D3.5 Sensitivity analysis of chosen parameters on EPC outputs

Task 3.4 Verification and control

WP3 Deriving technical Guidelines for EPCs

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EXECUTIVE SUMMARY

Work Package 3 in the crossCert project includes extended results analysis and the issuance of conclusions based on Work Package 2 results. As part of this work package, this report uses the results of the C-testing and P-testing included in Work Package 2 to perform a numerical analysis on the effects of variations of parameters and calculation approaches between methodologies on the final energy consumption values. In the C-testing round of the project, 10 different EPC methodologies were applied to 52 C-buildings. In addition, 8 P-buildings were modelled in IES-VE dynamic simulation package. In devising this report, the EPC certificates and the C-testing reports produced by the partners as well as the results of the dynamic energy models created in the P-testing phase were used as sources of information.

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1 Introduction

In the C-testing phase of the crossCert project, different EPC methodologies were applied to the same buildings to compare various aspects of the methodologies as well as the assessment results. The countries were paired together in C-testing clusters based on HDD (heating degree days) and CDD (cooling degree days) values. The C-testing reports resulting from this round of testing show that between these methodologies, input parameters can vary significantly, in terms of how they are defined (default or tailored values for each building), as well as their numerical values. In addition, variations exist in the general methodology approaches, such as calibrating models to measured energy data, using dynamic simulations, inclusion of different energy consumption categories, etc. Such variations are clarified in more detail in other project deliverables (D3.1 (Sayfikar and Jenkins, 2022), D3.2 (Sayfikar and Jenkins, 2023) and D2.4 (Gómez and Fueyo, 2023) and briefly summarized in Table 1 and

Table 2. In total, during the C-testing round, 14 comparisons between EPC methodologies of ten different European countries were performed. Fifty case study buildings were used for these comparisons.

Table 2 shows all the comparisons performed during this stage.

Table 1- Summary of comparison of country methodologies

	Temperature setpoints non-residential	Temperature setpoints residential	U values	Infiltration rate	Schedules	HVAC performance parameters
No default values	Bulgaria	Bulgaria	Malta (residential)	UK (new buildings)	Bulgaria	Bulgaria
			Austria	Bulgaria		
	Spain	Austria	Bulgaria	Austria	Poland	Spain
	Denmark	Denmark	Croatia	Croatia	Spain	Austria
	Austria		Denmark	Denmark	Slovenia	Croatia
	Croatia	Greece	Greece	Greece	Austria	Denmark
	Greece	Malta	Malta (non-residential)	Malta	Croatia	Greece
	Malta	Poland	Poland	Poland	Denmark	Malta
	Poland	Slovenia	Slovenia	Slovenia	Greece	Poland
	Slovenia	Spain	Spain	Spain	Malta	Slovenia
Default values	UK	UK	UK	UK	UK	UK

Highly tailored									Highly standardized
Bulgaria	Poland	Slovenia	Croatia	Denmark	Spain	Greece	Malta	Austria	UK

Table 2- Energy categories included in country methodologies.

		Heating	Cooling	DHW	Lighting	Equipment
Austria	Residential	✓	-	✓	✓	-
	Non-residential	✓	✓	✓	✓	-
Bulgaria	Residential	✓	✓	✓	✓	✓
	Non-residential	✓	✓	✓	✓	✓
Croatia	Residential	✓	-	✓	-	-
	Non-residential	✓	✓	✓	✓	-
Denmark	Residential	✓	✓	✓	only in communal parts of multi-family houses	-
	Non-residential	✓	✓	✓	✓	-
Greece	Residential	✓	✓	✓	✓	-
	Non-residential	✓	✓	✓	✓	-
Malta	Residential	✓	✓	✓	✓	-
	Non-residential	✓	✓	✓	✓	-
Poland	Residential	✓	✓	✓	-	-
	Non-residential	✓	✓	✓	✓	-
Slovenia	Residential	✓	✓	✓	✓	-
	Non-residential	✓	✓	✓	✓	-
Spain	Residential	✓	✓	✓	-	-
	Non-residential	✓	✓	✓	✓	-
UK	Residential	✓	-	✓	✓	-
	Non-residential	✓	✓	✓	✓	-

Table 3- Comparisons in the C-testing round

Country 1	Austria	Austria	Austria	Bulgaria	Bulgaria	Bulgaria	Bulgaria	Croatia
Country 2	Croatia	Slovenia	Poland	UK	Poland	GR	Spain	Slovenia

Country 1	Croatia	Denmark	Greece	Greece	Poland	Spain
Country 2	Denmark	Poland	Malta	Spain	UK	UK

In addition to these comparisons, a separate round of testing was performed by Heriot-Watt University (HWU), which was referred to as P-testing. During the P-testing phase, a dynamic simulation software (IES-VE) was used to create digital models of eight buildings. For these buildings, in addition to the neutral data inventory documents, detailed floor plans and in some cases metered energy consumption data were supplied by the partners. Table 4 provides a list of all P-building pairings. For each building, various simulations were performed using the weather data of each C-testing country of that building. The simulation results were then compared against other countries as well as to the corresponding C-testing results. These comparisons are used to highlight the level of the impact of weather data on the results, which helps clarify the level of impact of other variables which are different in EPC methodologies, complementing the results from the C-testing stage. It is also worth mentioning that for consistency purposes, in all P-building simulations, UK National Calculation Methodology (NCM) profiles were used for occupancy, electrical appliances, lighting and HVAC systems.

Table 4- P-buildings

Building code	Building type	Country	Simulations
UK1	Educational	Scotland, United Kingdom	UK, Poland, Bulgaria
UK2	Educational	Scotland, United Kingdom	UK, Poland, Bulgaria
UK3	Educational	Scotland, United Kingdom	UK, Bulgaria
BG08	Commercial (office-restaurant-retail)	Bulgaria	UK, Bulgaria
PL01	Educational	Poland	UK, Poland
AT08	Commercial (retail)	Austria	UK, Austria
ES14	Commercial (office)	Spain	UK, Spain
ES16	Commercial (office)	Spain	UK, Spain

This report uses the results of the C-testing and P-testing phases to perform a numerical analysis of the effects of variations of parameters between methodologies on the final energy consumption values. Final energy consumption values of EPC calculations for clustered methodologies are compared against each other, and the important parameters affecting the differences in results are discussed. In addition, P-testing results are compared against these values for the P-buildings. In devising this report, the EPC certificates and the C-testing reports produced by the partners were the main sources of information.

2 Comparing methodologies and results

2.1 Comparison between UK and Polish methodologies

The UK and Polish methodologies were compared by applying both EPC methodologies to UK1, UK2, and PL1 buildings. In addition, all three buildings were simulated in IES-VE and dynamic simulation results using relevant UK and Polish weather inputs were compared.

Table 5 shows that the difference between UK and Polish EPC values ranges from 6.6 to 95%. Comparing the P-testing results shows that the dynamic simulation results only changed between 4 to 22.8% when the weather data was changed from Edinburgh to Warsaw, indicating that the sensitivity of the results to the weather data is not significant in these case study buildings (particularly for UK02 and PL01) and the differences are caused by other factors.

As can be seen from Table 1, the UK methodology is highly standardized, while the Polish methodology is considered to be highly tailored. For example, for occupancy and HVAC operation schedules, the Polish methodology allows using the actual schedules (provided in the neutral data inventory files for each building) whereas the UK methodology applies the NCM schedules automatically. In terms of temperature setpoints, while both methodologies provide default values, these default setpoint values differ between the two methodologies. Such differences could lead to differences in the results when the UK and Polish methodologies are applied to the same building.

Table 5- UK and Poland comparison

	Annual final energy consumption (kWh/m2year)					
Building ID	UK EPC	Polish EPC	Difference %	UK P-testing	Polish P-testing	Difference %
UK1	137	128	6.6	203.4	249.7	-22.8
UK2	32	62.6	-95.6	45.3	47.9	-5.7
PL01	57	21.9	61.5	41.4	43.4	-4.7

