CYPRUS BUILDING ENERGY PERFORMANCE METHODOLOGY: A COMPARISON OF THE CALCULATED AND MEASURED ENERGY CONSUMPTION RESULTS

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Summary

In order to fulfil article 4 of the 2002/91/EC Directive (EPBD) a national methodology for the energy performance of buildings was drafted and approved by the Government of Cyprus in 2009. This methodology is in line with the European standards prepared to facilitate EPBD implementation and follows the asset rating approach that is, it represents the intrinsic annual energy use of a building under standardised conditions. CEN standards leave an option, quite suitable for existing and complex buildings, for operational rating, which is an energy rating based on measured amounts of delivered and exported energy. The calculated and measured rating exhibit advantages and disadvantages and as expected the results of the two approaches vary, since the measured rating approach takes into account the effect of user behaviour, the actual weather conditions and the realized (actual) thermal comfort conditions inside the building. This paper presents the Cyprus legal framework for adopting the EPBD and exhibits the Cyprus methodology for the energy performance of buildings. Moreover the advantages and disadvantages of the asset and operational rating approaches are discussed and a comparison of the results of these two approaches for a selected number of dwellings is presented. One of these cases is also examined with respect to the climatic conditions, by changing the climatic zone in which

the building is erected. The latter reveals the effect of climate on the calculated energy requirements of the building for both heating and cooling.

Keywords: 2002/91/EC Directive (EPBD), energy rating, asset rating, operational rating national energy performance methodology, implementation of EPBD

1 Introduction

Cyprus is an island located in the Eastern Mediterranean, at 35° north latitude, and has a typical Mediterranean climate. The climatic conditions of Cyprus are predominantly very sunny with daily average solar radiation of about 5.4 kWh/m^2 on a horizontal surface. The solar energy input is particularly high at areas where the dry summer is well pronounced, lasting from April to October. In the lowlands, the daily sunshine duration varies from 5.5 h in winter to about 12.5 h in summer. Mean daily global solar radiation varies from about 2.3 kWh/m^2 in the cloudiest months of the year, December and January, to about 7.2 kWh/m^2 in July. The Heating Degree and Cooling Degree Days for the year 2005 were 687 and 1572 respectively [1]. The morphology of Cyprus is dominated by two mountain masses, Pentadaktylos on the north and Troodos on the south and a central lowland. The capital, Nicosia, is situated in the central lowland whilst the three other towns Lemesos, Larnaca and Paphos are on the coastline. The location and shape of Cyprus are depicted in figure 1.

Fig. 1 Cyprus island and its geographical location

1.1 The building sector and its relevance to energy consumption

The existing buildings' stock in the EU-27 accounts for over 40% of final energy consumption. Residential use alone accounts for 63% of the latter value [2]. Consequently, an increase of building energy performance is an important instrument in the efforts to lessen Europe's dependency on energy imports as well as carbon dioxide emissions. The European commission acknowledged this opportunity and prepared a number of legislative tools, one of which is the 2002/91/EC, so as to facilitate the 2020 target of 20% energy saving.

1.1.1 Cyprus residential building stock

The construction and the real estate sector in Cyprus contribute 18.3% of the national GDP and employ 20.5% of the labour force. According to statistical data it is estimated that the share of construction in residential buildings is about 55% of the total output, the one of non-residential buildings is 28%, while civil engineering infrastructure projects (mainly funded by the public sector) accounted for 17% [3]. The dwelling stock in Cyprus at the end of 2007 reached 357,870 units. Of these dwellings, 63.3% were in the urban areas. The occupied living quarters in 2007 were 283,000 units. It becomes apparent that the energy behaviour of the average dwelling in Cyprus plays a significant role to the energy consumption of the building sector and therefore the apprehension of the existing dwelling stock's energy behaviour is quite significant for policy makers, engineers and other involved parties. Unfortunately, the existing knowledge on this subject is rather poor. As a remedy a research project supported by a research grant by the Research Promotion Foundation of Cyprus is been carried out since December 2008 with the main objective being the investigation of the energy behaviour and other characteristics of the residential building stock of Cyprus [4-6]. The key findings of this project, with regards to the dwelling characteristics in Cyprus, are presented below.

1.1.2 The Cyprus dwelling stock characteristics

Due to the lack of comprehensive building codes the dwelling stock in Cyprus exhibits non homogenous characteristics in terms of shape, facade structures and use of building materials. This is mainly due to the fact that for a great period of time the building codes in Cyprus regulated only abstract issues, like distance from the road, building height, number of floors and the maximum useful area, by means of imposing limits to the building density coefficient. Although peculiar, the enforcement of thermal insulation of buildings and the compulsory submission of a design study for the HVAC and lighting installation as a prerequisite for obtaining a building permit was regulated only after 2006, whereas sun shading measures and a quota in the use of glazing, especially in the western facades, are still being missed [7]. Therefore, the aesthetic and architectural trends, the availability and costs of building material and the taste of the customers influenced the typology of the dwelling in Cyprus.

As noted above, there is a great variance in the typology of the dwellings in Cyprus. The most frequent typology commands that the bearing structure of the building is made of reinforced concrete. The walls are constructed from hollow bricks, covered with plaster on both sides. The floors are made of concrete slabs. The floor finishing consists of a layer of mortar usually covered with tiles, marble, or granite sheets. Flat roofs consist of the slab, usually 150 mm in thickness, with an additional layer of plaster of 3 cm on the underside. The roof is usually water-proofed with a thin layer of bitumen and painted with a white or aluminium colour on top [8].

