			-1.684	-8,03		
HTEB			8.011	38,19		
HEB			4.070	19,40	126,0	erfüllt
EEB			4.070	19,40		
PEB						
CO2						

ERLÄUTERUNGEN

Heizwärmebedarf (HWB):	Vom Heizsystem in die Räume abgegebene Wärmemenge die benötigt wird, um während der Heizsaison bei einer standardisierten Nutzung eine Temperatur von 20℃ zu halten.
Heiztechnikenergiebedarf (HTEB):	Energiemenge die bei der Wärmeerzeugung und -verteilung verloren geht.
Endenergiebedarf (EEB):	Energiemenge die dem Energiesystem des Gebäudes für Heizung und Warmwasserversorgung inklusive notwendiger Energiemengen für die Hilfsbetriebe bei einer typischen Standardnutzung zugeführt werden muss.

Die Energiekennzahlen dieses Energieausweises dienen ausschließlich der Information. Aufgrund der idealisierten Eingangsparameter können bei tatsächlicher Nutzung erhebliche Abweichungen auftreten. Insbesondere Nutzungseinheiten in besonderer Lage können aus Gründen der Geometrie und der Lage hinsichtlich ihrer Energiekennzahlen von den hier angegebenen abweichen.

EA-01-2007-SW-a
EA-WG
25.04.2007

Bulgaria

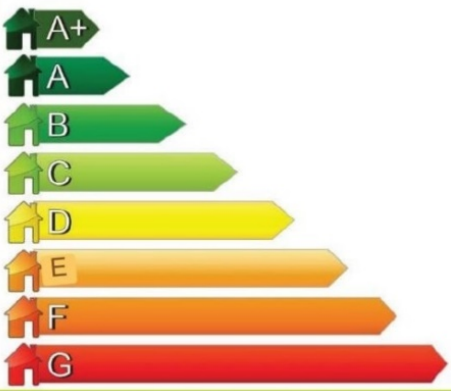
EPmin kWh/m²	EPmax kWh/m²	Primary energy consumption scale kWh/m²	Before measures kWh/m²	After mesures kWh/m²
<	48	A+		
48	96	A		
96	190	B		187
191	240	C		
241	290	D		
291	363	E	291	
364	435	F		
>	435	G		

Energy performance characteristics of the building	
Specific annual final energy consumption	159,86 kWh/m²
Specific annual final energy consumption for heating, ventilation and DHW	145,82 kWh/m²
Total annual final energy consumption	789,55 MWh
Generated CO_2 emissions	357 t/a

ТИФИКАТ

EXISTING SITUATION AT THE MOMENT OF THE ENERGY AUDIT				
System	***Energy source***	***Generator***	***Annual final energy consumption***	
			Specific	***Total***
Type	***Type***	***Type***	***kWh/m²***	***kWh***
Heating	District heating	Sub-station	**110,84**	**547 441**
Ventilation			**0,00**	**0,00**
Cooling			**0,00**	**0,00**
Domestic hot water	Electricity -	Volume boilers	**25,24**	**124 668**
Lighting	Electricity		**1.58**	**7 788**
Others – appliances using energy	Electricity		**12,46**	**61 562**

Croatia

ENERGY CLASS OF THE BUILDING	Specific annual required thermal energy for heating Q''H,nd [kWh/(m²a)]	Specific annual primary energy Eprim [kWh/(m2a)]
	197,44	336,38
	E	G
Specific annual delivered energy Edel [kWh/(m²a)]	298,82	
Specific annual CO2 emission [kg/(m²a)]	10,49	
Enter "nZEB" if the energy property of the building (Eprim) meets the requirements for almost zero energy buildings prescribed by the valid TPRUETZZ	–	

ENERGY NEEDS	REFERENCE CLIMATE DATA		REQUEST 2
	Total [kWh/a]	Specific [kWh/(m²a)]	Allowed [kWh/(m²a)]
Annual required thermal energy for heating QH,nd	187,564.00	197.44	49,48
Annual required thermal energy for cooling Qc,nd	12,279.00	12.92	50.00
Annual delivered energy Edel	283,877.27	298.82	60.00
Annual primary energy Eprim	319,563.05	336,38	90.00