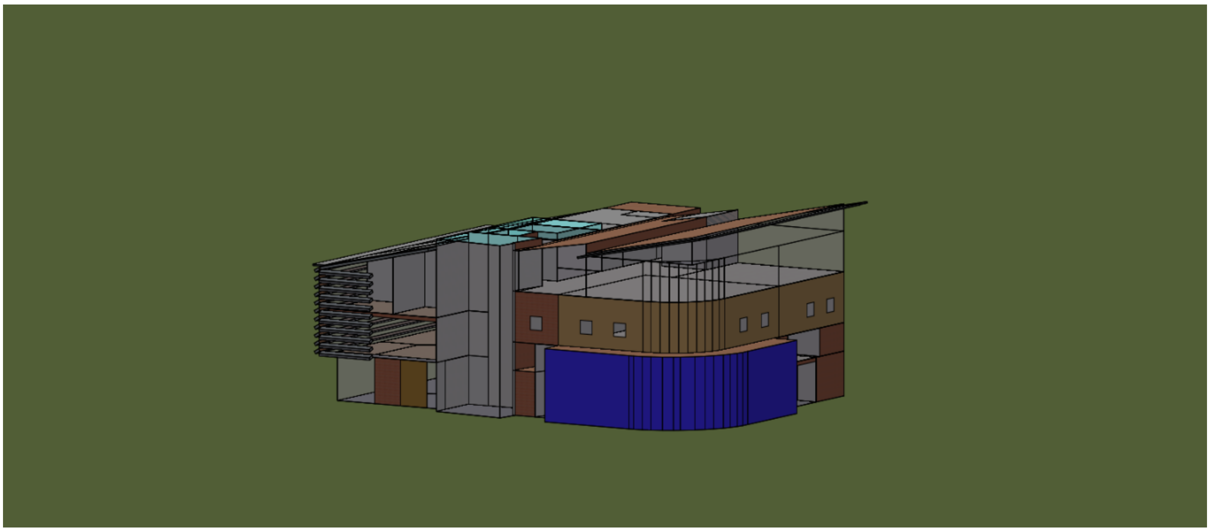

Figure 1- IES model of UK01

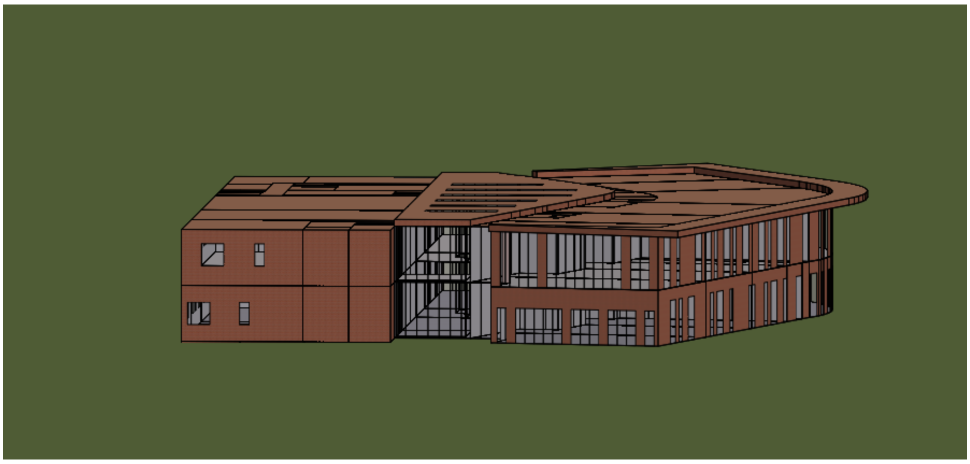

Figure 2- IES model of UK02

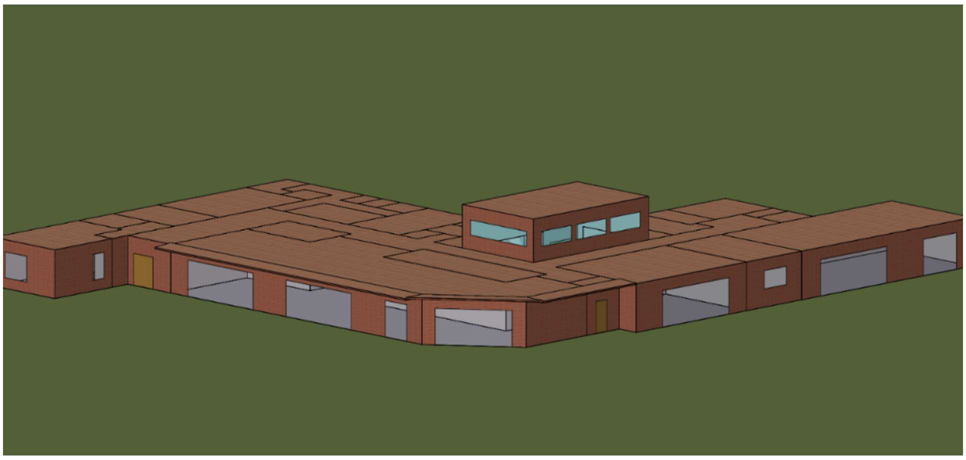

Figure 3- - IES model of PL01

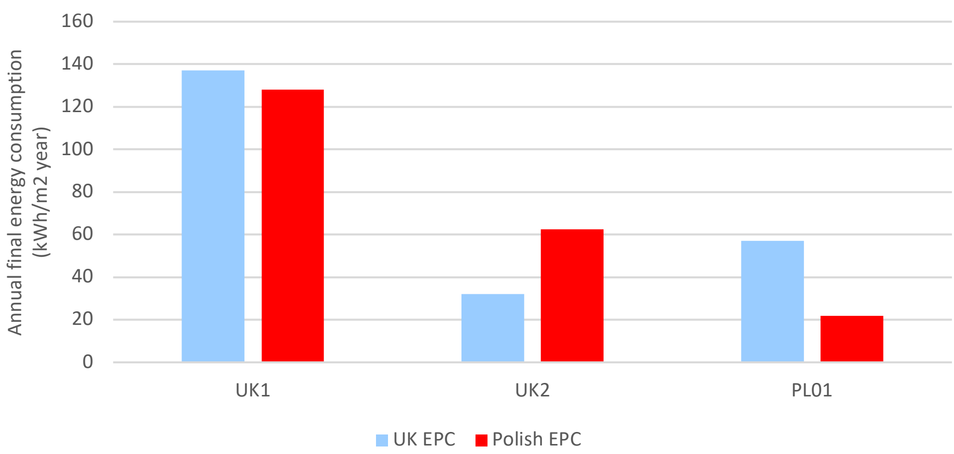

Figure 4- UK and Poland C-testing results

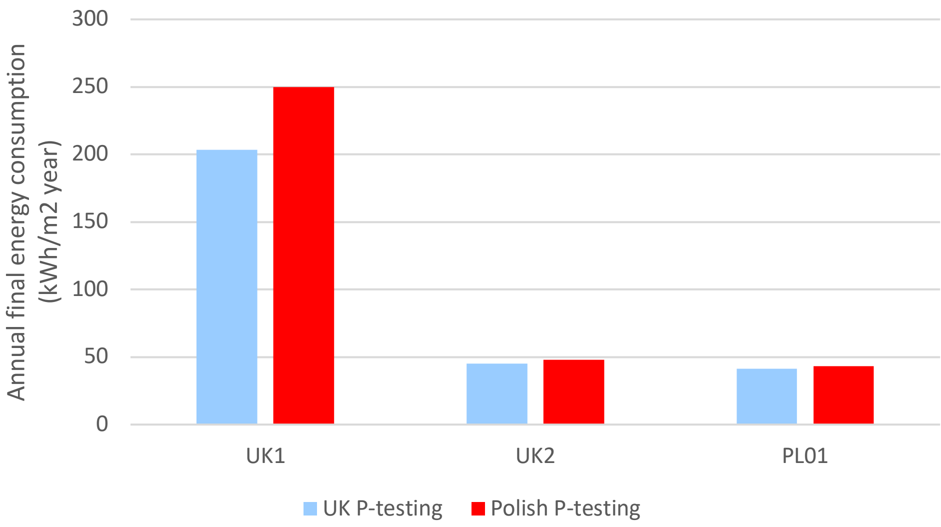

Figure 5- UK and Poland P-testing results

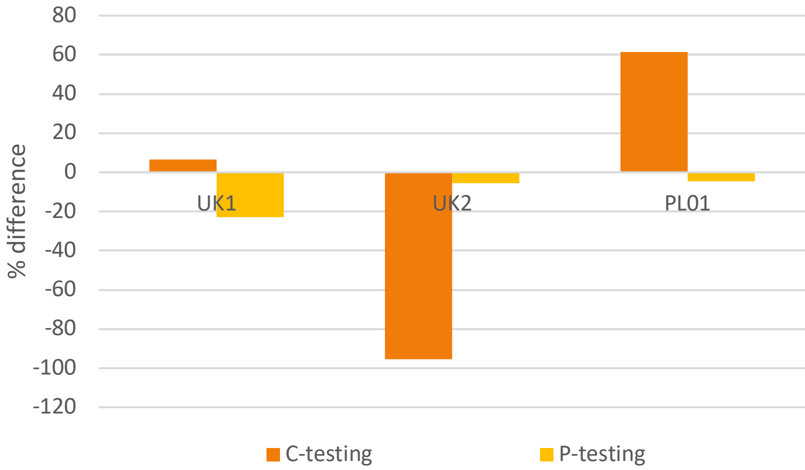

Figure 6- UK and Poland results

2.2 Comparison between UK and Bulgarian methodologies

The UK and Bulgarian methodologies were compared by applying both EPC methodologies to UK1, UK2, BG04 and BG08 buildings. In addition, UK1, UK2, UK3 and BG08 were simulated in IES-VE and dynamic simulation results using relevant UK and Bulgarian weather inputs were compared.

Table 6 shows that the final energy consumption values of UK and Bulgarian EPCs for UK buildings have a small difference (1.8-5.6%), whereas the differences are higher when the UK methodology was applied to the Bulgarian buildings. The Bulgarian methodology includes a calibration step, which requires the assessor to calibrate the initial model to measured energy consumption values. For the UK01 and 02 buildings, the models created using the Bulgarian methodology were calibrated against the UK EPC values which has led to small differences in the results, despite considerable differences in the inputs and methodologies.

As can be seen in Table 1, the Bulgarian and UK methodologies are located at the opposite ends of the standardisation spectrum. The Bulgarian methodology takes most of its inputs from the neutral data inventory files (in terms of schedules and temperature setpoints) whereas the UK methodology applies the values from NCM standards. These differences in approach and input values are reflected in the results of BG4, BG8 and ES16, which were certified using the UK methodology. In addition, the inclusion of electrical appliances' energy consumption in the Bulgarian methodology contributes further to these differences. For BG04, which is a residential building, unlike the Bulgarian methodology, the UK methodology doesn't consider cooling energy consumption which also increases the difference in results.

Comparing the dynamic simulation results shows that using the same inputs for each building and only changing the weather data has led to differences ranging between 4.7-21.2%. For BG08, changing the weather data from Edinburgh to Sofia has led to 21.2% higher energy consumption. This could indicate that the results of EPC calculations have even higher differences, but some of the differences have been cancelled out by the effects of various parameters.

Table 6- UK and Bulgaria comparison

	Annual final energy consumption (kWh/m2year)					
	UK EPC	BG EPC	Difference %	UK P-testing	BG P-testing	Difference %
UK1	137	139.5	-1.79	203.4	220.6	-8.4
UK2	32	30.2	5.6	45.3	47.5	-4.7
UK3	113	-	-	188.3	212.7	-13.0
BG4	199.9	131.7	34.1	-	-	-
BG8	179	147.2	17.8	99.3	120.3	-21.2
ES16	75.2	46.2	38.6	70.6	65.6	7.2

