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An investigation of the appropriateness of current methodologies for energy certification of Mediterranean housing

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ABSTRACT

The Energy Performance of Buildings Directives (EPBDs) are political initiatives taken by the European Union to tackle the problems of climate change and security of energy supply. One of the key measures of these directives is the use of Energy Performance Certificates (EPCs) to model the energy performance of housing. This research investigates whether the current calculation methodologies in use for the generation of EPCs in the Mediterranean are appropriate. The analysis was carried out by comparative testing using different national methodologies from Cyprus, Italy, Malta and Spain on four test case study dwellings. The test results were validated against the output from dynamic simulation software and against monitored temperature and energy data from the test case properties. Considerable differences in the outputs from the various national methodologies currently in use were found. It was concluded that several of the EPC calculation methodologies have not been calibrated against the energy profile representative of the national or regional building stock; accurate definition of the operating parameters for the heating and cooling system is particularly significant if a more precise prediction of the energy performance of the dwelling is required; and the underlying assumptions made by the national application of the EN ISO 13790 standard for the calculation of the energy use for space heating and cooling have a greater influence on the outputs from the certification methodology than the choice of calculation method. It is quite clear that calibration of the EPC methodology is essential for the certificates to provide an effective means of achieving the aims of the EPBD. However, at a conceptual level, the results from this research have also shown that the mild Mediterranean climate with its inherently low energy demand for residential space heating and cooling could justify a different regional approach to tackle the EPBD goals of reduction in carbon emissions and dependency on imported fuels.

1. Introduction

This research investigated the methodologies implemented for energy certification of housing in the Mediterranean region of Europe, specifically Cyprus, Italy, Malta, and Spain. The methodologies were applied to four test case properties, which were also modelled using the dynamic simulation software IES-VE. Actual internal conditions and energy consumption of the test case properties were metered and analysed. The predicted energy performance generated by the methodologies was compared to the dynamic simulation models generated by IES-VE and the metered data from the test case properties. The objective was to determine whether the certification methodologies provide an accurately calculated value of energy demand in Mediterranean housing.

The Energy Performance of Buildings Directives (EPBDs) form part of the initiatives taken by the European Community in relation to climate change and the security of energy supply. The first directive 2002/91/EEC [14] was intended to counteract the increasing dependence of the European Community on external energy sources, as well as to meet commitments made under the Kyoto Protocol to cap and to reduce greenhouse gas emissions. The energy certificates calculated by the methodologies are one of the main outcomes of the EPBD. According to the results of the European Commission's Internal Market Scoreboard, the EPBD was the worst performer in terms of transposition before the deadline date of May 2006 with nine countries (Belgium, Greece, France, Cyprus, Luxembourg, Hungary, Malta, Austria, Slovenia) failing to fully transpose the directive as at May 2008 [13]. A comparative analysis of progress towards implementation in the member states

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revealed significant diversity and found that only some member states managed to fully implement the directive with most countries still at the half way point [3] , and a small number still in the early stages of implementation [2]. Whilst the first EPBD was clearly a step in this direction, it became necessary for the European Commission to implement more concrete strategies to achieve the great unrealised potential for energy savings in buildings and to reduce the large differences between Member States' results in this sector [15]. The recast directive was approved on the 19th May 2010, and was intended to strengthen the energy performance requirements and to clarify and streamline some of the provisions from the 2002 Directive it replaced. One of the key features introduced by the 2010 recast directive was the introduction of a requirement for property advertisements to include the energy performance certificate.

The certificates themselves, and the data contained therein, constitute a measure of the energy efficiency of the certified buildings. The generation of energy certificates which bear no relationship to the actual or the typical energy use of the national building stock is detrimental to both the effectiveness of the certificates and the aims of the EPBD. Whilst there are a number of mature certification schemes in north and central Europe, the concept of energy efficiency in relation to building performance, particularly in the residential sector, is relatively recent in southern Europe. Furthermore, the energy performance of housing in south Europe has to consider air-conditioning in summer and heating in winter, whereas in the north and central Europe, the focus is exclusively on winter heating. The effect of the summer air-conditioning load can clearly be see in Fig. 1 which compares data from Malta and Cyprus.