Denmark

CALCULATED ENERGY REQUIREMENTS OF THE BUILDING

Warm up

FORM OF SUPPLY	HEAT REQUIREMENT IN kWh	CONVERTED TO ENERGY UNIT FOR SUPPLY FORM
Natural gas	63,560	5,778.2 m³ natural gas

Other energy needs

ELECTRICITY FOR OTHER*	kWh
Electricity for building operation	1,788
Electricity for consumption	7,334

Greece

Estimated annual primary energy consumption	
Reference building [kWh/m2]:	188.8
of inspected building [kWh/m2]:	244.8

Actual Annual Consumption of Inspected Building:	
Electricity [kWh/m]:	----
Thermal energy (fuel) [kWh/m2]:	----
Total annual primary energy consumption [kWh/m2]:	----

Annual CO2 emissions of inspected building	
Estimated annual CO2 emissions [kg /m]:	83.3
Actual annual CO2 emissions [kg /m]:	----

Thermal comfort p	Visual comfort t	Acoustic comfort ☑	Indoor air quality

• The energy efficiency of a building is determined based on the calculated annual energy consumption to cover the needs associated with using it to achieve conditions of thermal and visual comfort

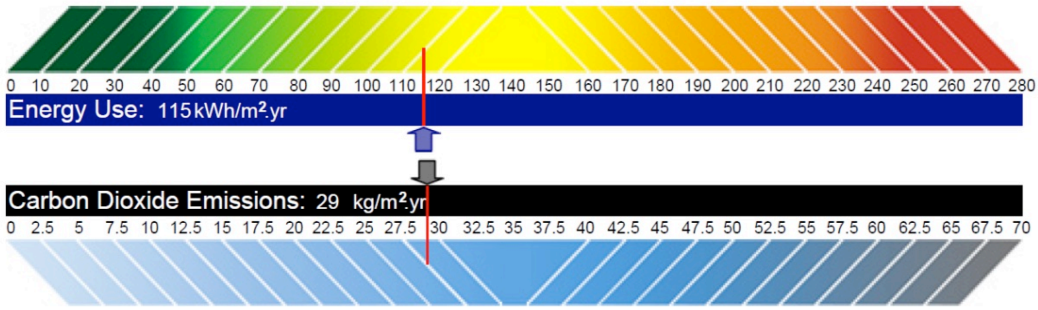
Calculated annual energy requirement per end use [kWh/m2				
	Heating	Cooling	DHW	Lighting
Reference building	5.2	46.0	0.0	---
Inspected building	6.1	53.4	0.0	---

Calculated Annual Final Energy Consumption by Energy Source & End Use [kWh/m²]						
Energy source	Heating	Cooling	DHW	Lighting	Total	Contribution to the energy balance of the building [%]
Electric	5.3	28.0	0.0	51.0	84.3	
Oil	0.0	0.0	0.0	0.0	0.0	
Natural gas	0.0	0.0	0.0	0.0	0.0	
Other Fossil Fuels	0.0	0.0	0.0	0.0	0.0	
Solar	---	---	---	---	0.0	
Biomass	---	---	---	---	0.0	
Geothermal energy	---	---	---	---	0.0	
Another RES	---	---	---	---	0.0	0
Total	5.3	28	0	51	84.3	100.0

Use the PEA to:

- compare the energy efficiency of single-use buildings based on their classification in an energy
- category, find out about saving energy and money through interventions to improve energy efficiency.

Malta



Poland

Evaluation of the energy performance of the building10>		
Energy Performance Indicators	Rated building	Requirements for a new building according to technical and construction regulations
Indicator of the annual demand for usable energy	EU = 14.60 kWh/(m2 year)	
Indicator of annual demand for final energy	EK = 21.92 kWh/(m2 year)	
Index of annual demand for non-renewable primary energy 11)	EP = 45.90 kWh/(m2 • year)	EP = 110.00 kWh/(m2 year)
Unit amount of CO2 emissions	E = 0.02t CO2 I(m2 year)	
Share of renewable energy sources in the annual demand for final energy	uo,c = 34.70 %	