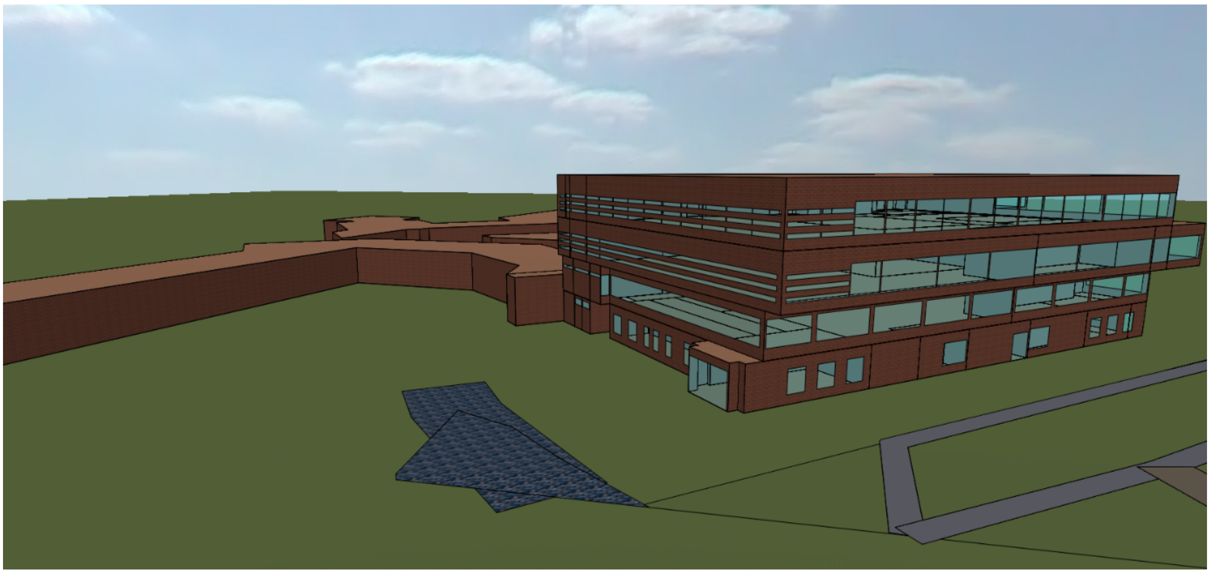

Figure 7- IES model of UK03

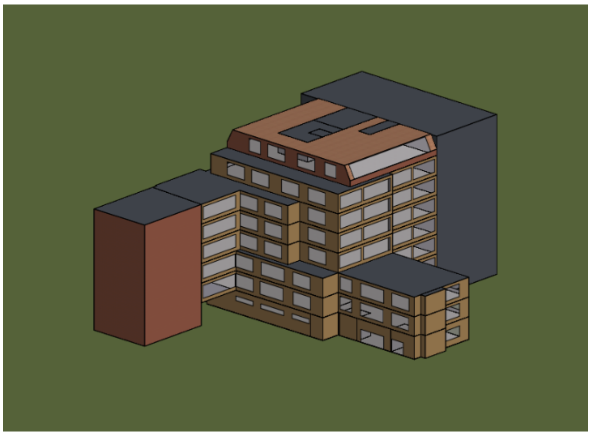

Figure 8- IES model of BG08

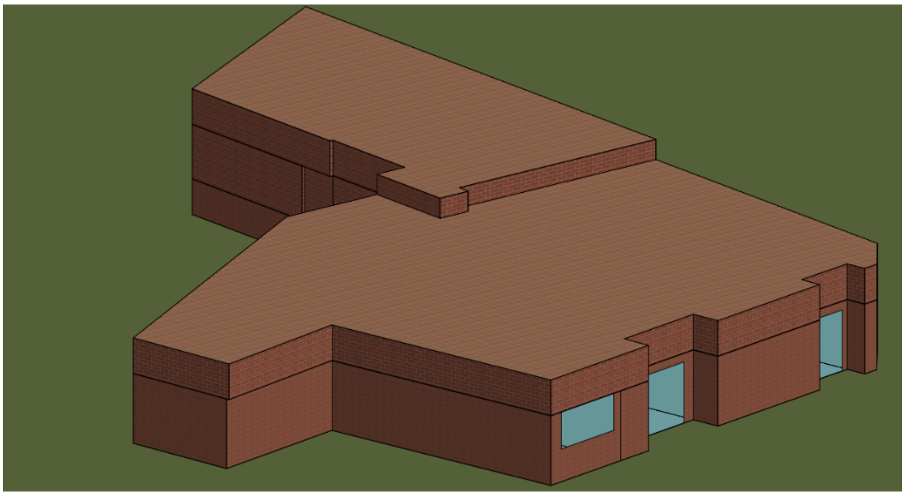

Figure 9- IES model of ES16

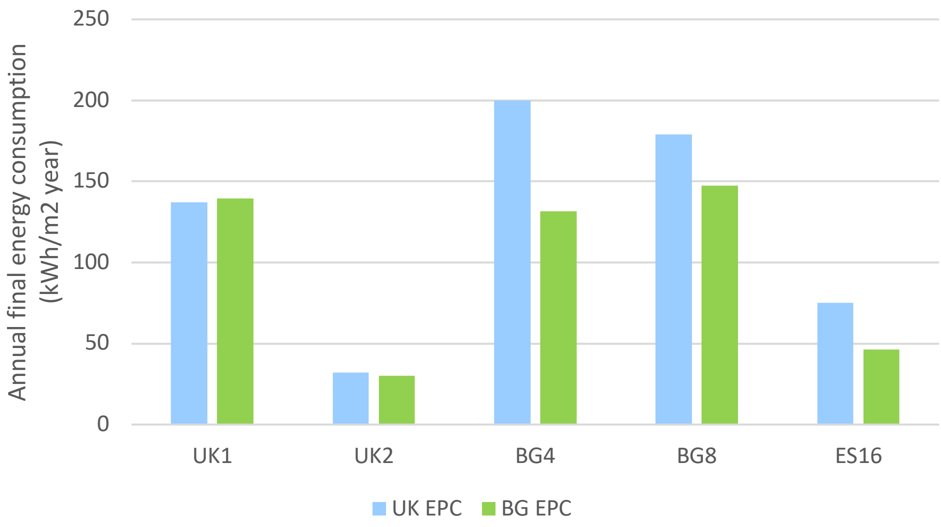

Figure 10- UK and Bulgaria C-testing results

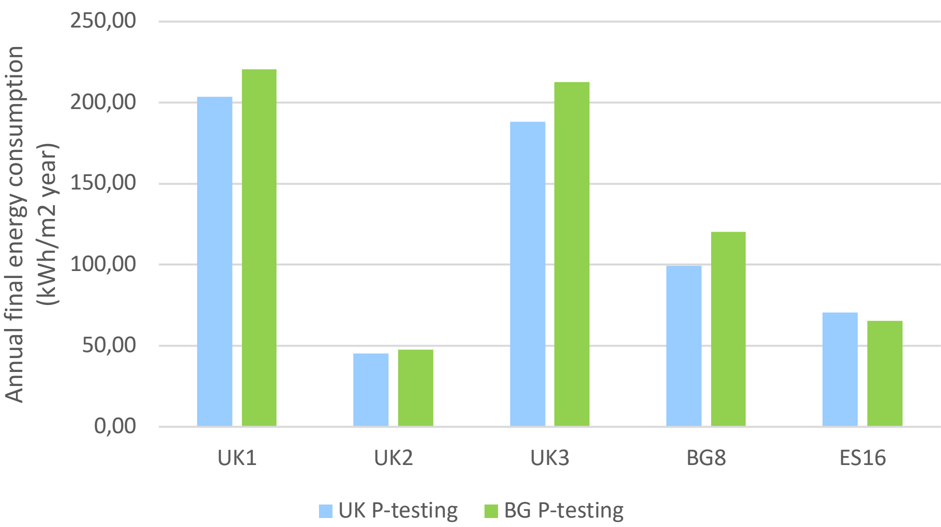

Figure 11- UK and Bulgaria P-testing results

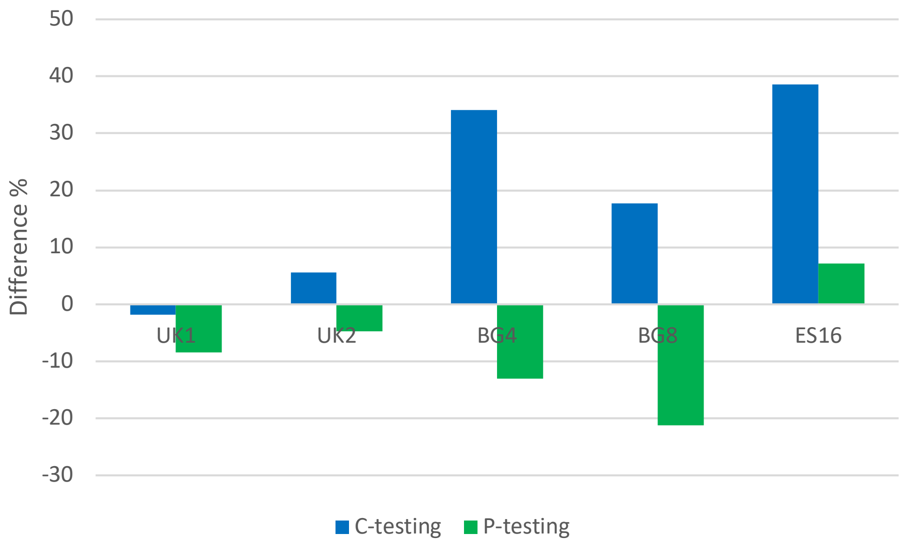

Figure 12- UK and Bulgaria results

2.3 Comparison between UK and Spanish methodologies

The UK and Spanish methodologies were compared by applying both EPC methodologies to UK4, ES14 and ES16. For UK4, which is an educational building in England, only the annual CO_2 emissions value is provided on the EPC document and final (or primary) energy values are not available. Therefore, for this building, the CO2 emission values are compared in Table 7.

In addition to the C-testing results, ES14 and ES16 were simulated in IES-VE and the dynamic simulation results using corresponding UK and Spanish weather inputs are compared.

Table 7 shows that the differences in EPC calculations between the two methodologies range between 23.5-58% while the dynamic simulation results using UK and Spain weather inputs only differ by 4.6-7.4%. This shows that the differences in inputs including schedules, temperature setpoints and other factors have played a larger part in the gap between the results. While both of these methodologies use default values, the schedules, the internal gain density values and temperature setpoints used in each one are different.

Table 7- UK and Spain comparison

	Annual final energy consumption (kWh/m2year)		Difference %	Spain P-testing	UK P-testing	Difference %
	UK EPC	Spain EPC				
UK4	19.9 *	24.6 *	-23.5	-	-	-
ES14	60.1	37.4	37.8	68.8	65.6	4.57
ES16	75.2	31.6	58.0	65.8	70.6	-7.4
* CO2 emissions						