2. Theory

The first part of this study examined the state of existing research into the validity of the EPC as a tool to accelerate the transformation of the existing housing stock into low-energy dwellings, within the context of Mediterranean housing. It was found that the effectiveness of EPCs was restricted and that the expected impact on energy and financial savings had not been attained, mainly due to difficulties in implementation, monitoring, and quality control of the energy certification of buildings [40,3,11]. Insofar as research into Mediterranean housing is concerned, the focus is on the differences between north and south Europe, and the increasing use of air-conditioning [43,29]. Several researchers have regarded traditional housing as a reference model for energy efficient design [10,27,44,50,17], while others have investigated new and innovative techniques and materials for low energy housing [47,48,36,18]. The main emphasis is on research into the effects of insulation, thermal mass, ventilation, and shading [35,9,12], but examples of the development and construction of high performance energy saving buildings in the region are clearly limited [23,41,17]. Some work has been done on the analysis of the certification methodologies in the region [19], but the amount of published research which includes both cooling and heating performance is limited [5]. The majority of residential certification methodologies are based on the quasi steady state method proposed by EN ISO 13790, and researchers have often compared the results obtained to those produced by a dynamic simulation model generated by TRNSYS, EnergyPlus, IES VE, or similar programs [4,30,34,20,37]. Analyses of the implementation of the EN ISO 13790 steady state methodology have generally found that this required calibration in order to produce results significantly close to those obtained by dynamic simulation [24,8,33,45,25,46]. The parameters requiring calibration are the utilisation factors, the building reference time constant and the numerical coefficient. Comparisons of the output from EPC calculations to the measured energy are rather less frequent, but the few published studies generally identify significant differences between the measured and the calculated cooling loads [7,28]. These differences have generally been attributed to discrepancies between the assumptions made by the calculation methodology and the actual occupants' behaviour and lifestyle [6]. In north and central European countries, where the domestic energy profile is dominated by space heating, and cooling is practically non-existent, studies comparing certificate values and actual energy use found significant differences between the two. When the EPC data is extended to calculate the projected savings from energy performance improvements to the building, it was found that the actual savings would probably not exceed 50% of the value of the calculated savings [42,49]. These differences between actual and calculated energy performance are at the heart of widespread criticism of the EPC, and could also be part of the cause of general reluctance to adopt and implement the energy performance certification system for buildings.

3. Research approach

Following the literature review, the principal and subsidiary research questions (a-c) were formulated:

To establish whether the current certification methodologies used in South Europe (Malta, Italy, Spain, Cyprus) provide an accurately calculated value of energy demand in Mediterranean housing.

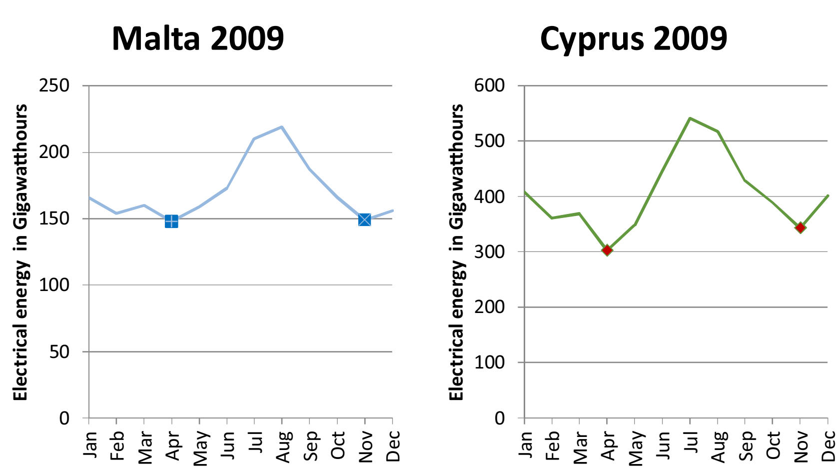

Fig. 1. Monthly electrical energy available for Malta and Cyprus 2009 [16].

(a) What are the consequences of the differences in the energy performance of housing between North and South when implementing a common policy directive?
(b) What techniques can be applied to ensure reliability of the energy performance certificate methodologies in a climate where heating and cooling are required for residential buildings?
(c) Can the differences between national methodologies applied in similar climates be justified?

The research is centred in the geographical area defined by the Mediterranean regions of southern Europe, within the field of construction and the built environment. The nature of the research incorporates requirements for both quantitative and qualitative techniques, and this was the basis for the decision to opt for a mixed methodology, and to operate in the framework of the case study approach. The case studies selected consisted of four national certification calculation methodologies adopted in Malta, Cyprus, Italy and Spain. Since the methodologies are implemented through software routines, the research technique considered the three categories of software testing recommended by Judkoff [26], namely empirical validation, analytical verification, and comparative testing. The certification calculation methodologies are expected to meet the requirements of EN ISO 13790, and three out of the four case study methodologies selected are actually based on the monthly quasi-steady-state calculation method prescribed by the standard as one of three different types of calculation method. The study examined this calculation method since it is central to the current implementation of the EPC and this was followed by an overview of the four national approaches selected as case studies, namely EPRDM (Malta), CERMA (Spain), DOCETpro (Italy), and iSBEMcy (Cyprus). Appendix A presents an overview of the main differences between these calculation methodologies. Appendix A is an introduction to the IES VE dynamic thermal simulation software used for analytical verification of the building models generated by the national software programs used for generation of EPCs.

Four test case properties were used for comparative testing of the four case study methodologies. Brief details of each property are as follows:

Test Case 1 (TC1): St. Vincent Street, Sliema, Malta is a second floor apartment in a block of four. The block is terraced and therefore only the west facing façade and the rear wall are exposed. The net floor area of the apartment is approximately 108 m^2. The main bedroom and the main living area are air- conditioned, and the main unit in the living area is a heat pump.