Calculated annual amount of energy carrier or energy consumed by the building12I			
technical system	Type of energy carrier or energy	The amount of energy carrier or energy	Unit/(m2 year)
Heating	1) Electricity	9.83	kWh
Preparation of hot tap water	1) Solar energy	1.10	kWh
	2) Electricity	3.03	kWh
cooling			
Built-in lighting installation11I	I) Electricity	7.93	kWh

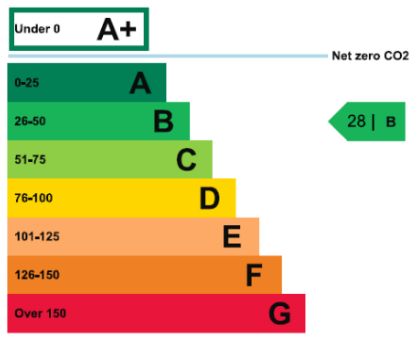
Rest of the UK non-Residential

Breakdown of this property's energy performance

Main heating fuel	Natural Gas
Building environment	Air Conditioning
Assessment level	5
Building emission rate (kgCO2/m2 per year)	12.61

Energy efficiency rating for this property

This property's current energy rating is B.



Properties are given a rating from A+ (most efficient) to G (least efficient).

Rest of the UK Residential

Estimated energy use and potential savings

Estimated yearly energy cost for this property	£1107
Potential saving	£311

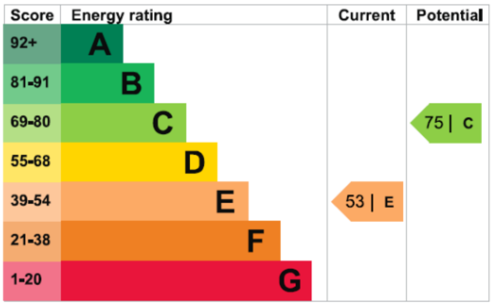
Estimated energy used to heat this property

Space heating	12354 kWh per year
Water heating	2935 kWh per year

Energy efficiency rating for this property

This property's current energy rating is E. It has the potential to be C.

See how to improve this property's energy performance.



The graph shows this property's current and potential energy efficiency.

Properties are given a rating from A (most efficient) to G (least efficient).

Properties are also given a score. The higher the number the lower your fuel bills are likely to be.

For properties in England and Wales:

the average energy rating is D
the average energy score is 60

Environmental impact of this property

One of the biggest contributors to climate change is carbon dioxide (CO2). The energy used for heating, lighting and power in our homes produces over a quarter of the UK's CO2 emissions.

An average household produces	6 tonnes of CO2
This property produces	6.1 tonnes of CO2
This property's potential production	3.3 tonnes of CO2

By making the recommended changes, you could reduce this property's CO2 emissions by 2.8 tonnes per year. This will help to protect the environment.

Environmental impact ratings are based on assumptions about average occupancy and energy use. They may not reflect how energy is consumed by the people living at the property.