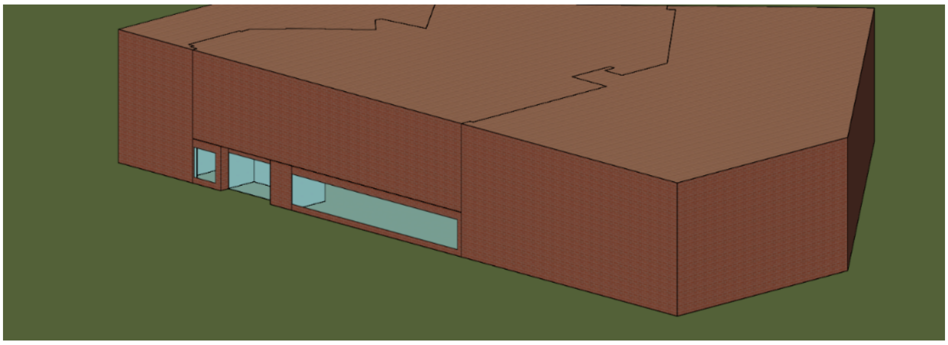

Figure 13- IES model of ES14

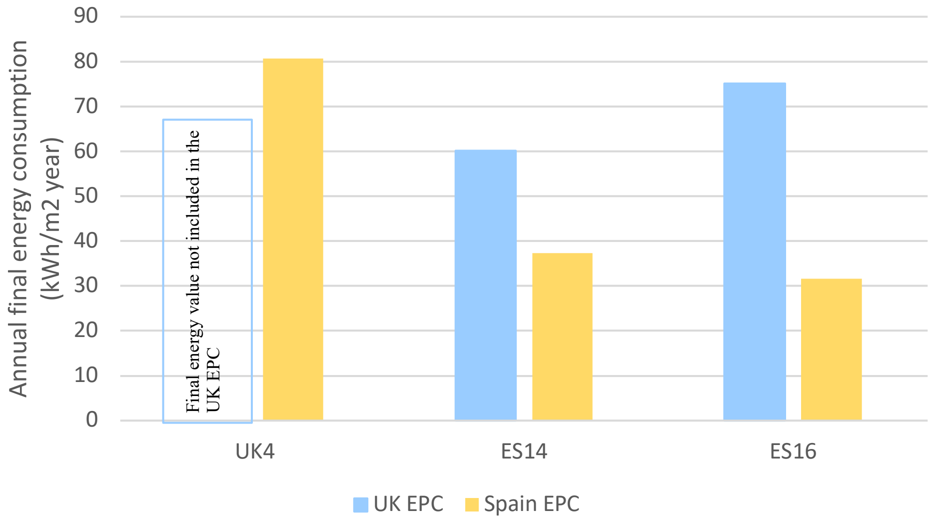

Figure 14- UK and Spain C-testing results

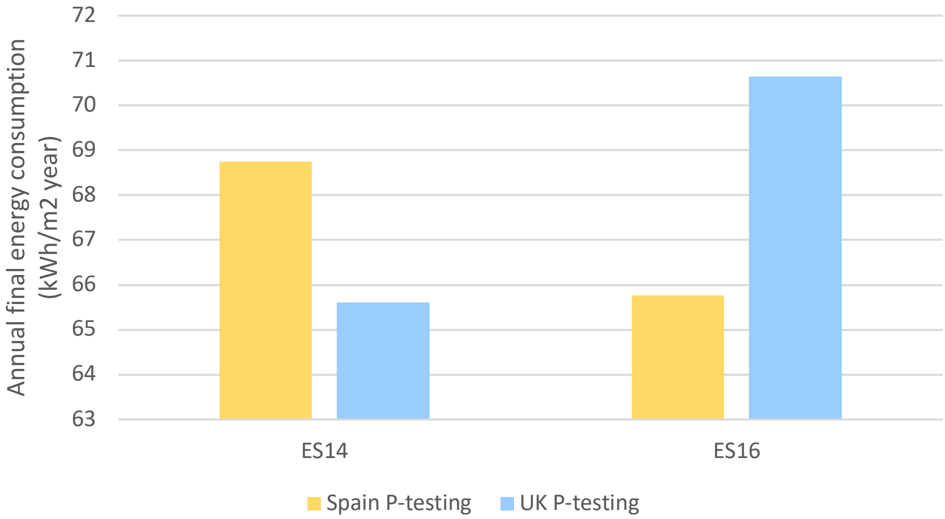

Figure 15- UK and Spain P-testing results

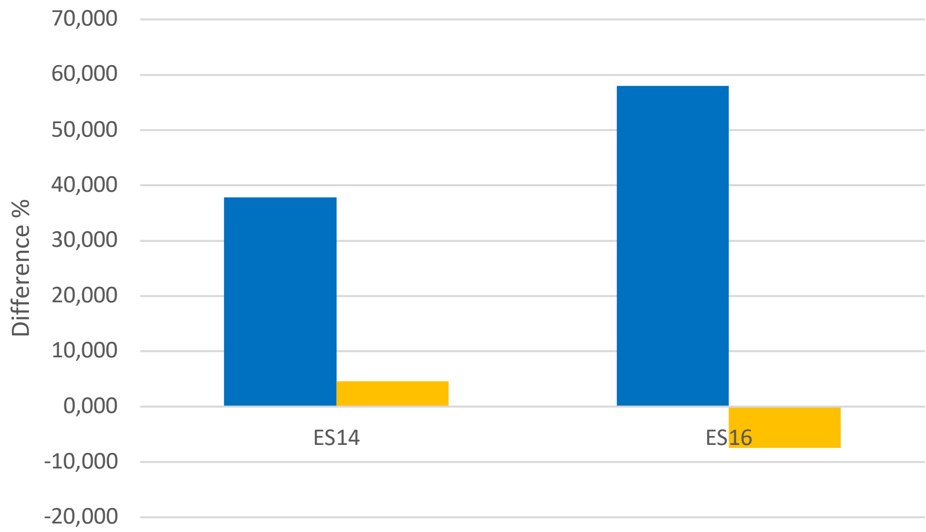

Figure 16- UK and Spain results

2.4 Comparison between Austrian and Slovenian methodologies

The Austrian and Slovenian methodologies were compared by applying both EPC methodologies to AT2, AT5, AT10 and four Slovenian buildings including the SL08, SL06, the faculty of administration and the SL09.

AT02 and AT05 are residential buildings, and unlike the Slovenian methodology, the Austrian methodology doesn't include the cooling demand in energy consumption for residential buildings. This could have contributed to the 242.7% difference in results for AT02. However, the Slovenian methodology result for AT05 is lower than the Austrian result, which shows that cooling demand has not affected the results significantly for this building.

AT10, SL08, SL06, faculty of administration and SL09 are all non-residential buildings. As can be observed from Table 8, there is no clear trend in the difference between the results for these buildings, and the differences range between 38.1-242.7% where the Slovenian results are higher for SL08 and SL09 and lower for the rest.

In terms of using default values, the Slovenian methodology allows the assessor to use tailored schedules, or use the default values, whereas the default values embedded in the Austrian calculation software are automatically applied and can't be changed. This can significantly affect the results of the calculations, as the occupant behaviour profiles play an important role in energy consumption values calculated by EPC methodologies. In addition, temperature setpoints vary between countries which can also affect the results significantly. For example, for the SL09, the Austrian methodology calculates the heating energy consumption as 138.7 kWh/m2year, whereas the value in the Slovenian EPC is 349 kWh/m2year. Another difference contributing to these differences is the reference area. In Slovenia, the reference area is the net floor area, while in Austria it is the gross floor area. In addition to these points, it is important to note that in Slovenia, non-residential buildings can be certified using measured energy consumption, therefore the differences in results don't necessarily reflect differences in calculation methodologies.

Table 8- Austria and Slovenia comparison

	Annual final energy consumption (kWh/m2year)		Difference %
	AT EPC	SL EPC	
AT10	117.5	37	68.5
AT2	9.92	34	-242.7
AT5	188.2	162	13.9
SL8	172.3	367.6	-113.3
SL6	200.4	105.9	47.1
faculty of administration	149.3	92.3	38.2
SL9	204.6	509.5	-149.0

Figure 17- Austria and Slovenia C-testing results

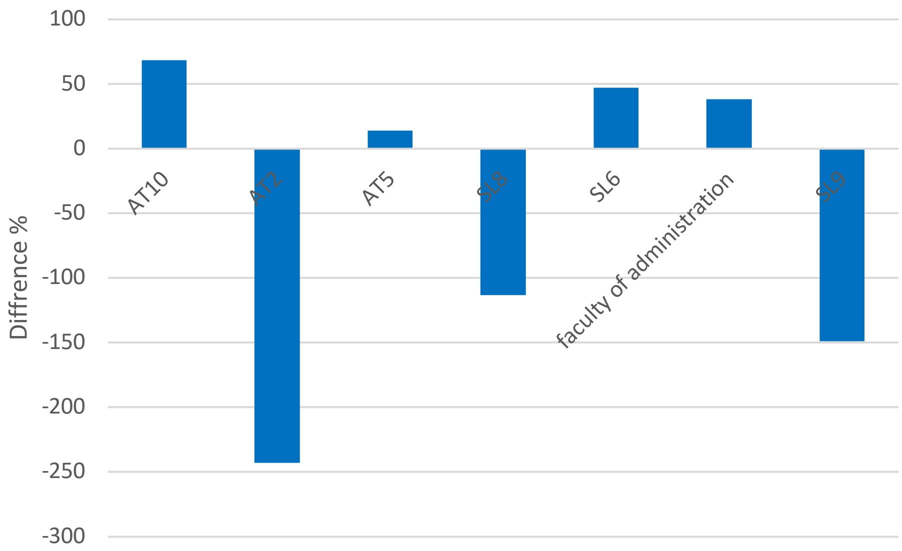

Figure 18- Austria and Slovenia results

2.5 Comparison between Austrian and Croatian methodologies

The Austrian and Croatian methodologies were compared by applying both EPC methodologies to AT2, AT6, HR05, HR18, and three Slovenian buildings including the faculty of education, the faculty of architecture, and the faculty of medicine. The results show that the largest difference in results is for AT02, which is a residential building. This could be due to the fact that the Austrian methodology doesn't include cooling in residential buildings in EPC calculations. For the rest of the buildings, the Austrian methodology returns higher values of energy consumption, which could be due to the different operation profiles as well as different setpoints in the two methodologies. It's important to note that both countries use default profiles in their EPC calculations.

Table 9- Austria and Croatia comparison

	Annual final energy consumption (kWh/m2year)		Difference %
	AT EPC	HR EPC	
AT02	9.92	32.0	-222.9
AT06	79.4	57.7	27.4
HR05	91.5	15	83.6
HR18	130.2	131.5	-1.0
Faculty Of Education	172.3	110.2	36.0
Faculty Of Architecture	200.4	109.2	45.5
Faculty Of Medicine	204.6	156.4	23.5

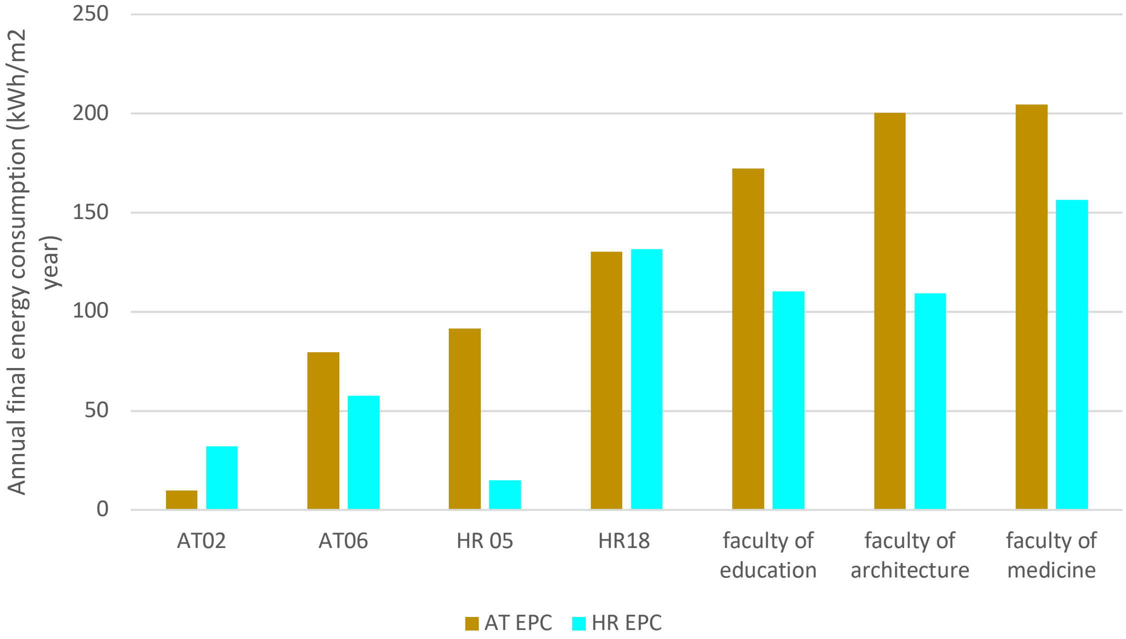

Figure 19- Austria and Croatia C-testing results

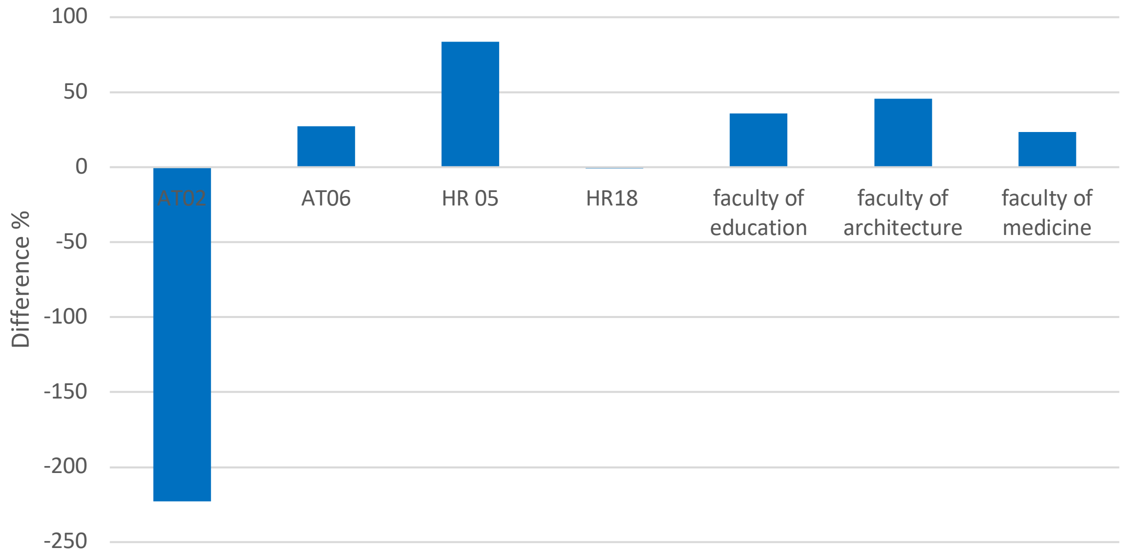

Figure 20- Austria and Croatia results

2.6 Comparison between Austrian and Polish methodologies

The Austrian and Polish methodologies were compared by applying both EPC methodologies to the PL11 building. Unlike the Polish methodology, which is tailored to each building, the Austrian methodology is highly standardised. Therefore the inputs to the Polish methodology can reflect the actual building operation (taken from the neutral data inventory information) whereas the Austrian methodology automatically applies the standard values, which could lead to considerable differences in results.