Test Case 2 (TC2): Goldfinch Street, Kappara, Malta is a semi-detached villa. The property has a net floor area of 237 m^2 over two floors with an overlying washroom on the third floor. This does not include a separate garage. The entire property is air-conditioned by a variable refrigerant flow (VRF) inverter type heat pump system.

Test Case 3 (TC3): Peg Street, Swieqi, Malta is a semi-detached villa. The property has a net floor area of 210 m^2 over two floors with an overlying washroom on the third floor. This does not include the separate garage. The three bedrooms and the main living area are air-conditioned by individual split type heat pump units.

Test Case 4 (TC4): Cyprus. This is a fully detached villa constructed to an energy efficient design in 2008. The property has a net floor area of 238 m^2 over two floors excluding the adjacent garage. Air-conditioning and heating is provided by inverter type split units.

Whereas there has been similar research examining the energy performance certificate methodologies in South Europe, this previous work has hitherto taken the format of either comparing different methodologies amongst each other in a national context, or comparing a national methodology against one or several commercial or academic software packages, or comparing the methodology against metered data for a test case. The research reported in this paper is unique in that it has considered three separate approaches for verification, namely comparative testing of the methodologies with each other, analytical verification of the methodologies against an established dynamic simulation software package, and empirical validation against metered data for the test case properties, and this has all taken place across four nations or regions, providing a much larger backdrop for the work.

Table 1
Temperature data for test case properties for case study methodologies.

Methodology	*EPRDM*	*DOCETpro*	*CERMA*	*SBEMcy*
State	*Malta*	*Italy*	*Spain*	*Cyprus*
Location	*Malta*	*Agrigento*	*Almeria*	*Larnaca*
Month	Average Monthly Temperatures			
Jan	12.20	10.40	12.68	10.25
Feb	12.40	10.80	13.32	8.42
Mar	13.40	12.70	14.33	14.00
Apr	15.50	15.60	15.88	16.72
May	19.10	19.40	18.71	19.84
Jun	23.00	24.10	20.84	21.13
Jul	25.90	26.90	24.29	26.71
Aug	26.30	26.50	24.49	26.41
Sep	24.10	24.00	21.69	23.81
Oct	20.70	19.90	19.89	18.65
Nov	17.00	15.90	15.74	14.19
Dec	13.80	12.20	13.36	10.38
AVERAGE	18.62	18.20	17.94	17.54

4. Results

Each test case property was used to generate a model using each of the four methodologies, and after establishing that the differences in the weather data for the methodologies are minimal (see Tables 1 and 2), the delivered energy calculated for space heating, space cooling, and domestic hot water were compared for each property.

The calculated values for space heating and domestic hot water for the different methodologies tended to converge, but that there were pronounced differences between the calculated values for space cooling. Two calculation methodologies, EPRDM and CERMA, displayed better agreement between the space cooling results, even though CERMA was the only case study methodology not directly based on the EN ISO 13790 quasi-steady-state calculation procedure. The use of dynamic simulation to model the behaviour of the test case properties showed considerable divergence from the results produced by the case study certification methodologies. Once again the results for space heating show better agreement

Table 2
Solar radiation data for test case properties for case study methodologies.

Methodology	*EPRDM*	*DOCETpro*	*CERMA*	*SBEMcy*
State	*Malta*	*Italy*	*Spain*	*Cyprus*
Location	*Malta*	*Agrigento*	*Almeria*	*Larnaca*
Month	Horizontal Irradiation MJ/m^2			
Jan	9.47	8.80	9.46	8.25
Feb	12.92	12.50	18.12	10.58
Mar	18.00	16.90	21.31	17.7
Apr	21.42	22.20	27.12	20.71
May	26.42	26.90	31.61	27.24
Jun	28.04	29.50	34.09	29.74
Jul	28.51	29.60	34.33	28.15
Aug	25.09	27.00	30.93	25.22
Sep	20.23	20.90	25.07	21.06
Oct	14.76	14.60	18.97	15.94
Nov	10.98	10.10	14.32	11.15
Dec	8.35	8.20	11.54	6.52
TOTAL	224.21	227.20	276.86	222.26