With regard to some overall characteristics of the dwelling stock, the majority of dwellings in Cyprus are not insulated and there is evidence that in most cases the HVAC installations were not properly designed or there was no design at all [7]. Moreover it is estimated that one third of dwellings have an oil fired boiler as a heating system and at least half of them are equipped with heat pumps (split units) for cooling and sometimes for heating purposes. The majority of dwellings, more then 90%, use solar water heaters for domestic hot water purposes [9]. Another complimentary characteristic of the residential stock in general is that the size and useful floor area per person for the average dwelling exceed significantly the EU average [5,6]. Finally, the built environment in Cyprus is characterized by low density city centres, which led to sprawl town phenomenon, where the multi-storeyed family buildings became the dominant trend. In the suburbs the dominant trend is the detached single family dwelling, which accounts for the lion's share in the total dwelling stock of Cyprus.

2 The EPBD Directive and its national implementation in Cyprus

The European Directive 2002/91/EC (EPBD) on the Energy Performance of Buildings specifies that all member states should endorse EPBD into their national legislation by January 2006. The pillars of the EPBD are the preparation of a methodology for the calculation of the energy performance of buildings, the application of minimum requirements for the energy performance of new buildings and for large existing buildings that are subject to major renovation, the energy performance certification (labelling) of buildings and regular inspection of boilers and air-conditioning systems in general as well as a once off assessment of heating systems with boilers that are more than 15 years old.

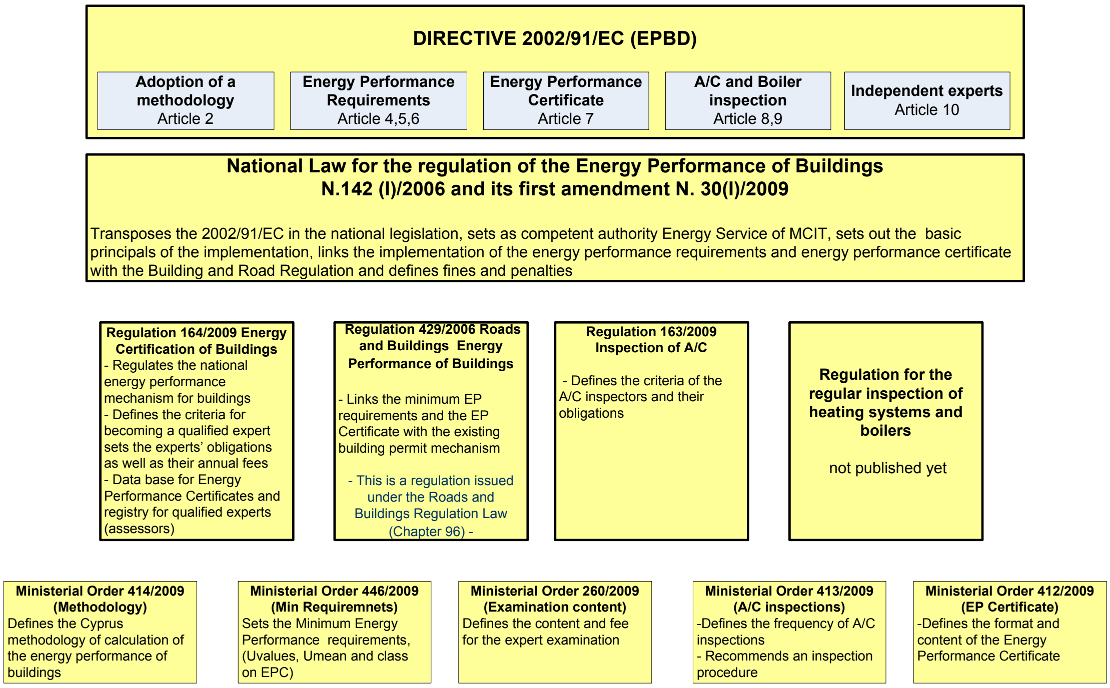
2.1 The adoption of 2002/91/EC in Cyprus

EPBD was transposed into national legislation with the Law for the Regulation of the Energy Performance of Buildings of 2006-N.142(I)/2006 and its Amending Law N.30(I)/2009. Moreover as prescribed by the law, a number of secondary legislation including Regulations and Ministerial Orders were issued for the regulation of various issues, such as the national methodology (article 2), the minimum requirements of the energy performance (article 4,5,6), the procedure for the certification of buildings and the qualifications of the qualified experts (article 7), the procedure of the inspection of air conditioning systems (article 8,9) and the qualifications of experts and inspectors (article 10).

Article 4 of EPBD requires that member states should ensure that "when buildings are constructed, sold or rented out, an energy performance certificate is made available to the owner or by the owner to the prospective buyer or tenant". At the harmonization stage a debate took place regarding the exact implementation mechanism for the obligation of presenting an energy performance certificate when buildings are constructed. Due to the fact that, at the time of making that decision, the majority of properties were sold at the design stage, it was decided to regulate this obligation through the national building permit and control mechanism which is the Roads and Buildings Regulations Law (Chapter 96.).

In a nutshell, the Roads and Buildings Regulations states that no person can proceed to perform any construction works unless he has a building permit. This linkage was performed through the Regulation 429/2006 which stated that, amongst other documents, an energy performance certificate should be submitted to the building authority prior to the issue of a building permit. The latter approach utilized a well established existing building permit mechanism and ensured that for all new buildings an energy performance certificate will be issued. Inevitably, this choice commanded the use of design energy rating, which is a rating based on design data and it represents the calculated intrinsic annual energy use of a designed building under standardised conditions. Due to the weaknesses of the existing building permit mechanism, this approach raised a question on the quality assurance and the realization of what the certificate promises in reality. A proposal of making obligatory the issue of a preliminary energy certificate or energy certificate as designed (design energy rating) for building permit purposes and an energy certificate as built (standard energy rating) with actual data for the building, with the completion of the building, was rejected, due to higher costs for the consumer and to the higher administrative burden for the building authorities.