Table 10- Poland and Austria comparison

	Annual final energy consumption (kWh/m2year)		Difference %
	PL EPC	AT EPC	
PL11	232.6	128	45.0

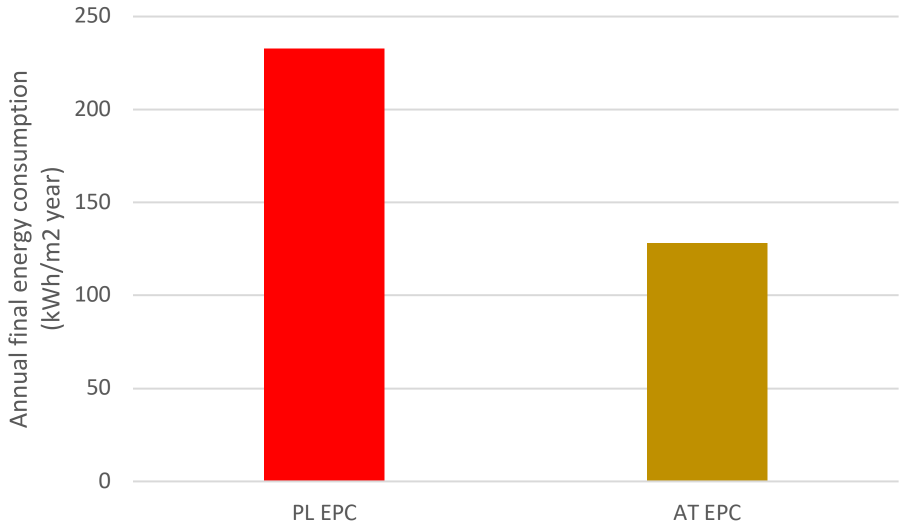

Figure 21- Poland and Austria C-testing results

2.7 Comparison between Bulgarian and Polish methodologies

The Bulgarian and Polish methodologies were compared by applying both EPC methodologies to the UK1 and UK2 buildings. The results of dynamic simulations using IES-VE are also included in Table 11. It is clear that even though changing the weather data in the dynamic simulation had minimal impact on the results for UK02, the differences in EPC methodologies led to highly different annual energy consumption values.

Table 11- Bulgaria and Poland comparison

	Annual final energy consumption (kWh/m2year)					
	BG EPC	PL EPC	Difference %	BG p-testing results	PL EPC p-testing results	Difference %
UK1	139.4	128	8.2	220.6	249.7	-13.2
UK2	30.2	62.6	-107.2	47.5	47.9	-0.9

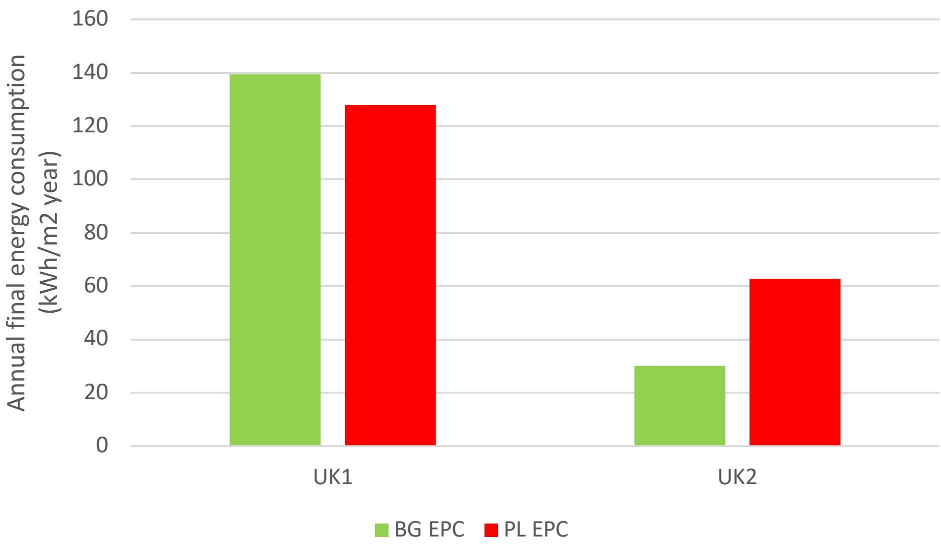

Figure 22- Bulgaria and Poland C-testing results

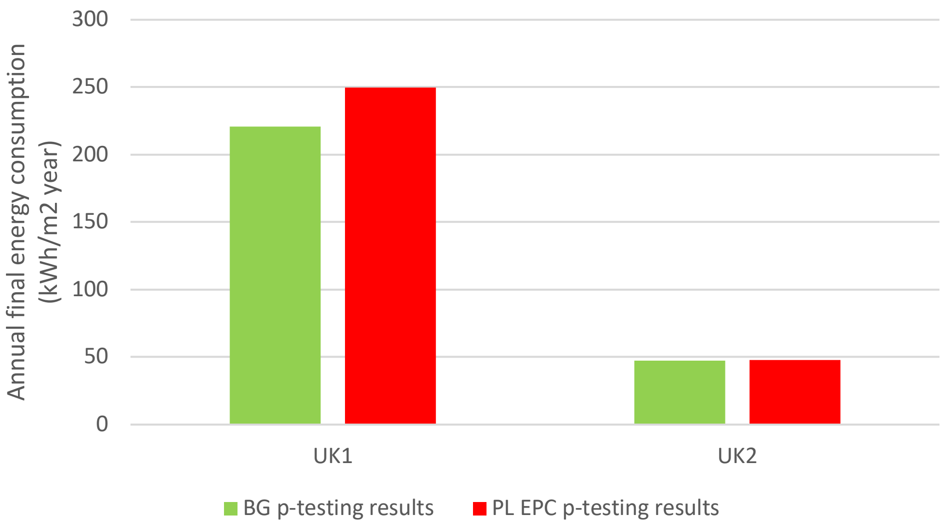

Figure 23- Bulgaria and Poland P-testing results

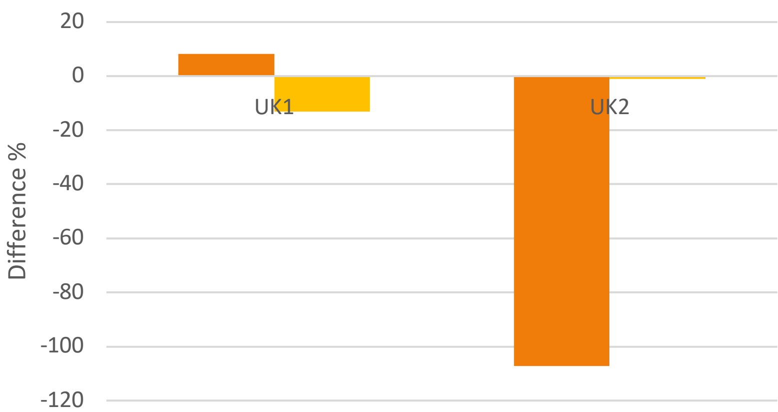

Figure 24- Bulgaria and Poland results

2.8 Comparison between Spanish and Greek methodologies

The Spanish and Greek methodologies were compared by applying both EPC methodologies to the ES11 and GR8 buildings. Since these methodologies are quite similar and the heating and cooling degree days between the two climates (Valladolid with Tripoli) are very close, the differences in results are low. These small differences could be due to parameters such as user profiles and temperature setpoints being different in the two methodologies. Also, the Greek methodology includes the energy consumption of pumps in residential buildings, which is not the case in the Spanish methodology and can affect the results. In addition, the required data about efficiency parameters of HVAC systems are different in the two methodologies (SCOP in the Spanish software, and efficiency grade in the Greek software) which can create some errors.

Table 12- Spain and Greece comparison

	Annual final energy consumption (kWh/m2year)		
	Spain EPC	GR EPC	Difference %
ES11	189.0	200.2	-5.92032
GR8	150.3	176.2	-17.24

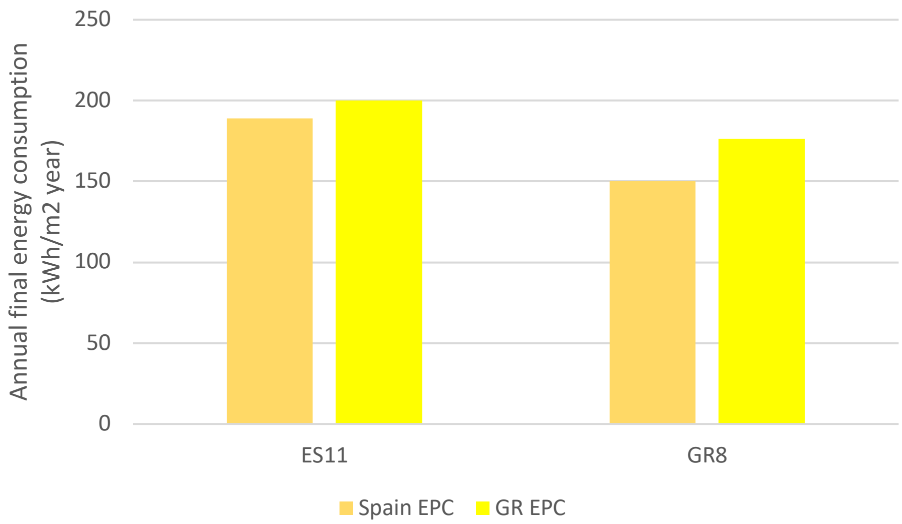

Figure 25- Spain and Greece C-testing results

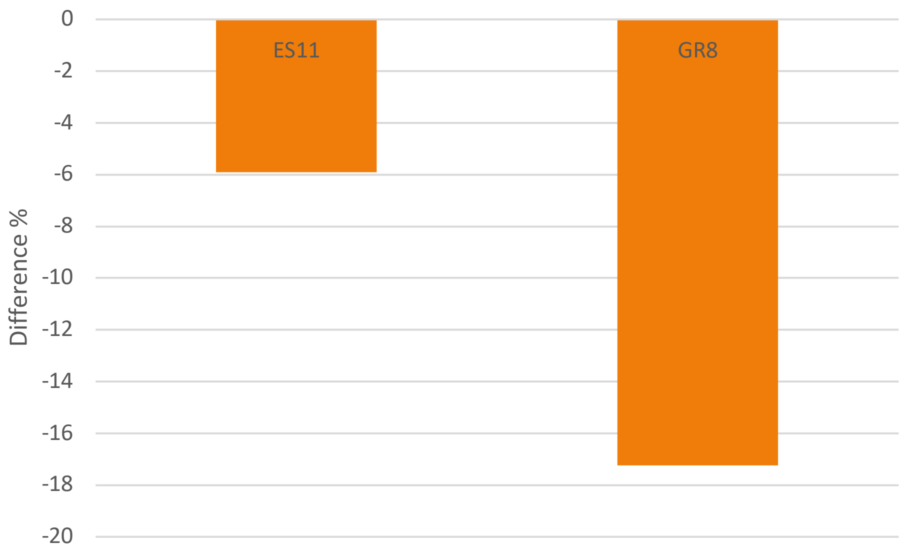

Figure 26- Spain and Greece results

2.9 Comparison between Bulgarian and Greek methodologies

The Bulgarian and Greek methodologies were compared by applying both EPC methodologies to the BG7, GR11 and GR15 buildings. As can be observed from the results, despite the differences in methodologies, the differences in final energy consumption values are very low for GR11 and GR15. Looking at the detailed results for GR11 and GR15, the difference between heating and cooling demands in the two methodologies is negligible. The main difference in results is seen in the DHW and lighting calculations. In the Greek EPCs of these buildings, the DHW energy consumption is zero whereas the Bulgarian methodology has calculated this demand. For lighting calculations, in the Bulgarian methodology the energy consumption for lighting is calculated based on the simultaneous power as an input parameter (which was estimated based on the data for the total installed power and adjustment coefficients) whereas in the Greek methodology, the software calculates this amount based on the illuminance and power density of the installed lighting systems. Another parameter which is different between the two methodologies is the inclusion of electrical appliances in Bulgarian EPCs. It is also worth noting that unlike the Greek methodology which uses a default number of hours (for building operation profiles) embedded in the software, the Bulgarian methodology requires tailored inputs from the assessor, which could contribute to differences in results between these two methodologies. However, since the Bulgarian methodology includes a calibration step, which in these cases was performed against the Greek EPC values, the differences in results are minimal. Differences are more evident in the BG07 results, as the calibration step doesn't exist in the Greek methodology.