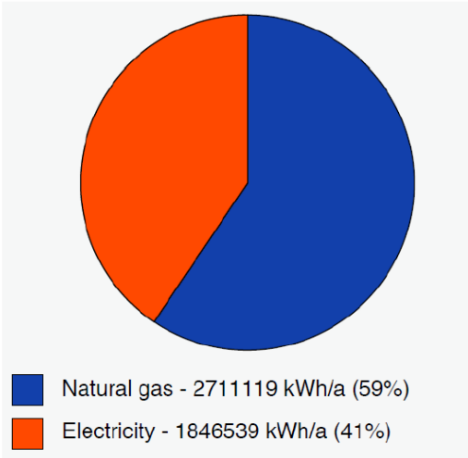
Slovenia	

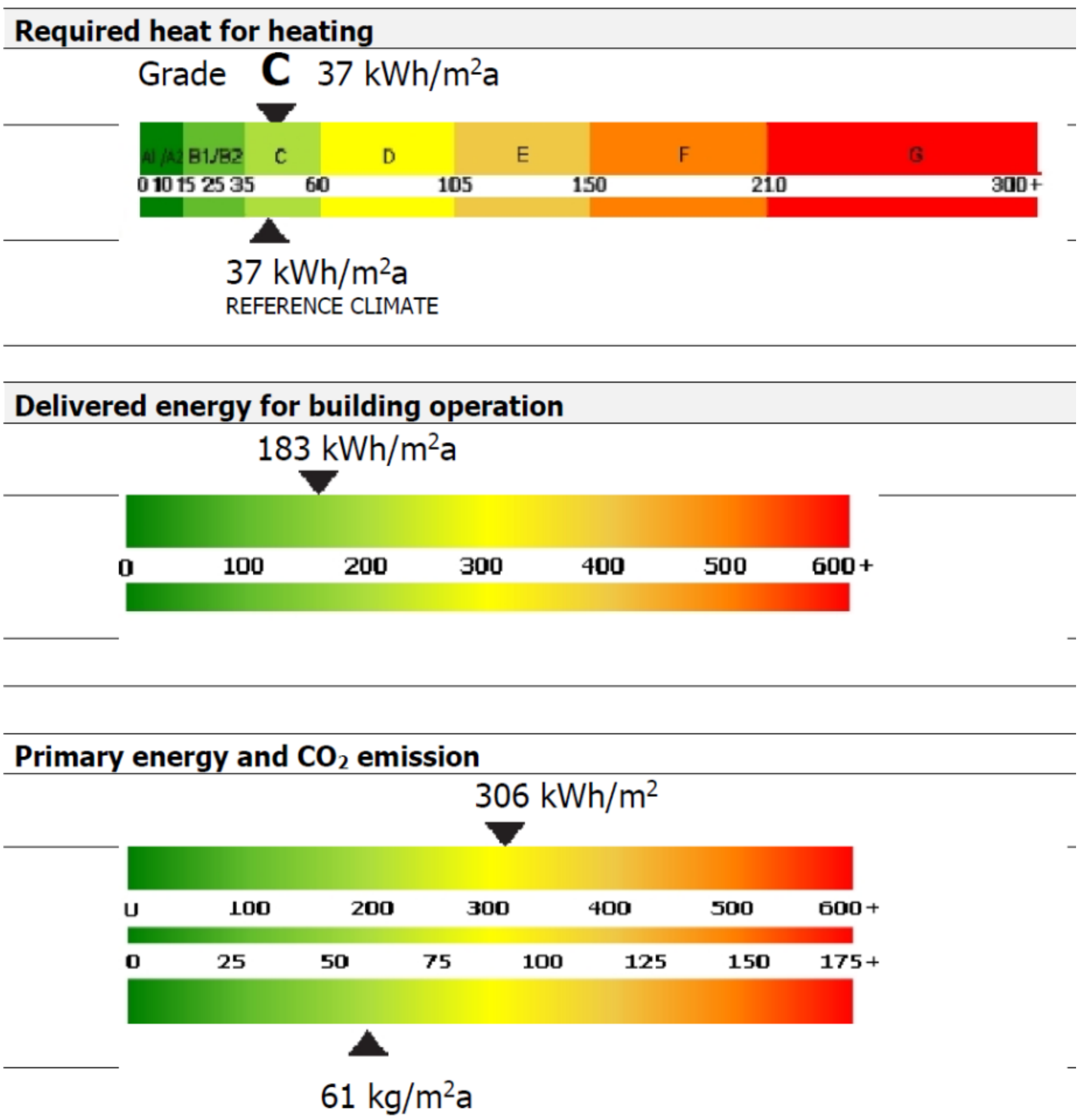
Delivered energy for building operation

Delivered energy for building operation	Delivered energy kWh/a	kWh/m²a
Heating $Q_{f,h}$	1.085.094	44
Cooling $Q_{f,c}$	10.495	0
Ventilation $Q_{f,V}$	955.098	38
Humidification $Q_{f,st}$	319.063	13
Domestic hot water $Q_{f,w}$	1.626.026	65
Lighting $Q_{f,l}$	536.446	22
Electricity $Q_{f,aux}$	25.437	1
Total delivered energy for building operation	4.557.659	183