With regards to qualified experts it was decided to set as minimum criteria the registration at the Technical Chamber of Cyprus in the disciplines of Architect, Civil Engineer, Mechanical Engineer and Electrical Engineer, 3 years of experience and a successful examination prepared by the Energy Service. An overview of the laws and regulations issued is presented in figure 2.



DIRECTIVE 2002/91/EC (EPBD)

Adoption of a methodology Article 2

Energy Performance Requirements Article 4,5,6

Energy Performance Certificate Article 7

A/C and Boiler inspection Article 8,9

Independent experts Article 10

National Law for the regulation of the Energy Performance of Buildings N.142 (I)/2006 and its first amendment N. 30(I)/2009

Transposes the 2002/91/EC in the national legislation, sets as competent authority Energy Service of MCIT, sets out the basic principals of the implementation, links the implementation of the energy performance requirements and energy performance certificate with the Building and Road Regulation and defines fines and penalties

Regulation 164/2009 Energy Certification of Buildings
- Regulates the national energy performance mechanism for buildings
- Defines the criteria for becoming a qualified expert sets the experts' obligations as well as their annual fees
- Data base for Energy Performance Certificates and registry for qualified experts (assessors)

Regulation 429/2006 Roads and Buildings Energy Performance of Buildings
- Links the minimum EP requirements and the EP Certificate with the existing building permit mechanism

- This is a regulation issued under the Roads and Buildings Regulation Law (Chapter 96) -

Regulation 163/2009 Inspection of A/C
- Defines the criteria of the A/C inspectors and their obligations

Regulation for the regular inspection of heating systems and boilers

not published yet

Ministerial Order 414/2009 (Methodology)
Defines the Cyprus methodology of calculation of the energy performance of buildings

Ministerial Order 446/2009 (Min Requiremnets)
Sets the Minimum Energy Performance requirements, (Uvalues, Umean and class on EPC)

Ministerial Order 260/2009 (Examination content)
Defines the content and fee for the expert examination

Ministerial Order 413/2009 (A/C inspections)
-Defines the frequency of A/C inspections
- Recommends an inspection procedure

Ministerial Order 412/2009 (EP Certificate)
-Defines the format and content of the Energy Performance Certificate

Fig. 2 The legal framework for harmonizing EPBD

3 Energy ratings of buildings

The backbone of the EPBD is the issuance of an energy certificate, which will be available to the owner, the prospective buyer or tenant. This will encourage governments, building designers, owners, operators and users to improve the energy performance of buildings. Energy certification of buildings requires an assessment method which will be applicable to both new and existing buildings and which will treat them in an equivalent way. The directive sets the general framework on this issue. The detailed proposed energy rating approaches that Member States could adopt are described in the EN 15603:2007 standard [10].

The two principal types of energy ratings for buildings, as proposed by EN 15603:2007, are the calculated or asset energy rating and the measured or operational energy rating. The standard calculated energy rating (or asset rating) considers standard conditions of occupancy, climate, environment, and use and it includes, according to EPBD, only heating, cooling, hot water and ventilation loads. Lighting load is included for most buildings but may be omitted for dwellings. The measured rating (or operational rating) is based on metered energy consumption and includes energy uses for all purposes and in actual conditions. An illustration of the two energy ratings is presented in figure 3.

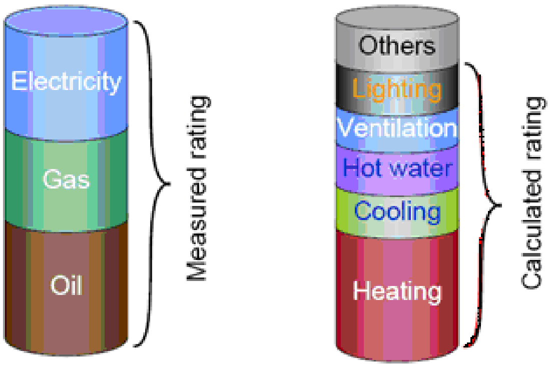


Fig. 3 Measured and calculated energy ratings

In accordance to the principles of subsidiarity and proportionality the EPBD leaves the decision to the Member States, to choose between the two approaches. During the harmonization period a discussion took place in many Member States, in order to define their rating system to be chosen. The operational rating is in principle easier, less laborious and therefore inexpensive, but de facto it cannot be used for newly erected buildings where data are not available. Because it is an easy methodology it is suitable for existing and complex buildings. Furthermore, it takes into account the usage and the energy management of the building and therefore is useful for energy managers and potential users, since it considers factors they can control. The latter makes this rating suitable for public buildings. One disadvantage of the operational rating is that in the case where there are no metering devices it is hard for the expert to brake down consumption, estimate savings and give cost effective energy saving advice.

On the other hand, and although it may depend on the methodology used, the calculated rating is in principle a more complicated and expensive approach. Nevertheless it assesses the intrinsic energy performance of the building under standardized conditions, providing a necessary and valuable piece of information for the potential buyer. Moreover, it is suitable for existing and new buildings and it can be utilized when linking the energy performance to the building permit mechanism. The assumptions are clearer to the expert and the results are more comparable. Finally, the calculated rating approach provides insight to the expert and he can more easily provide energy saving advice. It must be noted that the calculated rating can be classified into three categories. The *standard energy rating* which takes into account actual data for the building and standard use dataset, *design energy rating* which takes into account design data for the building and standard use dataset and *tailored energy rating* which is the calculated energy rating using actual data for a building and actual climate and occupancy data [10].