Table 13- Bulgaria and Greece comparison

	Annual final energy consumption (kWh/m2year)		
	BG EPC	GR EPC	Difference %
BG7	34.2	24.6	28.1
GR11	185.5	185	0.3
GR15	194.2	192.7	0.8

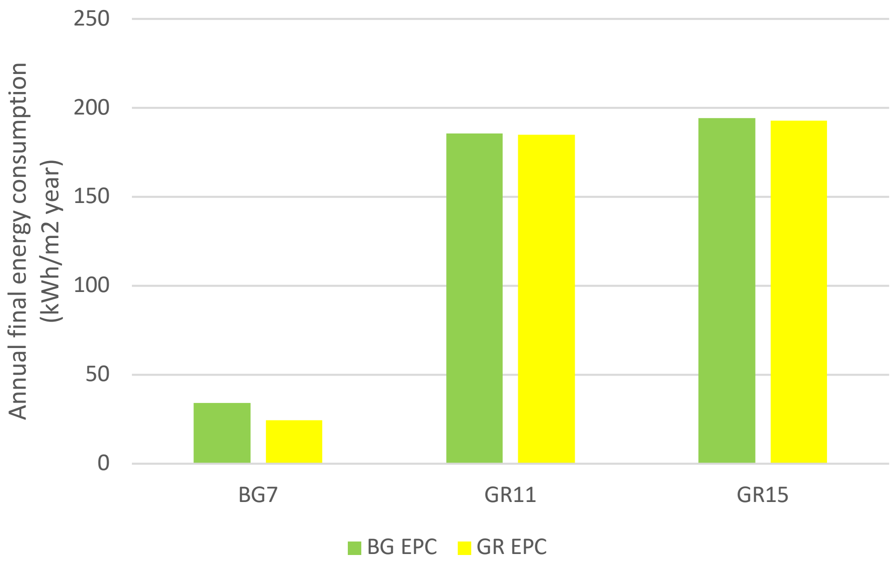

Figure 27- Bulgaria and Greece C-testing results

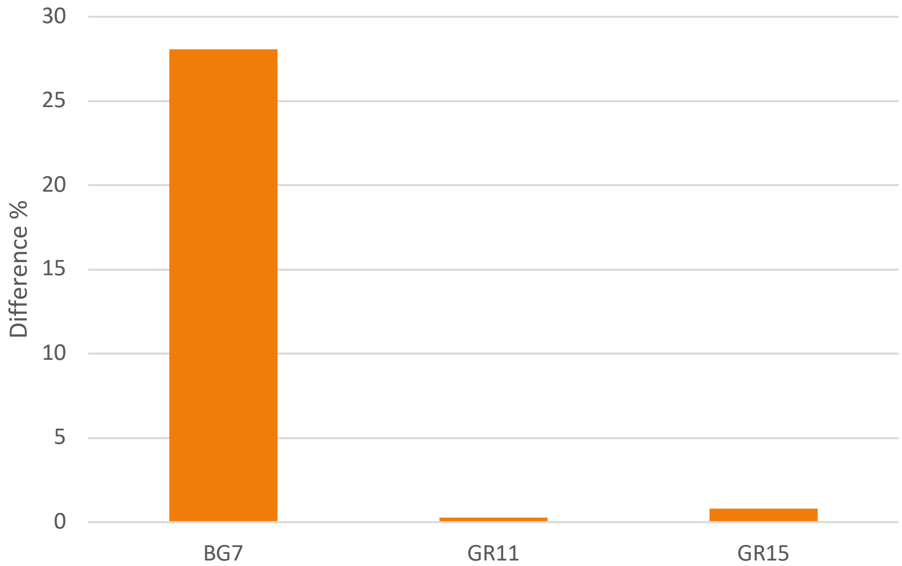

Figure 28- Bulgaria and Greece results

2.10 Comparison between Danish and Croatian methodologies

The Danish and Croatian methodologies were compared by applying both EPC methodologies to DK02, DK04, HR1, HR7 and HR9 buildings. For HR01 and HR07, the heating demand is calculated 32% higher with the Danish methodology. For HR09 however, the Danish methodology has returned a 38% lower value for the heating energy consumption. As this is a public building, this difference may relate to relatively higher default values for this type of building in the Croatian methodology. For DK02, the difference between the results is 28.5%, which is mainly caused by a 12% difference in heating demand as well as differences in cooling demand. For DK04, the two methodologies have returned very similar results, as the heating demand values are identical. In general, the differences in results are potentially caused by differences in the weather data, as the Croatian methodology only provides two reference cities as the basis for calculations, Zagreb and Split. In addition, even though these methodologies are similar in terms of their use of default values for most inputs, each country has specific values which are different and can contribute to slight differences in results.

Table 14- Denmark and Croatia comparison

	Annual final energy consumption (kWh/m2year)		
	DK EPC	HR EPC	Difference %
DK2	140.8	100.7	28.5
DK4	136.9	129.7	5.3
HR1	95.8	72	24.8
HR7	89.3	72	19.3
HR9	63.8	117.4	-84.1

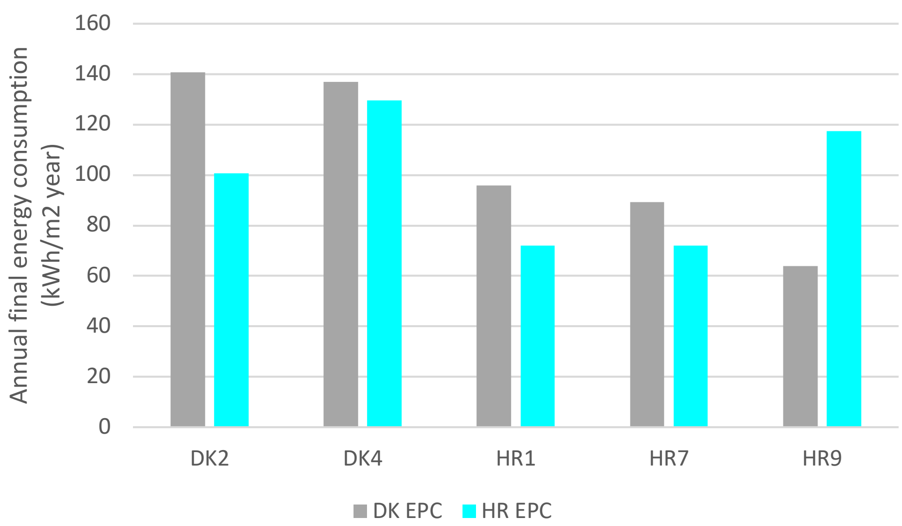

Figure 29- Denmark and Croatia C-testing results

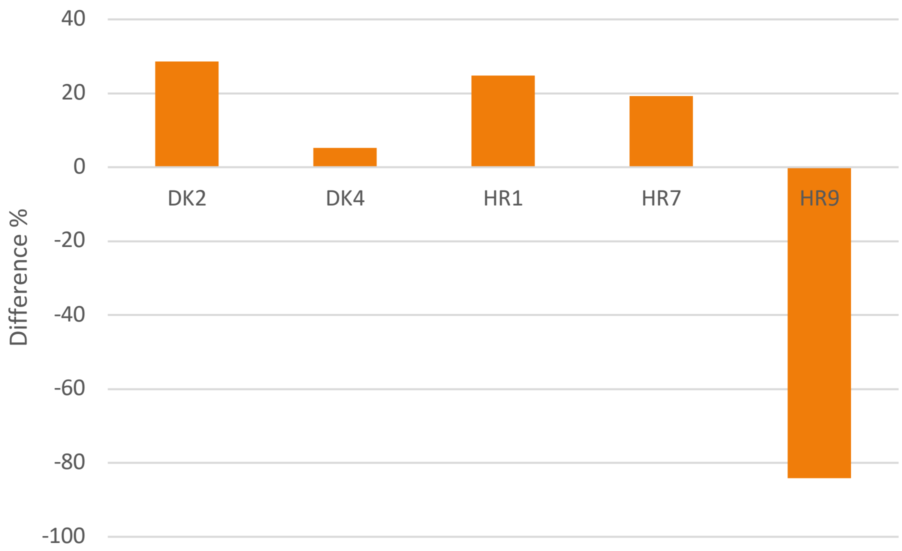

Figure 30- Denmark and Croatia results

2.11 Comparison between Danish and Polish methodologies

The Danish and Polish methodologies were compared by applying both EPC methodologies to PL3, PL5, PL7, PL9, DK6, DK7, DK8, DK9 and DK10 buildings. As can be observed inTable 15, the differences in results vary between 0.5-240% which is a considerably large range.

Overall, the Polish methodology is a more tailored approach compared to the Danish methodology which uses more default inputs. There are also differences in how each methodology approaches inputs including ventilation systems, distribution pipes' heat losses, and internal heat gains. Also, due to the high levels of insulation for walls in Danish buildings, the orientation of walls is not included in EPC calculations, and only window orientation is required, which is not the case for the Polish methodology. There are differences in default values between the two methodologies as well, including the Domestic Hot Water demand values, occupancy and electrical devices' heat gains, and the building operation times. These factors all contribute to the differences between results depending on the characteristics of the case study building.