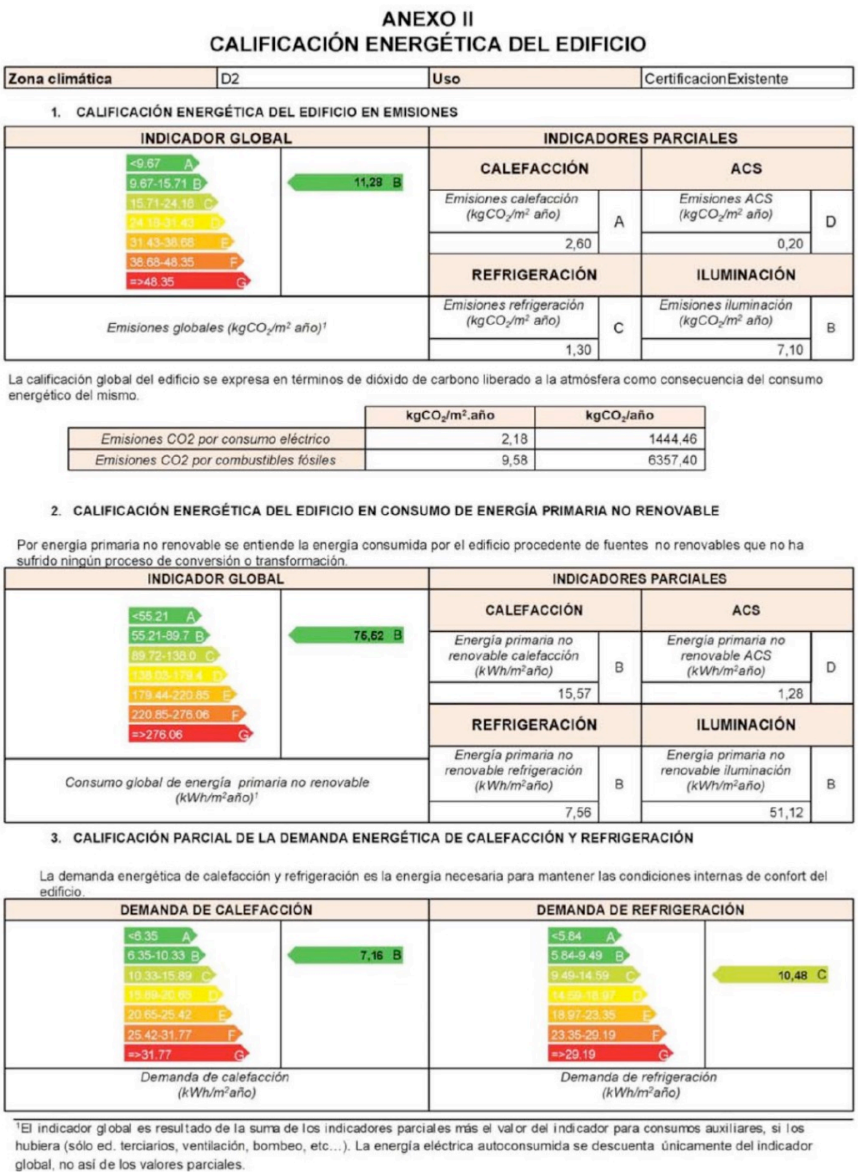
Renewable energy used in building (kWh/a)	0
Primary energy for building operation (kWh/a)	7.621.442
CO_2 Emissions (kg/a)	1.520.890

Structure of total energy use for building operation by energy sources (kWh/a)




Required heat for heating
Grade C 37 kWh/m²a
A1/A2
B1/B2
C
D
E
F
G
0 10 15 25 35 60 105 150 210 300+
37 kWh/m²a
REFERENCE CLIMATE
Delivered energy for building operation
183 kWh/m²a
0 100 200 300 400 500 600+
Primary energy and CO₂ emission
306 kWh/m²
0 100 200 300 400 500 600+
0 25 50 75 100 125 150 175+
61 kg/m²a