As aforementioned the EPBD leaves the option to Member States (MS) to decide for the energy rating approach they will adopt in their country. According to the results of a survey discussed in the fifth EPBD Concerted Action II meeting in Amsterdam on January 2010 the majority of MS (52%) chose the calculated rating only. From the remaining Member States that chose both ratings, a small percentage (14%) defined that operational rating is used exclusively for existing and non residential buildings. Finally, a number of Member States (33%) allow the parallel use of the two ratings for the same type of buildings. Member States who chose the calculated rating approach responded that their motivation was the fact that calculated rating procedures are more robust and produce comparable results, whereas Member States who chose measured rating as well, responded that they took into account the cost effectiveness, the administration aspects and the fact that they monitor the actual energy consumption [11].

It becomes apparent that in some countries two ratings (measured and calculated) can exist for the same building simultaneously. Due to the differences in the way these two ratings are obtained they should not be directly compared, especially by the end user of the certificate e.g. the consumer. Nevertheless, the comparison of the results of these two approaches is an interesting topic by itself, and not only an academic aspect. Furthermore, this comparison can provide useful insights and can be used to assess the cumulative effects of actual construction, systems and operating conditions (user habits, thermal comfort conditions, weather conditions) versus standard ones, and also the contribution of energy uses not included in the calculated energy rating. Moreover, a comparison might lead to conclusions that will improve the quality of input data used for the calculation method, and thus increase confidence in the model used for calculation.

4 Cyprus Methodology for Assessing the Energy Performance of Buildings

As already mentioned, Cyprus choose the calculation rating approach as the only methodology for the energy rating of buildings. The core of the methodology for the calculation of the annual energy use for space heating and cooling is the monthly quasi-steady state method described in the EN ISO 13790 standard. In addition a number of CEN standards mentioned in the CEN Technical Report 15615: 2008 Umbrella Document [12], like EN 15193-1, EN 15243, EN ISO 13786:2005, EN ISO 13789, EN15316-3, EN 15316-4-3-2007 are utilized. An overview of the linkages among CEN EPBD standards is exhibited in figure 4.

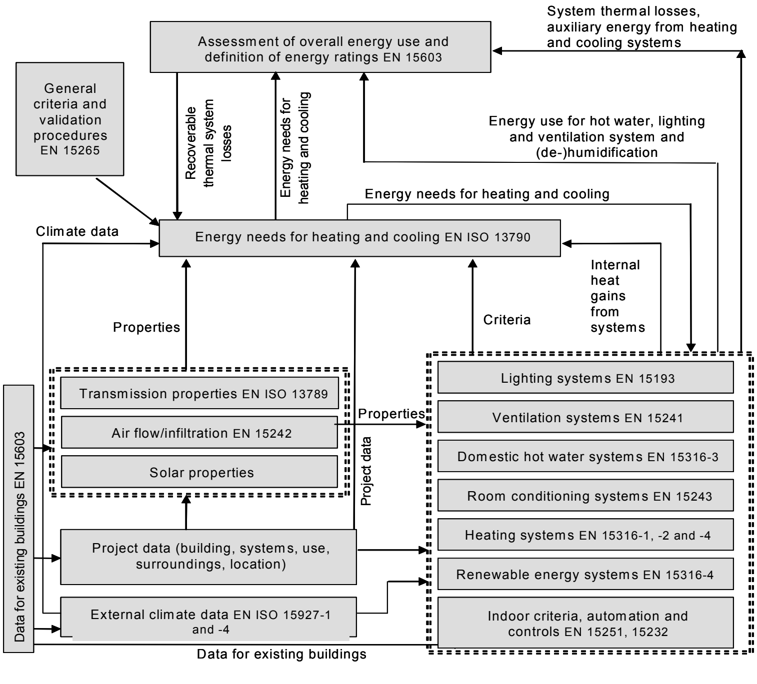


Fig. 4 Linkages of standards for the energy performance of buildings [10]

The Cyprus calculation methodology relies on the use of a notional building, an option given in the EN 15217:2007 standard [13]. This is a building which has the same geometry, location, building function, size, but with parameters such as insulation level, heating system efficiency, internal heat gains etc. substituted by reference values. The methodology requires that two calculations will be performed: one on the actual building with the actual fabric and actual heating, ventilation, air-conditioning and lighting systems; and one on the notional equivalent building, which sets the benchmark. The calculation takes into account activity area data, which is kept the same in both buildings. When a new building is considered, the resulting relationship between the two buildings yields a design rating; whilst in the case existing buildings for sale or rent, the yield is a *tailored energy rating.* The classification on the energy performance certificate depends on the quotient of the calculated primary energy of the building divided by the calculated primary energy of the notional building. If the quotient is in the range of 0 – 0.5 the building is classified as a A class, if the quotient is in the range of 0.5 – 1 the building is classified as a B class, if the quotient is in the range of 1 – 1.5 the building is classified as a C class and so forth. It must be noted that one minimum requirement of the energy performance of new buildings in Cyprus is their classification as B or better, which means that the new building under investigation should achieve a better energy performance compared to the notional building [14].

The Cyprus Energy Performance methodology flowchart is presented in figure 5 below.