Table 15- Poland and Denmark comparison

	Annual final energy consumption (kWh/m2year)		
	PL EPC	DK EPC	Difference %
PL03	36.3	98.8	-172.1
PL05	30.8	45.5	-47.7
PL07	137.42	104.3	24.1
PL09	23	78.3	-240.4
DK6	169.1	107.6	36.4
DK7	189.3	166.6	12.0
DK8	165.6	107.7	35.0
DK9	180.4	179.4	0.5
DK10	204.5	150.1	26.6

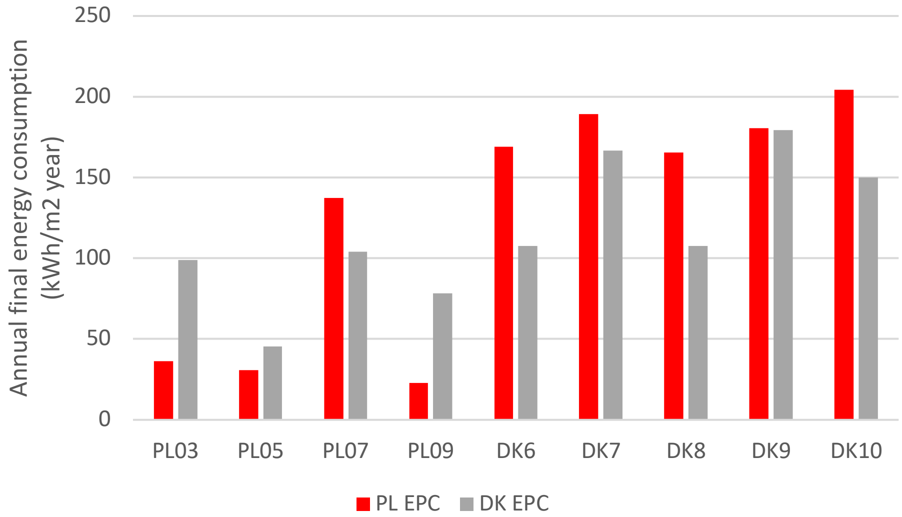

Figure 31- Poland and Denmark C-testing results

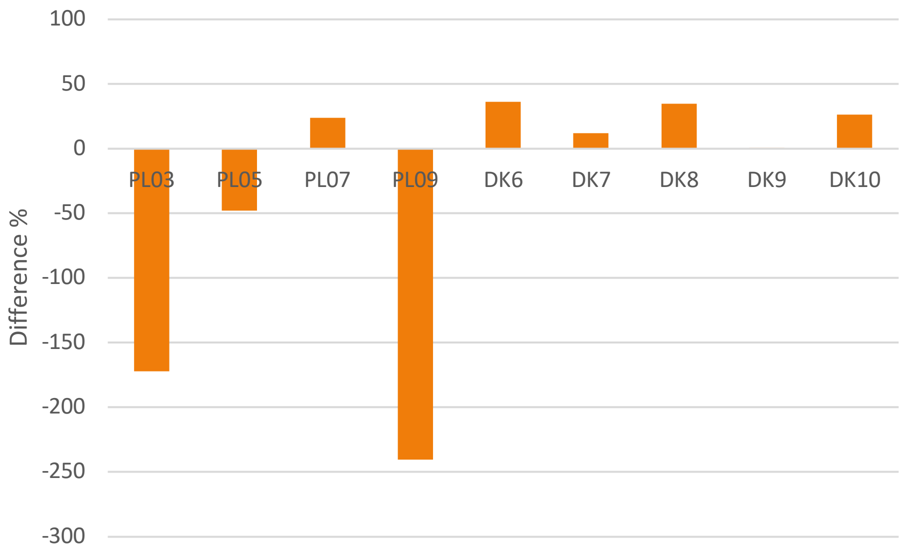

Figure 32- Denmark and Poland results

2.12 Comparison between Croatian and Slovenian methodologies

The Slovenian and Croatian methodologies were compared by applying both EPC methodologies to HR2, HR4, SL6, SL8 and SL9 buildings. In the Croatian methodology, for residential buildings lighting and cooling are not included in the EPC calculations, whereas the Slovenian methodology accounts for these values.

For SL06, the two methodologies returned similar results. However, for the other buildings, the differences range between 47.2-604.5%. For SL08, the detailed calculations show that the heating demands are similar for both methodologies, therefore the main differences lie in other usages including lighting and cooling. For SL09, however, the Slovenian methodology reported the heating demand as 349 kWh/m2year and the Croatian methodology calculated it as 90.4 kWh/m2year. Detailed results showed that transmission heat losses were very close in both results and the main differences were in the internal gains, solar gains, and ventilation heat losses. Weather input differences, as well as differences in the schedules used in each methodology, are amongst the parameters that lead to such differences. The Croatian methodology uses default values for operation profiles, whereas the Slovenian methodology allows the assessor to use tailored values for each building, leading to differences in the internal heat gains. In addition to these points, it is important to note that in Slovenia, non-residential buildings can be certified using measured energy consumption, therefore the differences in results don't necessarily reflect differences in calculation methodologies.

Table 16- Croatia and Slovenia comparison

	Annual final energy consumption (kWh/m2year)		
	HR EPC	SL EPC	Difference %
HR2	64	451	-604.7
HR4	91	134	-47.3
SL6	109.2	105.9	3.0
SL8	110.2	367.6	-233.5
SL9	156.5	509.5	-225.7

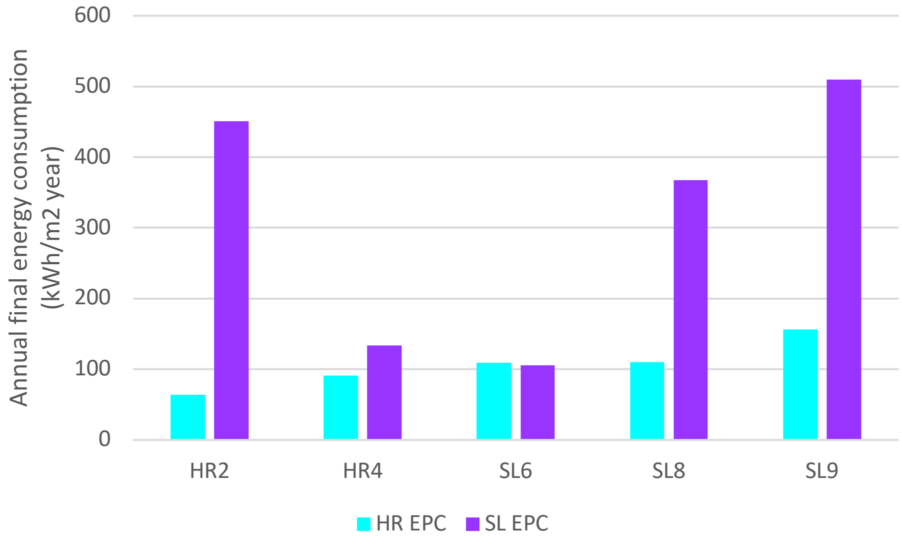

Figure 33- Croatia and Slovenia C-testing results

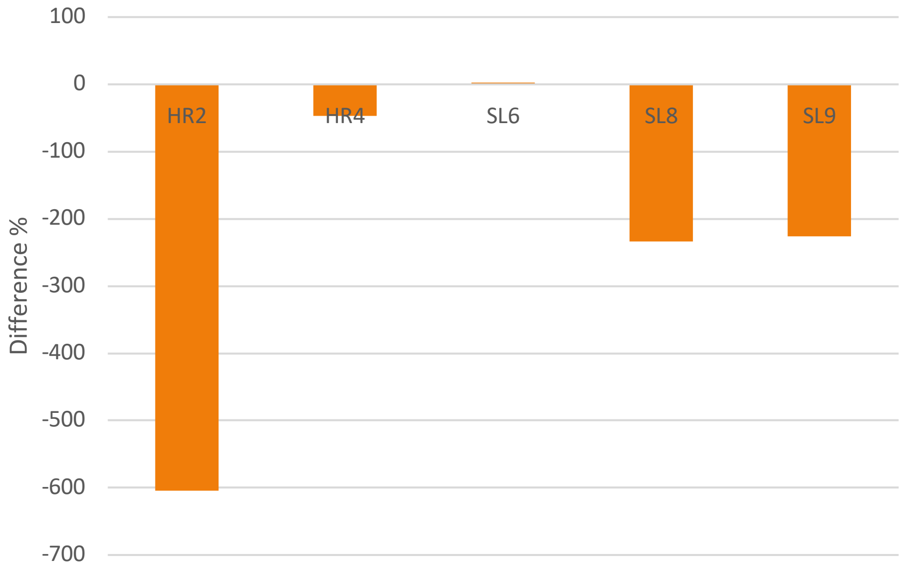

Figure 34- Croatia and Slovenia results

2.13 Comparison between Spanish and Bulgarian methodologies

The Spanish and Bulgarian methodologies were compared by applying both EPC methodologies to ES8 and ES16 buildings. ES16 was also modelled using IES-VE and the results of the simulations using Spanish (Salamanca) and Bulgarian (weather zone 9) weather inputs are compared in Table 17.

The Bulgarian software does not provide values for schedules and parameters related to the heating and cooling demands. Therefore, the assessor has to provide such values based on the actual building operation, or the norms in Bulgaria. For ES08, the typical values for operating schedules, ventilation rates, hot water demand, and the number of people for Bulgarian museums were applied in modelling the building, whereas in the Spanish methodology, default operation hours were used. For this building, the results of the model in the Bulgarian methodology were calibrated against the Spanish EPC results, which has led to the differences between the results of the two methodologies being very low despite different assumptions and approaches in modelling. The detailed results show that while the heating energy consumption results are very close, the cooling energy consumption in the Spanish results is 2.6 times higher than the Bulgarian, which is mostly attributed to the difference in the weather inputs and operation times. It is worth noting that the Bulgarian EPC includes appliances' energy consumption in the results while the Spanish EPC doesn't, which also contributes to the differences in the results.

Similar to ES08, the parameters required for calculating heat gains were taken from the Bulgarian norms for office buildings, which are different to the default values used in the Spanish methodology. For this building, despite calibrating the model created in the Bulgarian software to the Spanish EPC values, the results show a 46.2% difference which could be due to the inclusion of appliances in the Bulgarian methodology, or due to the differences in input parameters. Comparing the P-building results of this building shows that changing the weather data between the relevant locations in Bulgaria and Spain only changes the results by 0.32%, highlighting the fact that differences in the methodologies are the main cause of the differences in results.

Table 17- Spain and Bulgaria comparison

	Annual final energy consumption (kWh/m2year)					
	Spain EPC	Bulgaria EPC	Difference %	P-testing Bulgaria	P-testing Spain	Difference %
ES8	58.2	62.9	-7.9	-	-	-
ES16	31.6	46.2	-46.2	65.6	65.8	-0.3