Spain



ANEXO II
CALIFICACIÓN ENERGÉTICA DEL EDIFICIO

Zona climática	D2	Uso	CertificacionExistente

1. CALIFICACIÓN ENERGÉTICA DEL EDIFICIO EN EMISIONES

INDICADOR GLOBAL		INDICADORES PARCIALES			
<9.67 A 9.67-15.71 B 15.71-24.18 C 24.18-31.43 D 31.43-38.68 E 38.68-48.35 F =>48.35 G	11,28 B	CALEFACCIÓN		ACS	
		Emisiones calefacción ($kgCO_2/m^2$ año) 2,60	A	Emisiones ACS ($kgCO_2/m^2$ año) 0,20	D
		REFRIGERACIÓN		ILUMINACIÓN	
Emisiones globales ($kgCO_2/m^2$ año)[1]		Emisiones refrigeración ($kgCO_2/m^2$ año) 1,30	C	Emisiones iluminación ($kgCO_2/m^2$ año) 7,10	B

La calificación global del edificio se expresa en términos de dióxido de carbono liberado a la atmósfera como consecuencia del consumo energético del mismo.

	$kgCO_2/m^2$.año	$kgCO_2$/año
Emisiones CO2 por consumo eléctrico	2,18	1444,46
Emisiones CO2 por combustibles fósiles	9,58	6357,40

2. CALIFICACIÓN ENERGÉTICA DEL EDIFICIO EN CONSUMO DE ENERGÍA PRIMARIA NO RENOVABLE

Por energia primaria no renovable se entiende la energia consumida por el edificio procedente de fuentes no renovables que no ha sufrido ningún proceso de conversión o transformación.

INDICADOR GLOBAL		INDICADORES PARCIALES			
<55.21 A 55.21-89.7 B 89.72-138.0 C 138.03-179.4 D 179.44-220.85 E 220.85-276.06 F =>276.06 G	76,62 B	CALEFACCIÓN		ACS	
		Energía primaria no renovable calefacción (kWh/m^2año) 15,57	B	Energía primaria no renovable ACS (kWh/m^2año) 1,28	D
		REFRIGERACIÓN		ILUMINACIÓN	
Consumo global de energía primaria no renovable (kWh/m^2año)[1]		Energía primaria no renovable refrigeración (kWh/m^2año) 7,56	B	Energía primaria no renovable iluminación (kWh/m^2año) 51,12	B

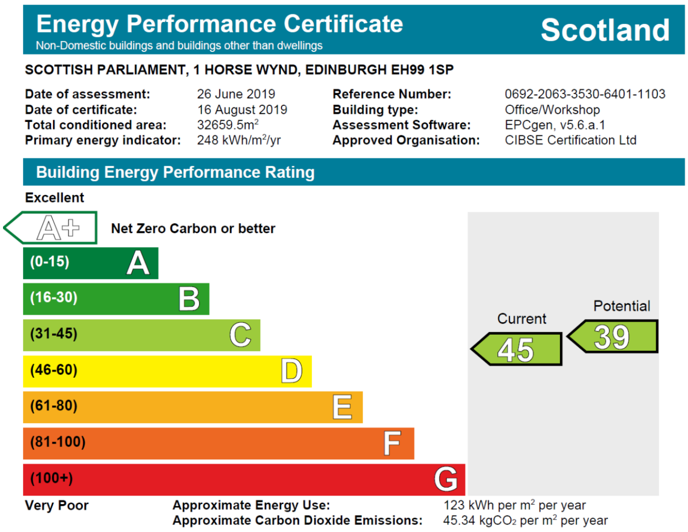
3. CALIFICACIÓN PARCIAL DE LA DEMANDA ENERGÉTICA DE CALEFACCIÓN Y REFRIGERACIÓN

La demanda energética de calefacción y refrigeración es la energia necesaria para mantener las condiciones internas de confort del edificio.