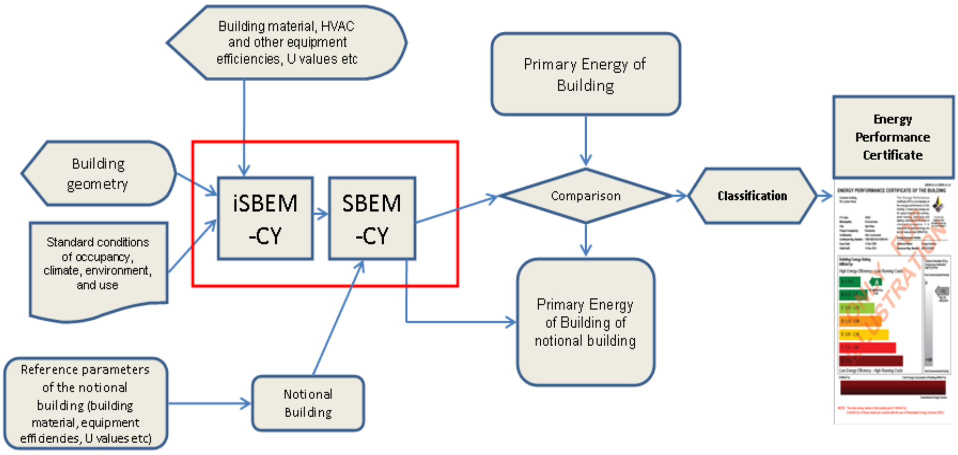


Fig. 5 Cyprus EP methodology flowchart

In order to calculate the reaction of the building and systems to the variable loads imposed by the external environment, the Cyprus methodology needs the input of weather data. In addition, information regarding weather data is necessary to calculate the energy yield by some renewable energy systems, such as solar and wind technologies. Considering the latter, Cyprus was divided in 4 climatic zones, with different weather characteristics like average temperature and moisture as shown in figure 6. These zones are the lowland, coastal, semi-mountainous and mountainous areas respectively.

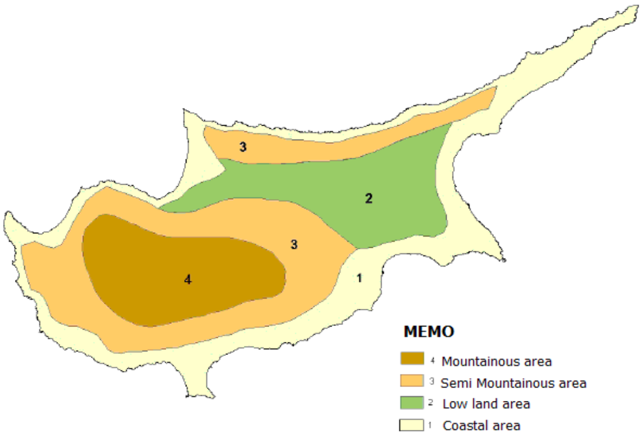


Fig. 6 Cyprus climatic ones

The *Framework law* N. 142(I)/2006 states that the Energy Service of the Ministry of Commerce, Industry and Tourism is obliged to prepare a software application for the calculation of the energy performance of buildings and the issuance of an energy certificate, that will be provided free of charge to all interested parties. The law gives an option for the development and use of a software developed by the private sector with the restriction that it will be accepted by the Energy Service. Up to now the only recognised software application is the one developed by the Energy Service which is a calibrated version of the SBEM algorithm-software used in the United Kingdom.

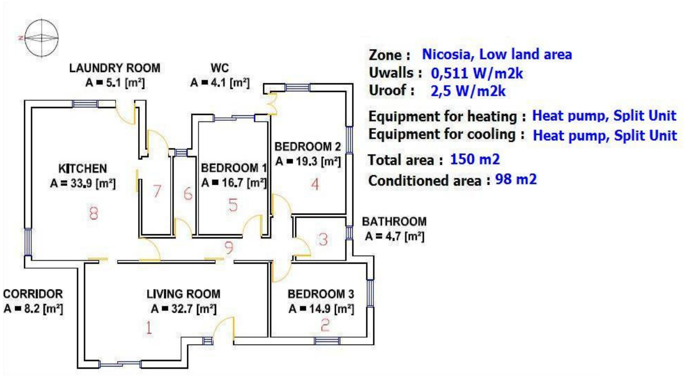
5 Selected case studies

A research project [4-6] which has as main task to investigate the energy behaviour of the existing dwelling stock in Cyprus and to classify it into different categories was launched in December 2008. This task was performed by means of collection and process of energy related data for 500 dwellings, based on face to face filled, structured questionnaires, which followed the principles set in the EN 15603, and in situ measurements in selected cases, something that could be regarded as an initial energy assessment. As a complimentary deliverable, and as a mean for quality assurance of the survey's results, it was decided to compare the energy consumption derived by an initial energy assessment (a measured rating approach) and in situ measurements to the energy demand derived by the legislated calculation rating procedure for a selected number of cases. Moreover, it was decided to gain an initial insight of the influence of weather conditions through the calculation (use of SBEM_Cy) of the energy demand of a dwelling erected in four different locations, one in each zone.

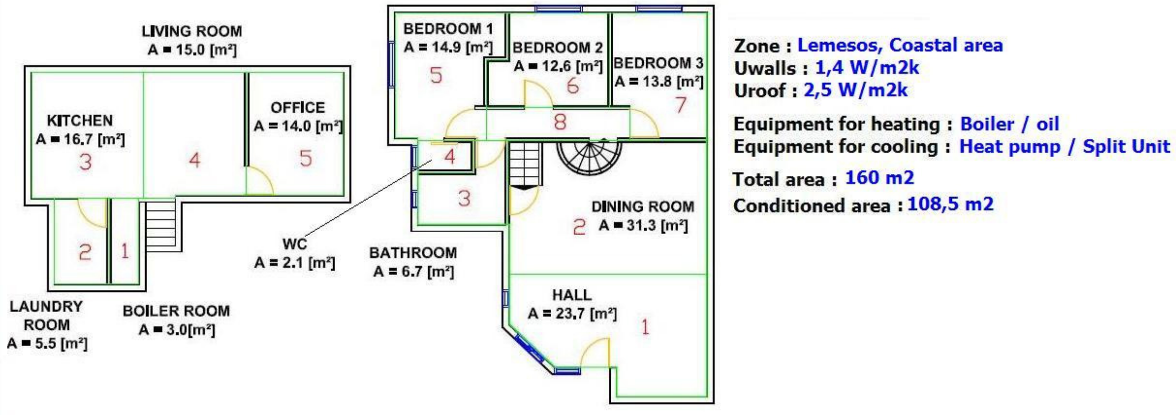
5.1 Comparison of the calculated and measured energy rating results

As already mentioned, the comparison of the results of these two approaches is a scientifically interesting topic, which can also provide useful insights and which can be used to assess the cumulative effects of actual construction, systems and operating conditions. For the scope of this paper the comparison will be performed for three selected dwellings. These three dwellings are representative for the dwelling stock in Cyprus. The plot of these dwellings and their major characteristics are presented in figure 7.