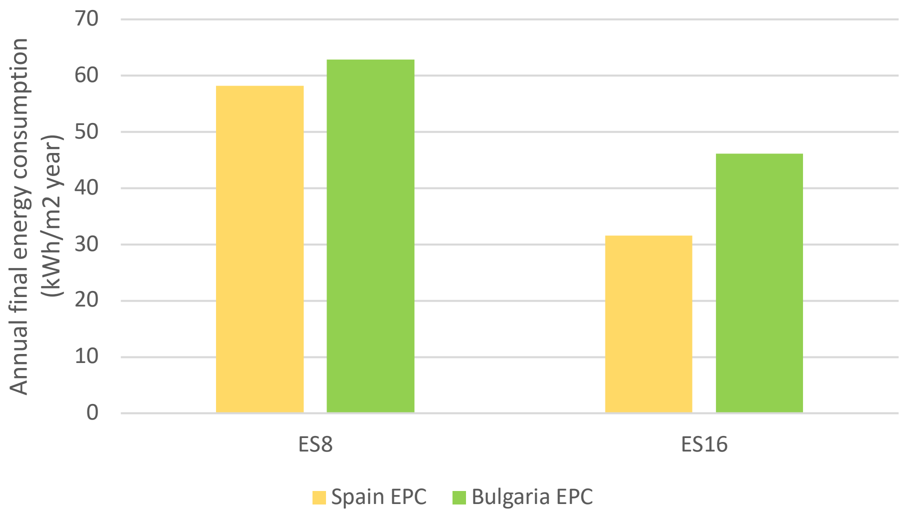

Figure 35- Spain and Bulgaria C-testing

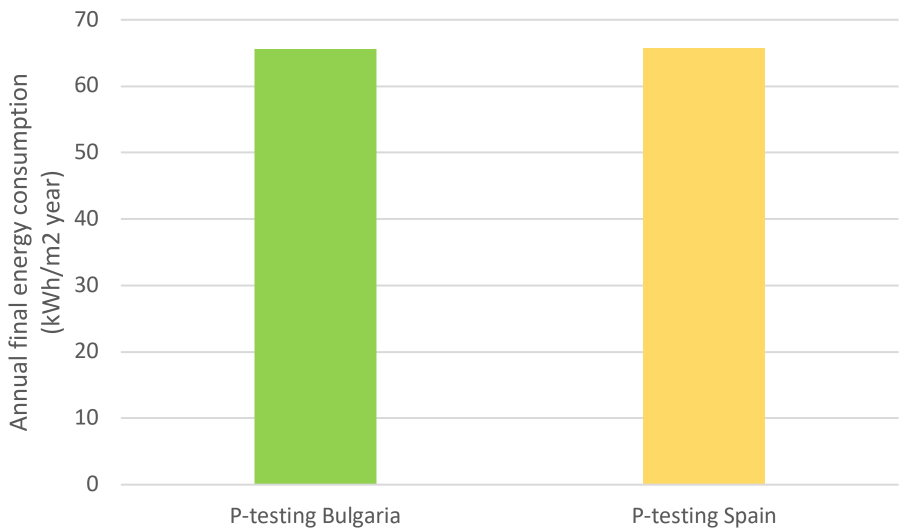

Figure 36- Bulgaria and Spain P-testing results

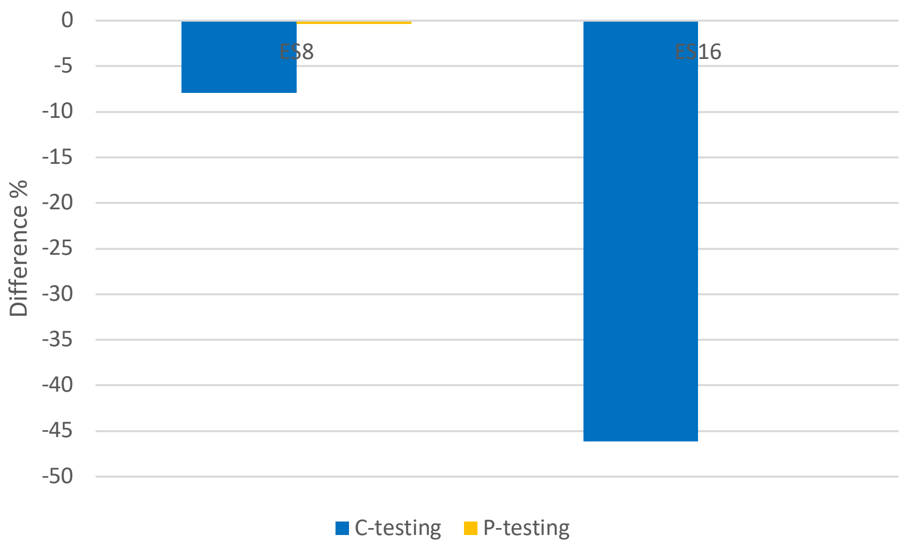

Figure 37- Spain and Bulgaria results

2.14 Comparison between Maltese and Greek methodologies

The Maltese and Greek methodologies were compared by applying both EPC methodologies to GR6, MT2 and MT5 buildings. It's important to note that the Maltese EPC documents don't provide the final energy consumption values, therefore for these buildings primary energy values were used for comparison. However, this approach is not accurate since each country uses different primary energy factors and differences in these values are not indicative of differences in EPC calculation inputs and approaches.

As shown in Table 18, The differences in results range between 10.8-539%. In addition to the differences due to different primary energy factors, other possible parameters leading to variations in results are as follows. The Greek EPC assumes a theoretical HVAC system in the absence of an actual one in MT02 and MT05 buildings. Also, lighting isn't considered in calculations for residential buildings in the Greek methodology (MT02, MT04 and GR06). For non-residential buildings, unlike the Greek methodology, the Maltese EPC methodology divides the building into various zones based on space usage. In addition, the DHW calculations are different between the two countries, which also increases the differences between the results.

Table 18- Greece and Malta comparison

	Annual final energy consumption (kWh/m2year)		Difference %
	Malta EPC	Greece EPC	
GR6	102.2	121.8	-19.2
MT2	99	109.7	-10.8
MT5	115.4	61.5	46.7
MT4	17.4	111	-539.0
MT9	479	144.2	69.9

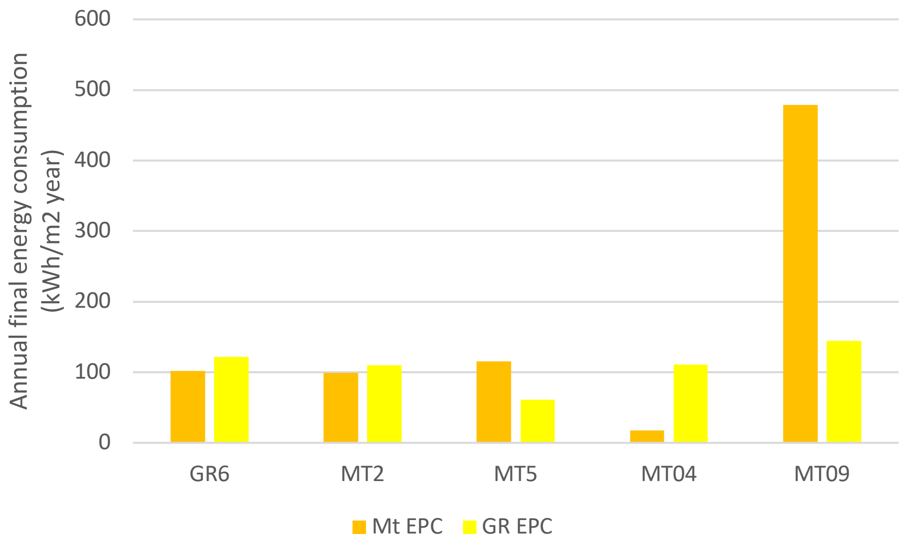

Figure 38- Malta and Greece C-testing results

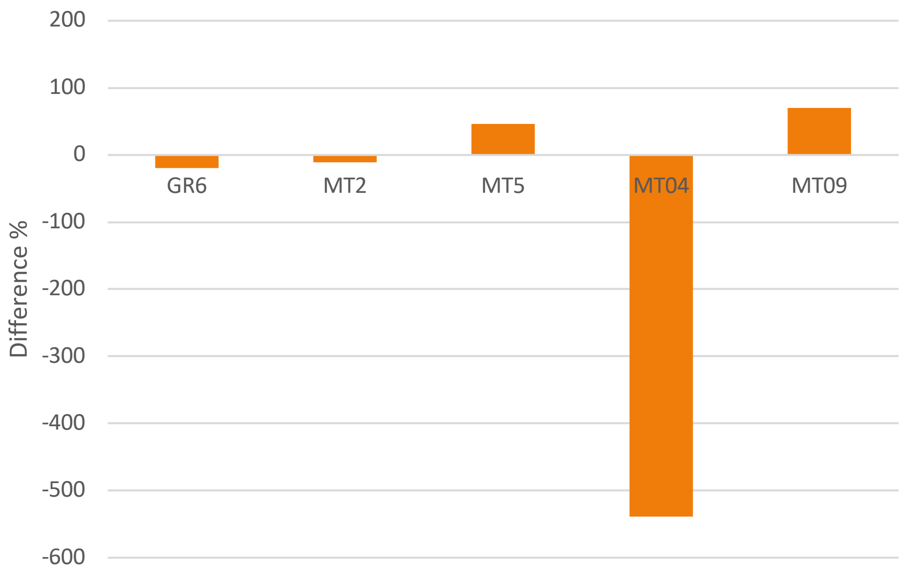

Figure 39- Malta and Greece results

3 Conclusion

This report provided a numerical analysis of comparisons between EPC methodologies of the crossCert countries and highlighted the differences between input parameters and calculation steps which contribute to differences in EPC results. Figure 40 shows the average values of differences in final energy consumption results between methodologies studied in crossCert. For calculating the average difference amounts, the absolute value of differences between final energy consumption results were considered in order to eliminate cancellation effects.

As can be observed from this graph, the comparisons between Bulgaria and other countries including the UK, Greece, and Spain are amongst the lowest values in the graph. This is not due to the similarities between the Bulgarian methodology to these countries, but rather due to the fact that this methodology includes a calibration step, requiring assessors to calibrate the model against actual energy consumption data. However, in the absence of actual energy consumption data for most of the buildings tested in the cross-testing phase, calibration was performed against EPC values. This has led to lower differences in the results of the buildings C-tested with the Bulgarian methodology. For other countries, the comparison between the Spanish to Greek methodology, and Danish to Croatian methodology have returned the lowest difference values, which could indicate a higher level of similarity between these methodologies.

More case studies are required to extrapolate on numerical results of these conclusions to wider building stocks in specific countries. However, the numerical results presented in this report should be placed in context of the knowledge of the applied EPC methodolgoies; that is, the modelled case-studies help illustrate known differences in those methodologies and provide some numerical indication of the likely consequences of those differences. This further illustrates the divergent approaches to EPC generation amongst the target countries, and the difficulty in comparing such bespoke, country-specific methodologies to buildings outside of the original, targeted geographical region.

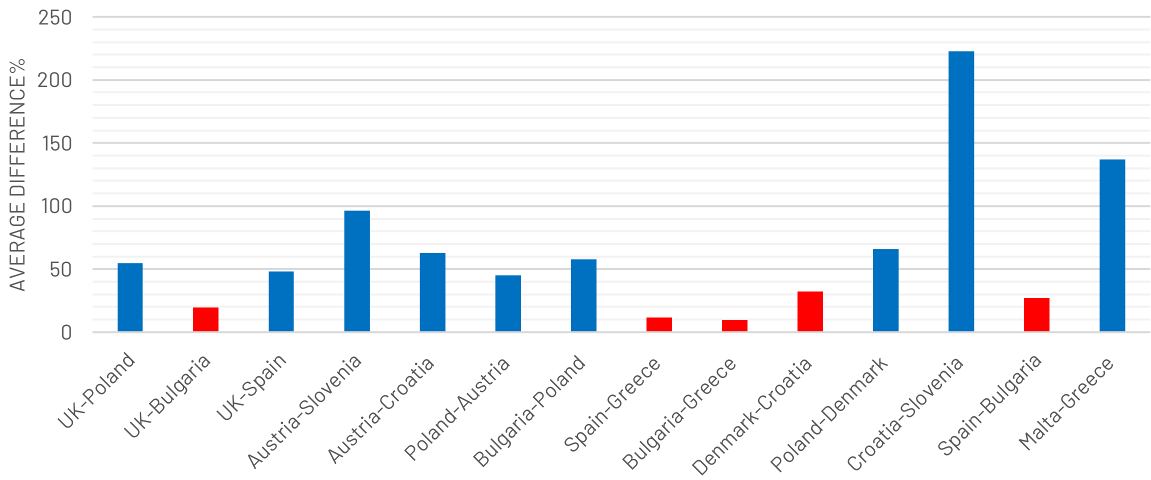

Figure 40- Average differences between C-testing results

4 References

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