DEMANDA DE CALEFACCIÓN		DEMANDA DE REFRIGERACIÓN	
<6.35 A 6.35-10.33 B 10.33-15.89 C 15.89-20.65 D 20.65-25.42 E 25.42-31.77 F =>31.77 G	7,16 B	<5.84 A 5.84-9.49 B 9.49-14.59 C 14.59-18.97 D 18.97-23.35 E 23.35-29.19 F =>29.19 G	10,48 C
Demanda de calefacción (kWh/m^2año)		Demanda de refrigeración (kWh/m^2año)	

[1]El indicador global es resultado de la suma de los indicadores parciales más el valor del indicador para consumos auxiliares, si los hubiera (sólo ed. terciarios, ventilación, bombeo, etc…). La energía eléctrica autoconsumida se descuenta únicamente del indicador global, no así de los valores parciales.

UK non-residential (Scotland)



Energy Performance Certificate — **Scotland**
Non-Domestic buildings and buildings other than dwellings

SCOTTISH PARLIAMENT, 1 HORSE WYND, EDINBURGH EH99 1SP

Date of assessment:	26 June 2019	**Reference Number:**	0692-2063-3530-6401-1103
Date of certificate:	16 August 2019	**Building type:**	Office/Workshop
Total conditioned area:	32659.5m²	**Assessment Software:**	EPCgen, v5.6.a.1
Primary energy indicator:	248 kWh/m²/yr	**Approved Organisation:**	CIBSE Certification Ltd

Building Energy Performance Rating

Excellent

A+ Net Zero Carbon or better

(0-15) A
(16-30) B
(31-45) C
(46-60) D
(61-80) E
(81-100) F
(100+) G

Current 45

Potential 39

Very Poor

Approximate Energy Use: 123 kWh per m² per year
Approximate Carbon Dioxide Emissions: 45.34 $kgCO_2$ per m² per year

UK residential (Scotland)

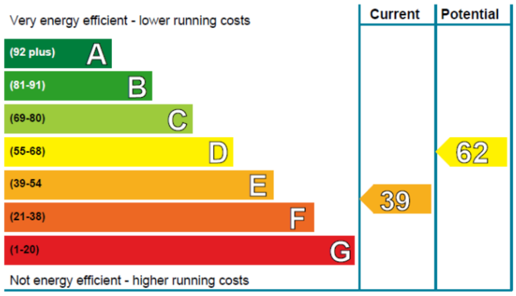
Dwelling type:	Semi-detached house	**Reference number:**	6215-1227-6000-0634-1906
Date of assessment:	04 March 2015	**Type of assessment:**	RdSAP, existing dwelling
Date of certificate:	07 March 2015	**Approved Organisation:**	Elmhurst
Total floor area:	93 m2	**Main heating and fuel:**	Boiler and radiators, mains gas
Primary Energy Indicator:	555 kWh/m2/year		

You can use this document to:

- **Compare current ratings of properties to see which are more energy efficient and environmentally friendly**
- **Find out how to save energy and money and also reduce CO_2 emissions by improving your home**

Estimated energy costs for your home for 3 years*	**£5,721**	See your recommendations report for more information
Over 3 years you could save*	**£1,284**	

* based upon the cost of energy for heating, hot water, lighting and ventilation, calculated using standard assumptions

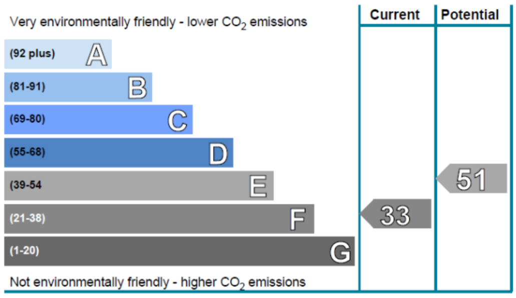


Energy Efficiency Rating

This graph shows the current efficiency of your home, taking into account both energy efficiency and fuel costs. The higher this rating, the lower your fuel bills are likely to be.

Your current rating is **band E (39)**. The average rating for EPCs in Scotland is **band D (61).**

The potential rating shows the effect of undertaking all of the improvement measures listed within your recommendations report.



Environmental Impact (CO_2) Rating

This graph shows the effect of your home on the environment in terms of carbon dioxide (CO_2) emissions. The higher the rating, the less impact it has on the environment.

Your current rating is **band F (33)**. The average rating for EPCs in Scotland is **band D (59).**

The potential rating shows the effect of undertaking all of the improvement measures listed within your recommendations report.