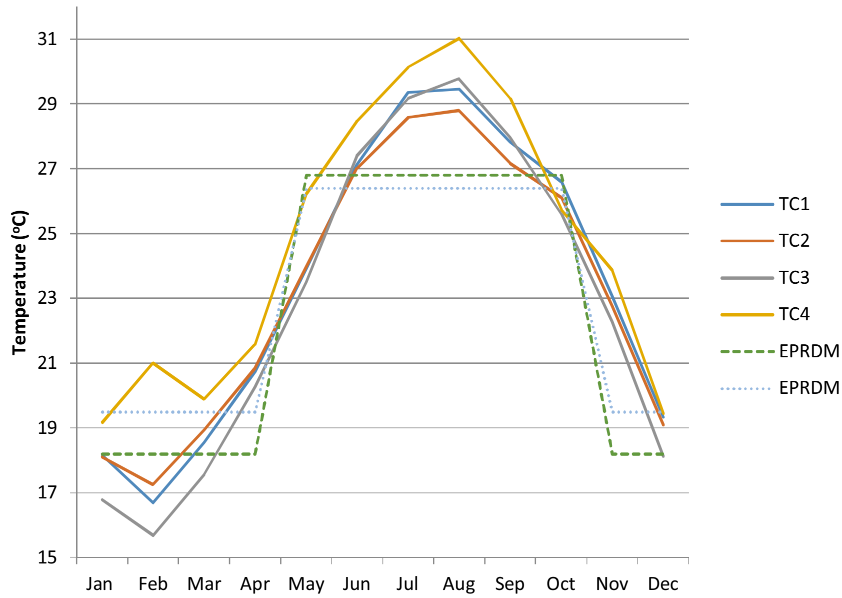

Fig. 2. Monthly average indoor temperature for test case properties.

than the results for space cooling, and the dynamic simulation appears to correspond more closely to the Maltese (EPRDM) and Spanish (CERMA) methodologies for the cooling calculation. On the other hand, the Maltese methodology shows the most pronounced variation from the dynamic simulation when the delivered energy for space heating is calculated. This comparison was carried out on the basis of a defined set of operating parameters, eliminating the effects of the random behaviour normally exhibited by occupants of dwellings.

The outcome of the monitoring of the test case properties was then compared with the results obtained from the calculation methodologies and the dynamic simulation. The measurements of the internal temperature in the test case properties showed that the assumptions made by the calculation methodology in connection with this fundamental parameter would benefit from refinement. Needless to say, without accurate definition of this parameter, the expected benefits from the increased accuracy of the dynamic simulation model are completely eliminated. Fig. 2 indicates that the variation in internal temperature between the test case properties is of the order of 3 °C in the hottest and coldest months (excluding T4 Feb) and is of the order of 1 °C for the shoulder seasons (spring/autumn). The clear trend demonstrating by the figure indicates that defining the average monthly internal temperature rather than simply having a seasonal temperature set-point could be a simple matter within the described tolerances.

The power data did not provide the equivalent level of detail to that of the temperature data, since the data were restricted to the monthly power measurements and corrected to give space heating and cooling energy. Nevertheless, Fig. 3 demonstrates that the correlation between the EPRDM methodology, the dynamic simulation model, and the metered data, is generally more precise for the summer cooling season than the winter heating season. This is in contrast to the indoor temperature profiles, where the correlation between the methodology and the measured temperatures is more accurate in winter than in summer. This suggests that in the summer, the building cooling energy performance is less sensitive to indoor temperature variations than during the winter heating season.

In the first example, TC1, the EPRDM provides a better model of the metered energy over the whole year, whilst in the second example, the IES provides a better model in winter whilst the EPRDM is again a better model of the summer energy requirements. Whilst the findings from such a limited number of properties cannot be conclusive, this demonstrates the difficulties of using simulation models, whether simple steady state or dynamic, to predict actual energy performance. The EPC is not intended to be used as a measure of operational rating or actual performance and hence the scope of the calculation methodology is to provide an effective asset rating which is statistically representative of the housing stock. An accurate simulation of measured performance is as dependent on the precise definition of building use and system management as it is on the precision of the calculation methodology. It is an established fact that building use and system management are randomly altered through the interaction of the occupants with the building, and Fig. 2 demonstrates the inadequacy of current methods in accurately defining a simple parameter, i.e. the indoor temperature.

The data collected from pressurisation tests confirmed the uncertainty of the air change rate estimation and justified the wide range of values calculated or assumed as default by the different certification methodologies.

Further data analysis identified a number of input parameters having considerable significance on the accuracy of the output of the energy performance calculation methodologies. The variances between these parameters on a national basis has a larger effect than differences of precision between the methods, or even differences in the detail and accuracy of data collection. The use of the EPC as a driver for the improvement of energy efficiency, or as a tool for taking and supporting decisions related to design and refurbishment for improved energy performance, has been rendered untenable due to unpredictability of the accuracy of output. This is attributable to the implementation of the EPC calculation methodologies without a mechanism to calibrate the output against the actual building stock performance, and does not necessarily imply any shortcomings in the methodologies themselves.

5. Discussion

This section of the paper commences with a consideration of the research in relation to how the questions posed in Section 3 have been addressed.