Dwelling 1



Dwelling 2



Dwelling 3

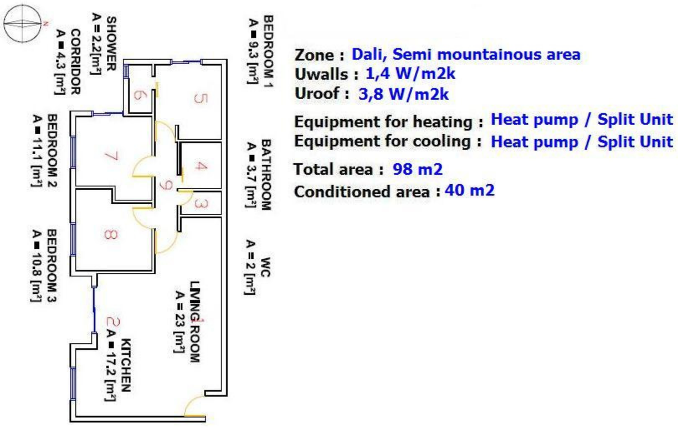


Fig. 7 Plot of the selected dwellings and their major characteristics.

Dwelling 1 and 2 are detached buildings and dwelling 3 is a flat in a multi-storeyed building. All three dwellings are built with conventional brick walls and all of them are equipped with a thermosiphonic solar water heating system for domestic hot water needs. For the purposes of this comparison the contribution of a 2m^2 solar water system is estimated to be 1806 kWh [14]. Dwelling's 1 walls are insulated whilst the other two dwellings have no thermal insulation. Moreover, following the average trend of the dwelling stock in Cyprus, none of the three dwelling's roof is insulated. All dwellings are equipped with a number of heat pumps (split unit air-conditioners) to cover their cooling demands. Only dwelling 2 has a central heating system with an oil fired boiler. The other two dwellings cover their heating loads with heat pumps or via other means e.g. mobile gas stoves. With regards to the area denominator for the measured energy rating an adjustment was made in order to take into account the spaces which are de facto unconditioned. For this, a weighted condition area (cooling and heating) was calculated and utilized. For the calculated rating the Cyprus methodology and the SBEM_Cy software application, presented above, is used.

The measured rating yielded quite low final energy consumption. As presented in figure 8 the energy consumption varies between the values of 85 and 115 kWh/m^2y with the lowest consumption observed in the dwelling with wall insulation. It must be noted that the relatively low measured energy consumption is a general finding of the research project ΑΕΙΦΟΡΙΑ/ΑΣΤΙ/0308 (ΒΙΕ)/02 ΚΤΙΡΙΑ [4-6] where the sample was 500 dwellings and the mean measured final energy consumption for the sample was 170 kWh/m^2y. Dwelling 3 exhibits the highest RES contribution, because it has the smallest useful floor area.

The calculation rating yielded quite higher final energy demands (see figure 9), which are almost double, or threefold in the case of dwelling 2, compared to the measured energy consumptions. A feedback received from dwelling 2 was that although it is equipped with 5 spit unit type air conditioning systems, one in each room, these are rarely in operation. The dwelling with the insulated walls exhibits the lowest final energy demand whereas the cooling demand is a dominant figure in all cases. The calculated heating demand seems to be equal with the measured oil consumption whilst the calculated cooling demand outreaches by far the electricity consumption. The results reveal that in reality only a fraction of the annual cooling need is satisfied and that the overall energy demand is not met. A first response to this observation is that dwellings in Cyprus suffer from poor thermal comfort conditions.

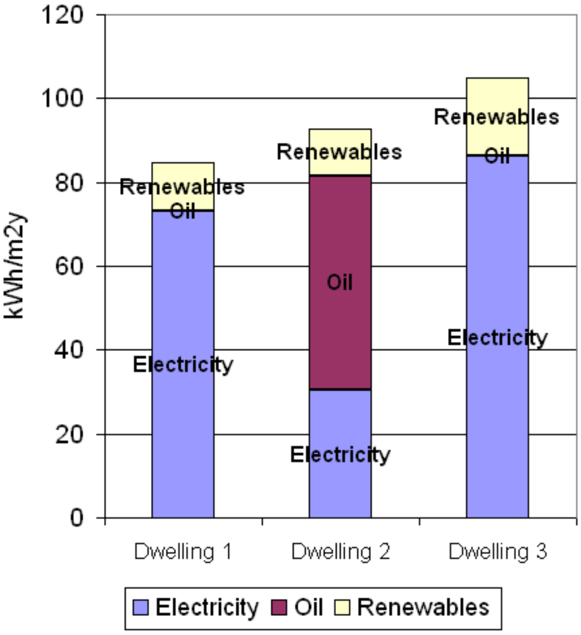


Fig. 8 Measured final energy consumption

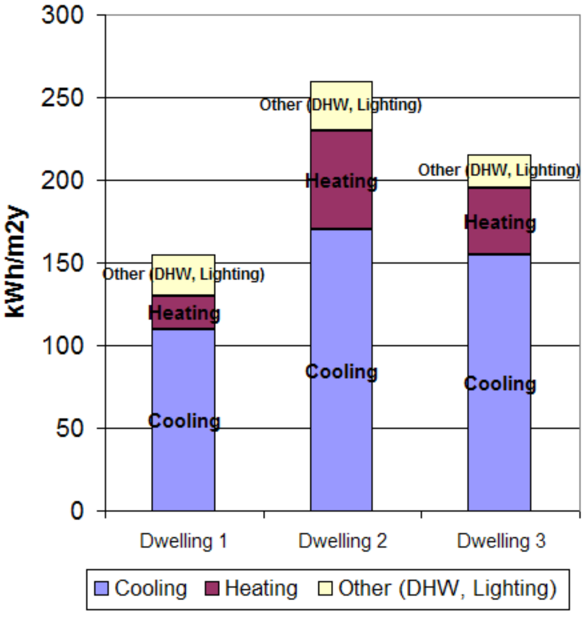


Fig. 9 Calculated final energy demand

Complimentary to the final energy consumption / demand comparison derived by the two ratings, a comparison of the primary energy consumption / demand was performed. In the measured rating approach the primary energy consumption was derived by the multiplication of the delivered final energy (oil and electricity) by the national conversion factors which are 2.7 for electricity and 1.1 for oil. In order to have a common base with the calculation approach to reach the primary energy consumption, the RES contribution is not taken into account. In the calculation rating approach the primary energy demand was an output of the software application prepared by the Energy Service.

Due to the fact that electricity is the main energy source, the primary energy consumption for all 3 dwellings is very high (see figure 10) and almost threefold compared to the final energy demand or consumption. The very high cooling demand of dwelling 2, which is covered by split unit type air conditioning systems (electricity), led to a significantly higher primary energy consumption / demand.

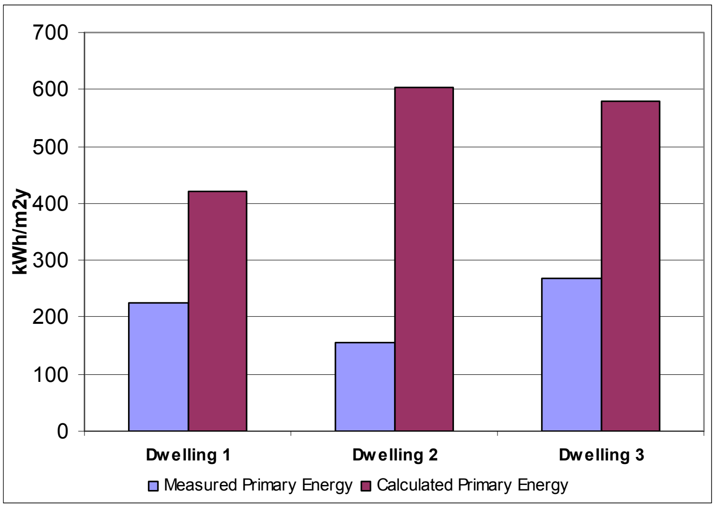


Fig. 10 Measured and calculated primary energy consumption / demand

5.2 Investigation of the impact of the climatic conditions to the calculated energy rating result

The climatic conditions have an influence on the energy demand of buildings. In order to investigate the effect of the climate on the energy performance of buildings, the energy demand of dwelling 2 described above was calculated via the SBEM_Cy for four locations, one in each climate zone. As presented in figure 11 the calculated energy demand varies between 260 and 390 kWh/m^2y with the lowest demand observed in the lowland and the highest in the mountainous zone. The coastal zone exhibits the highest cooling and the lowest heating demand, whilst in the mountainous zone we observe the opposite situation, with the highest heating and lowest cooling demand. Finally in the three most densely inhabited zones the cooling demands exceed the heating demand.

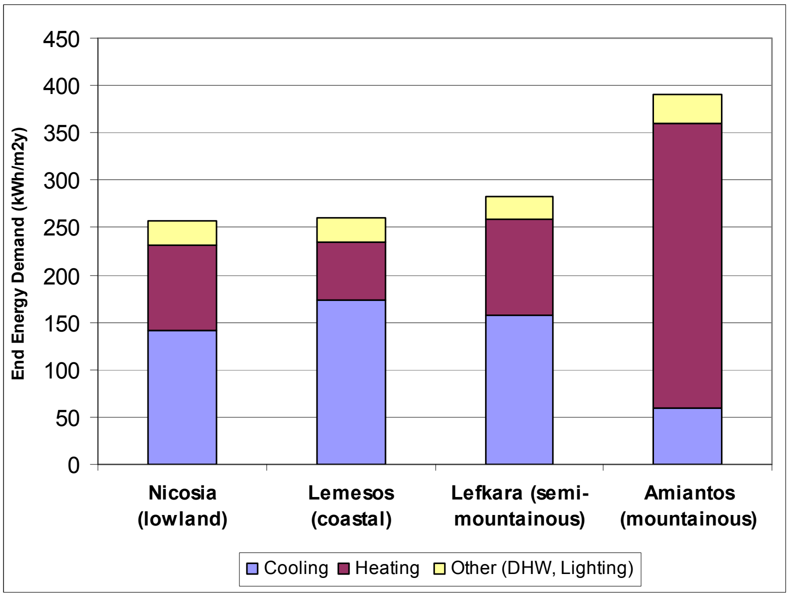


Fig. 11 Calculated final energy demand for 4 locations (zones)

5.3 Previous work performed within a similar context

It should be noted that the investigation of the variation of the energy demand (heating and cooling) of a standard dwelling, depending on the climate conditions and the insulation of its façade and roof, was performed previously by Florides *et al.* [16] and Kalogirou *et al.* [17]. By utilizing a simulation code prepared in TRNSYS the cumulative heating and cooling loads for a year were calculated for a standard dwelling for a number of scenarios. The first scenario [16] investigated the effect of wall and roof insulation to the heating and cooling loads. More specifically the energy demand of a single wall, a double wall with 2.5 cm insulation and a double wall with 5 cm insulation, as well as a single wall with no-roof insulation, a single wall with 2.5 cm roof insulation and a single wall with 5 cm roof insulation for a dwelling in Nicosia was calculated. A summary of the results is presented in table 1.