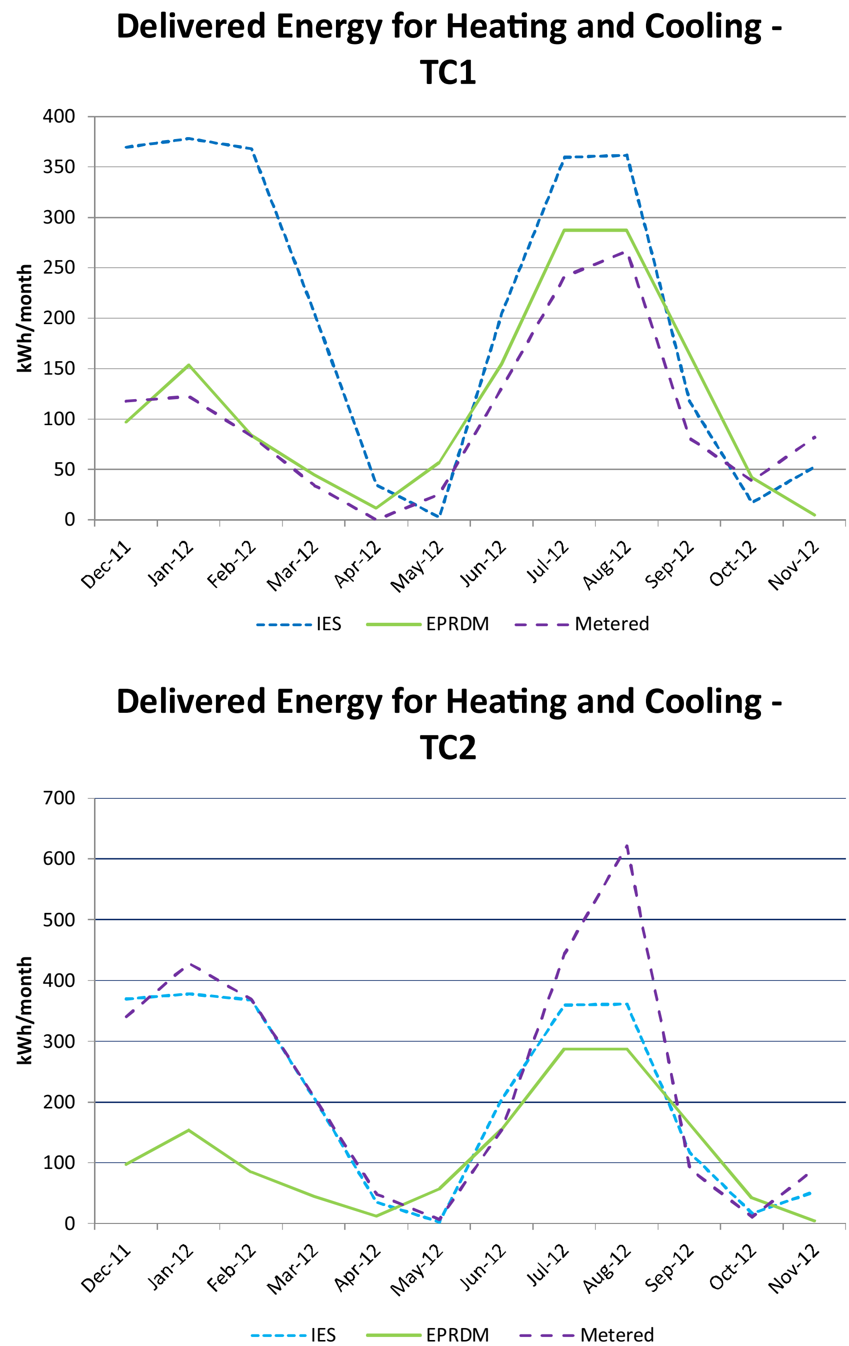

Fig. 3. Comparison between metered energy for heating and cooling and values calculated using IES and EPRDM.

5.1. *Principal research question*

This research has found that the current certification methodologies for south European dwellings have not been tried and tested, specifically in the regions where both space heating and space cooling are required for the occupants' comfort. The use of the energy certificates without associating them with the actual energy use of the national building stock is detrimental to both the effectiveness of the certificates and the aims of the EPBD. The shortcomings appear to be twofold, in that there is no clearly defined process for associating the body of certificates representing the national building stock with a statistical database representing building typology and energy profile, and that there is no procedure to calibrate, even in the most rudimentary way, the building model used for certification against the actual building. In other words, the EPCs issued by the national methodologies appear not to have undergone any form of calibration process, neither en masse against national statistics, nor individually against the specific building being certified.

The first level of calibration is dependent on the existence of national statistics relating the average or typical energy profile of dwellings to the predominant typologies, and this research has found that these statistics are not available, or not published, in the desired format. The relatively limited variety of energy sources in south European regions should mean that the extraction of the required statistics from energy company records ought not be an arduous task. The current unavailability of these statistics contributes to an impression that the energy performance of housing in the region is not an issue of political or economic importance.

At the same time, due to the unavailability of statistical data against which the certification methodologies for Mediterranean housing could be calibrated, the output from the certification methodologies can and has been compared, in this work and by others, to the results obtained from dynamic simulation models. Whilst these models are more time consuming to create and implement, they provide the facility to model the behaviour of the dwelling more precisely. This has prompted the suggestion that replacing the quasi-steady-state monthly method for the generation of EPCs by a more precise method, similar to or aligned with a dynamic simulation model, albeit in a simplified format, would lead to greater precision in the data output by the certification process.