Tab. 1 Investigation of the effect of insulation to the energy demand of a typical dwelling

Demand (kWh/m^{2}y)	Single wall / no-roof insulation	Insulated walls		Insulated roof	
		Double wall with 2.5 cm insulation / no-roof insulation	**Double wall with 5 cm insulation / no-roof insulation**	**Single wall with 2.5cm roof insulation**	**Single wall with 5cm roof insulation**
Cooling at 25°C	216	212	210	126	117
Heating at 21°C	81	75	73	33	27
Total	297	287	283	159	145

It can be seen, that the total demand for a non insulated typical dwelling is 297 kWh/m^{2}y and the cooling load is the dominant figure. The total energy demand for a dwelling with a 5 cm wall insulation is reduced to 283 kWh/m^{2}y and for a dwelling with an 5 cm insulated roof to 144 kWh/m^{2}y respectively. Although it was not calculated in [16,17], the energy demand of a dwelling with insulation both on the roof and in the walls is estimated to be approximately 130 kWh/m^{2}y.

The second scenario investigated the effect of climate to the heating and cooling loads [17]. The energy demand of a non insulated and insulated typical dwelling was calculated for 4 different locations which represent the different climatic zones in Cyprus. The results of this investigation are presented in a synoptic way in table 2. As shown, the total energy demand for a non insulated dwelling, depending on its location, varies from 297 kWh/m^2y to 348 kWh/m^2y, with the highest one observed in the mountainous area and the lowest one in the lowland. For an insulated dwelling the energy demand is reduced significantly and varies from 116 kWh/m^2y to 131 kWh/m^2y. For the insulated dwelling the coastal and semi-mountainous dwelling exhibit the lowest energy demand.

Tab. 2 Investigation of the effect of the location of erection to the energy demand

Location	**Cooling loads (kWh/m^2y)**		**Heating loads (kWh/m^2y)**		**Total demand (kWh/m^2y)**	
	A non insulated	B insulated	A non insulated	B insulated	A non insulated	B insulated
Nicosia lowland	213	111	84	20	297	131
Poli coastal	213	102	68	14	326	116
Saitas semi-mountainous	208	86	113	32	321	118
Prodromos mountainous	107	38	241	84	348	122

6 Discussion

In this paper the Cyprus legal framework for adopting the EPBD and the Cyprus methodology for the energy performance of buildings were presented. The Energy performance of buildings directive enforced the energy rating of buildings. This rating can be performed either by means of calculation (asset rating) or by means of measurement of the amounts of delivered energy (operational rating). Another approach is the use of dedicated simulation codes, traditionally used for academic purposes, which are beyond the scope of the EPBD's implementation. Considering the latter, both approaches exhibit advantages and disadvantages.

This work confirmed that the results derived by the two approaches vary significantly and therefore they cannot and should not be directly compared. More specifically, the calculated ratings yielded double energy consumptions compared to the measured ones whilst the results of the energy demand via simulation are slightly higher compared to the calculated ones. In the case of Cyprus the variance of the measured and calculated or simulated results can be justified by the incapability of the calculation or simulation methodologies to capture the occupant's behaviour and the local lifestyle, which commands that the average Cypriot family members spent a lot of time outdoors. Moreover, in Cyprus the cooling demand is dominant and by default is satisfied by split unit heat pumps. Additionally, and in contrast to other EU countries where the heating demand is in principle satisfied by central heating systems, the heating demand of more than half of the dwellings in Cyprus is covered by split unit heat pumps as well. In practice this means that the "quick start up" heat pumps are used for a smaller time period per day, compared to the anticipated one. Moreover, due to their characteristics they cover only a small part of the dwelling's heated area, whereas the calculation method assumes that the delivered energy should cover the domestic hot water and lighting needs but most importantly the heating energy and cooling energy needed to maintain the envisaged temperature conditions of the whole dwelling space, 24 hours a day for the whole year. This phenomenon is stronger in the case of dwellings, where the user's behavior influences significantly the energy consumption, compared to non residential buildings with central HVAC systems and standard operational patterns.

Finally, it was concluded that the location of the dwellings, and the respective climatic conditions, influence the final energy consumption by up to 35%. The trend of the weather influence on energy demand is confirmed by the simulation approach, though to a smaller spectrum of up to 20%.

7 Conclusions

The 2002/91 Directive requires from Member States to set an energy rating scheme which will lead to an energy performance certificate *made available to the owner or to the prospective buyer or tenant when buildings are constructed, sold or rented out.* The methodology of the energy rating should be balanced between detail/accuracy and usability in practice. The overall idea of EPBD is to set a common benchmark for the energy rating of buildings. In light of this the parallel use of the two energy ratings for the same building is not recommended since as this paper shows the results vary significantly. This recommendation becomes stronger for the case of dwellings.

This paper identified a gap between the calculated energy demand and the measured energy consumption mainly due to the distinctive situation of the high cooling demand and the extensive usage of split type heat pumps which exhibit some particular characteristics like area independent and interruptible cooling.

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