However this work has found that the underlying assumptions made about the use of the dwelling, particularly in relation to the heating and cooling plant, together with the indiscriminate use of default values, have a far greater influence on the outputs from the certification methodology than any inaccuracies in the calculation method itself. Several researchers have identified the indoor temperature as the most significant parameter when determining the energy performance of the dwelling. Whilst the indoor temperature is directly related to the behaviour pattern of the occupants, the measured data clearly shows a common trend for the four test case properties. Unlike the characteristic assumption of a fixed winter temperature and a fixed summer temperature, the actual indoor temperature in Mediterranean housing clearly appears to 'follow' the external temperature, in line with the principles of adaptive comfort.

Apart from the indoor temperature, both the length of the heating and cooling seasons and the operating schedule of the heating and cooling plant have a significant effect on the accuracy of the output from the certification methodology. These parameters are not user defined but are predetermined within the methodology, and when the selected values are inappropriate, the errors generated in the cooling energy calculation are significantly larger than for the heating energy calculation.

The infiltration rate, the utilisation factor, and the thermal capacity of the structure are also parameters in the certification methodology that are generally managed through the use of default values or standardised assumptions. Whilst these factors are not as significant as the above factors relating to the operation of the heating and cooling plant, there is also scope for the development of guidelines to ensure that values for these parameters are established on a national or perhaps a regional basis.

The analysis of the delivered energy for heating and cooling obtained from the four national EPC calculation methodologies, the dynamic simulation model, and the metered data, was directed towards determining the cause of the differences between actual and predicted energy consumption, and identifying the characteristics that have a major effect on discrepancies in the EPC calculation methodology. According to the results obtained, the main sources of error are inaccuracies in the application of the quasi-steady-state calculation model used. In particular, the accurate definition of the operating parameters for the heating and cooling system is particularly significant if a more precise prediction of the energy performance of the dwelling is required. It is suggested that it would be more appropriate to introduce guidelines to ensure the correct application of the existing model than to consider replacing the model with a more sophisticated method for the calculation of the dynamic thermal behaviour of the dwelling. The accuracy of the dynamic simulation model (IES VE) is counteracted by the fact that the behaviour of the occupants of the building cannot be modelled with equivalent accuracy, hence the additional time and effort required to set up the more sophisticated model are difficult to justify.

5.2. Consequences of North-South differences in energy performance

The mild Mediterranean climate is characterised by ambient temperatures that are closer to comfort levels than the colder northern climates. The dual space conditioning load that includes both summer cooling and winter heating necessitates an architectural compromise. Energy efficient building design should consider shading and ventilation for the summer season, and this does not correspond with the winter requirement for insulation, airtightness, and maximisation of solar gains. Whilst the magnitude of both the cooling and the heating load is not large, cooling is provided by air-conditioning equipment using electricity, which is mainly generated from fossil fuels, resulting in a high primary energy factor. This means that the energy supply can transform the relatively low energy requirements of Mediterranean housing into a substantial carbon footprint. The requirements of the EPBD cannot be considered to be biased in favour of property in any particular climatic region. However, the implementation of the EPBD has been most rapid in the colder regions of North and Central Europe, with the effect that South European regions and states have, in their majority, attempted to implement the EPBD in a similar manner. This has also had an effect on the concepts, materials, and techniques considered suitable for the energy efficient design of housing in the Mediterranean.

The accepted rationale for improving the energy efficiency of housing in colder climates is primarily to minimise the heating load through a well-insulated airtight envelope, and only after this is achieved is attention given to improving the efficiency of the heating plant. In terms of fuel, the generation of heat is possible using a variety of different sources, and this also lends itself to the maximisation of the use of low-carbon or alternative fuels, as well as large-scale solutions such as district heating.

The analysis of the building energy performance of the test case properties arising from the calculation methodologies, the dynamic simulation model, and the metered data demonstrates that the specific values for delivered energy for heating and cooling approach the design values for primary energy for low energy housing such as the Passive House, even though three out of the four test case properties have uninsulated building envelopes which could be considered as poor by European standards. On this basis, it is likely that the rationale for improving the energy efficiency of housing in the Mediterranean should, in complete contrast to the above, focus primarily on improving the conversion factor from delivered energy to primary energy, followed by ensuring the most efficient selection and operation of the heating and cooling plant, with improvements to the building envelope being given the lowest priority. This suggested approach should be particularly effective when evaluating cost effective methods of improving the energy efficiency of the existing building stock, since the costs of improvements to an existing building envelope are substantially higher than the cost of implementing improvements during the construction phase.

6. EPC methodology techniques where heating and cooling are required

Significant research directed towards improving the relationship between the energy performance certificates and actual energy consumption has been carried out for a number of north and central European countries [28,31,32]. This research is centred on the comparison of the calculated energy for space heating and domestic hot water with the metered consumption and it would be appropriate to apply similar techniques to compare the calculated energy for space cooling. This would be in addition to the proposal made earlier for the calibration of the certification methodologies against statistical data representative of the national or regional building stock. An additional complexity in the collection of data defining the metered consumption for space cooling is that the energy source is principally mains electricity and hence the data from meter readings include the consumption for all electrical appliances, lighting, etc., and the value for space cooling must therefore be either separately metered, or extracted in some way from the total consumption. The metered consumption for space heating and domestic hot water in colder climates is normally readily available from the metered gas consumption, which only includes a small element of consumption for cooking in addition to the main demand which is for heating and hot water.

Once the national methodology has been calibrated to correspond with the statistical data representative of the national building stock, so that the energy performance certificate becomes representative of the national stock when occupied under a standardised set of conditions which are also representative of national averages, the actual certificate can also be used to provide a set of tailored values relating to actual occupancy. These tailored values are the values to be used when estimating the projected energy savings arising from refurbishment or improvements to the property or the systems.

6.1. *Can the differences between national methodologies in similar climates be justified?*

The main factors contributing to the differences between the outputs from the national methodologies arose from differences in the method of application of the methodology, and not from differences in the calculation procedure. When considering that the mild Mediterranean climate reduces the significance of the thermal properties of the building envelope, and the limited variety of cooling systems and technologies suitable or available for installation in housing, it becomes difficult to justify differences in the application of national methodologies designed for use in regions with the same climate. At the same time, in larger EU states such as Spain and Italy, with significant north-south differences in climate, it is important to ensure that the standardised set of conditions defining the use and occupancy of the residences are representative of the different regions. This work has shown that the operation of heating and cooling systems in the Mediterranean region cannot be defined in the same manner as the operation of central heating systems in north and central Europe.

6.2. *The EPC in a Mediterranean context—at a conceptual level*

The scope of the EPBD is the reduction of the substantial energy use in buildings throughout the EU. The Mediterranean region is characterised by a mild climate which results in substantially lower heating loads in winter, but with an additional cooling load in summer. Although the climate is named after the Mediterranean sea, and is typical of the countries bordering this sea, the EU member states on the Mediterranean coast fall into a number of different categories. There are the island states, such as Malta and Cyprus, the island regions, such as Sicily and Crete, and the coastal regions of larger countries such as Spain, Italy and Greece. This variety is reflected in the implementation of the EPBD but there are a number of common attributes. Collectively, these states and regions do not have a long tradition in the field of energy saving in buildings and have not established or defined models for low-energy buildings [21]. The diversity of the different regions makes it hard to collect comparable statistics, particularly since these are generally available on a national basis. However, Panayiotou et al. [38,39] defined the average primary energy consumption of dwellings in Cyprus at 129 kWh/m^{2}yr, on the basis of measurements taken of 500 dwellings. This value is based on a primary energy conversion factor of 2.7, which implies an actual metered energy consumption of 47.8 kWh/m^{2}yr. A remarkably similar figure of 55.3 kWh/m^{2}yr has been established as the average metered energy consumption for Malta [1], although the higher primary energy conversion factor applied in Malta of 3.45 results in an average primary energy for dwellings of 190.7 kWh/m^{2}yr. The primary energy conversion factor is related to the choice of fuel and the efficiency of generation and distribution of energy, and has no direct relationship to the actual efficiency of the buildings. Clearly the metered energy consumption for dwellings in Malta and Cyprus is of the same order (47.8 and 55.3 kWh/m^{2}yr), and with the introduction of more efficient generating plant in Malta, the average primary energy consumption in Malta and Cyprus is in the region of 120 kWh/m^{2}yr, which is actually the defined maximum required by the PASSIVHAUS standard [22]. This implies that the average Mediterranean house, in a region without a long tradition of energy-saving regulations in buildings, meets the maximum energy requirements established in design guidelines for comfortable low energy homes, without any energy-saving interventions.

In the light of the above, it is useful to revisit the functions of the EPC, namely its dual purposes as a marketing tool and as a stimulus to encourage home owners to improve the energy efficiency of their property. The usefulness of the EPC as a marketing tool is enhanced by its accuracy in reflecting the energy performance of the certified property in relation to the national building stock. When, however, the use of the EPC as a stimulus to home owners is considered, the EPC has to incorporate additional data to enable the home owner to understand how the improvements considered could affect the actual energy performance of the property. The energy saving improvements generated by the EPC must take into consideration the potential for realistic savings, a potential which is limited by the inherently energy-efficient nature of the buildings in a mild climate. From a national or societal viewpoint, investment in more efficient means of the production and distribution of energy have the potential to be more cost effective in the reduction of primary energy and the carbon footprint of the Mediterranean residential building stock.

7. Conclusion

At the commencement of this research, the EPBD had been recently introduced as a legal instrument to achieve the great unrealised potential for energy savings in the building sector in the European Union. Labelling and certification schemes such as the EPC have been identified by the International Energy Agency as one of the main policy instruments to reduce energy demand in the building sector. Implementation of the EPBD and the dissemination of EPCs in south Europe has lagged behind both legislation and policy for building energy efficiency in north and central Europe. In relation to the EPC calculation methodologies for housing in the Mediterranean region, this has had a number of implications, namely that the methodologies are based on or adapted from methodologies from other regions where cooling is not a consideration in the housing sector; that information on the effect of space cooling on the energy performance of housing is limited and guidelines on the implementation of the relevant European Standards for the sector are too generic to be of specific use; that the methodologies themselves have not been tested or calibrated against statistical or actual data; that the effect of behavioural differences arising from the Mediterranean climate, building typology, and socio-economic framework have not been taken into account. This has manifest itself in the wide variety of results obtained from the certification methodologies, the monitored data, and the dynamic simulation, with the largest discrepancies arising from variations in the application of methodology rather than in the calculation methods. Whilst it is possible to fine tune the certification methodology in order for EPCs to provide a more accurate overview of the energy performance of Mediterranean housing, the inherently low energy demand of the sector, driven by the mild climate, challenges the cost effectiveness of the EPBD driven strategies which appear to be dominated by the high space heating loads characteristic of northern Europe. There can be no question that the Energy Performance Certificate has the potential to function both as a marketing tool and as a performance indicator for Mediterranean housing, but it is clearly not in a position to meet these requirements in its current format. Whilst it is technically possible for EPCs to provide a more accurate performance indication of Mediterranean housing, specifically when the certification methodologies are calibrated as shown by this research, the measures promoted by the recast EPBD for the reduction of energy consumption in buildings would benefit from conceptual analysis and prioritisation in accordance with the specific characteristics of the region. This research has shown that the application of methods and standards without due consideration of the regional context, and with the use of default assumptions that are not based on statistical data, produce EPC results which do not represent the actual energy performance of Mediterranean housing. Since national and regional governments are increasingly looking at their EPC databases to assess the current state of energy use in housing and the measure of its improvement, it becomes even more urgent to ensure that both the strategy and the implementation of energy efficiency in housing are tailored to the particular climatic and behavioural aspects of the Mediterranean region.

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Appendix A. Comparative analysis of methodologies

Methodology	EPRDM	CERMA	DOCETpro	SBEMcy
	Malta	Spain	Italy	Cyprus
Basis	EN13790 simplified monthly method	Simplified hourly simulation	EN13790 simplified monthly method	EN13790 simplified monthly method
Status	Unique national methodology	Compliant with national methodology and approved	Compliant with national methodology and approved	Unique national methodology
Climate data	Single zone		Six climatic zones	Four climatic zones
	Single weather data set	Weather data by city	Weather data by city	Weather data by city
Building definition	Single zone	Single zone	Multiple zone	Multiple zone
Internal temperatures				
Winter	Between 18.2 and 19.8 °C depending on property size	Between 17 and 20 °C depending on time of day	20 °C	Defined by activity in each zone with 21 °C in lounge and 18 °C in all other areas
Summer	Between 26.2 and 26.8 °C depending on property size	Between 25 and 27 °C depending on time of day with some free running	26 °C	Defined by activity in each zone with 25 °C in all areas except for bathroom at 27 °C
Length of heating and cooling season	6 months/6 months	6 months/6 months	Heating between 3.5 months and 7.5 months depending on climate zone	Not defined but possibility for year round operation of both systems
No of hours property used per day	8 weekdays	8 weekdays		Defined on a zone by zone basis between 5 and 14
	8 weekends	24 weekends		
No of hours heating/cooling system used per day	8 weekdays 8 weekends	8 weekdays 24 weekends	24 weekdays 24 weekends	Defined on a zone by zone basis between 5 and 14
Intermittency factor		Handled by hourly simulation		
Ventilation	Result of pressurisation test or calculated by algorithm typically 0.5–0.8 ach	In summer June to Sept 4ach between 24:00 and 08:00 due to opening of windows. Outside this period calculated by algorithm with default 1 ach	0.3 ach	8m^3/hm^2 which is about 2.6 ach
Internal loads	Lighting between 0.2 and 1 W/m^2	Lighting 2 W/m^2		Lighting 7 W/m^2
	Appliances 1.5 W/m^2 Metabolic 1.2 W/m^2	Appliances 2 W/m^2 Metabolic 2 W/m^2 sensible and 1.38 W/m^2 latent		Appliances 5 W/m^2 Metabolic 5 W/m^2
	Total between 2.9 and 3.9 W/m^2	Total 6 W/m^2 sensible	Total between 4.6 for 45m^2 and 2.65 W/m^2 for 170m^2	Total 17 W/m^2
No of occupants	1 per 60m^2 with minimum 2	1 per 33.3m^2		
Domestic hot water consumption	70 l per occupant per day	Between 22 and 30 l per occupant per day	Between 1.3 and 1.8 l per m^2 per day	
Temperature rise	From 18–60 °C		From 15–40 °C	From 10–60 °C
Specific heat capacity of structure	Default Cm of 370000 or defined by user	All structures considered as middleweight	Default Cm of 165 kJ/m^{2}K or defined by user	Cm 141 kJ/m^{2}K for ext walls Cm 121 kJ/m2 K for int walls Cm 240 kJ/m2 K for roofs
Time constant				
a(Ho) & a(Co) Table 9 monthly method	1		8.1	1
τ(Ho) & (Co)	15		17	15
b(Hred) & b(Cred) empricial correlation factor p 71	3			
f(Hhr) fraction hours of heating use per week p 71	0.33			
f(Cday)fraction hours of cooling use per week	0.5			
=−k Aw/Af − k			13	

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