Development of cost optimal building performance requirements for housing in a Mediterranean climate

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Abstract

The revised Energy Performance of Buildings Directive introduces the concept of cost optimality and places considerable importance on the relationship between cost and energy performance. All member states are obliged to set minimum energy performance requirements for buildings with a view to achieving cost-optimal levels. These are to be calculated using a comparative methodology framework on the level of the individual Member States.

Although considerable research has been carried out on the development of energy performance regulations in Northern and Central Europe, this has not been the case in Southern Europe. There are fewer exemplars of low energy buildings, building energy regulations have only been in place over the last few decades, and the implementation of these regulations is still in its early stages. At the same time, it is acknowledged that the technical requirements for the reduction of energy consumption in housing in the Mediterranean region are generally more complex due to the existence of both cooling and heating loads.

This paper outlines the development of the cost-optimised minimum energy performance requirements for housing in Malta. These are established by calculating the life cycle costs for the building and building elements on the basis of different packages of measures applied to a reference building. The procedure includes the definition of appropriate reference buildings for the Maltese building stock, as well as the selection of packages to be applied to reference buildings for both new-build and refurbishment scenarios.

A comparative analysis of the findings in relation to current construction practice and legislation in Malta and other Mediterranean states identifies the main areas for improvement in the energy performance of housing in the Mediterranean climate.

Introduction

The European Energy Performance of Buildings Directive (EPBD) 2002/91/EC introduced various obligatory requirements intended to achieve the reduction of the use of energy resources in buildings and, consequentially, the reduction of the environmental impact of energy use in buildings. Article 7 of the directive formally specified the current European requirement for the energy certification of buildings. In order to implement this requirement, a general framework for establishing a methodology of calculation of the total energy performance of buildings became necessary. A total of 30 European (EN) standards and 24 international (EN ISO) standards were drafted in order to define the necessary procedures to be introduced following the ratification of the EPBD. In 2010, a recast of the Energy Performance of Buildings Directive 2010/31/EC was adopted by the European Parliament and the Council of the European Union in order to strengthen the energy performance requirements and to clarify and streamline some of the provisions from the 2002 Directive.

In Northern and Central Europe it is estimated that over half of residential energy use can be attributed to home heating, (Van Raaij & Verhallen, 1983, Yao & Steemers, 2005). As a result, considerable research into energy efficient housing is focussed on the established strategy of improving insulation levels and airtightness, in order to minimise this predominant heating load, possibly reducing this to nil. This emphasis on the space heating load is apparent even in the standards that have been drafted in connection with the EPBD. The primary standard for the calculation methodology EN 13790:2008 was developed from the 'Calculation of Energy Use for Space Heating' (EN ISO 13790, 2003), the successor of the possibly still better known residential-only standard EN 832 'Calculation of Energy Use for Heating – Residential' (van Dijk et al, 2005).

The energy performance of residential buildings in South Europe has not been investigated as thoroughly as in North and Central Europe, and examples of energy efficient housing in a Mediterranean climate are limited. The milder climate means that the energy demand for housing is restricted to a short heating season, and prior to the substantial take-up of air-conditioning during the last twenty years, summer cooling meant the use of ceiling fans. Historically, energy use in housing was not an economic or social issue in the Mediterranean. Brick walls are single or, rarely, double layer with 4 centimetre air cavity and in most cases there is no thermal insulation (Andeweg et al, 2007).

Researchers have recommended that the continued further refinement of the cooling calculation methods is warranted so as to better evaluate the consumption of all possible means of cooling, including and in particular the low energy methods (Laskari & Santamouris, 2010). Comparative studies show considerable disagreement in the prediction of zone temperatures and energy loads even for very simple test case buildings, especially in situations that are strongly solar driven (Judkoff, 1988). It has been advised that attention is paid to the proper setting of default values. In particular, a differentiated approach between the heating and the cooling season is often justified, certainly for the variables that have a major impact, e.g. air tightness and thermal bridges (Laskari & Santamouris, 2010). It is also suggested that there are modelling levels and assumptions inherent to the current calculation methods, and recommended in some of the European Committee for Standardisation (CEN) standards concerned, that are not sensitive to relevant design decisions in summer performance. (Alvarez et al, 2010).

Politicians and scientists have acknowledged that improving the energy performance of buildings is a cost-effective solution to the problems of climate change and energy security. However, the definition of cost-optimal energy performance requirements is an arduous task which involves exploring a huge number of combinations of energy saving measures, energy supply systems, and building envelopes under a comparative framework methodology (Hamdy et al, 2013).

THE MALTESE CONSTRUCTION TYPOLOGY

The Maltese islands benefit from a mild Mediterranean climate with moderate temperatures. Until the introduction of the EPBD related legislation, there was no effort to introduce thermal insulation in any form within building structures in Malta. (Buhagiar and Borg, 2007). Traditionally the main construction material is the local globigerina limestone but this is often combined with or replaced by hollow uninsulated concrete blocks. The majority of structures consist of load bearing walls roofed by concrete slabs which are most often cast in situ, but could also be constituted from precast elements.

Houses built during the British colonial period (1800–1964) constitute 39 % of the current housing stock (NSO Malta, 2010). A sample of newly built dwellings establishes a mean floor area of 136 m^2 (Abela et al, 2012). Statistics for 2005 indicate a total of 139,178 (71 %) occupied dwellings, 10,028 (5 %) holiday homes, and 43,108 (23 %) vacant dwellings in Malta (NSO Malta, 2005). Out of the 139,178 occupied dwellings, a total of 123,195 (91 %) are either terraced houses (57,037), maisonettes (32,206), or flats (33,952). Since flats and maisonettes are predominantly terraced, it can be concluded that detached and semi-detached properties constitute approximately 9 % of total occupied dwellings. This is significantly less than the European average, which is 34.3 % for detached houses and 23 % for semi-detached houses in 2009 (Eurostat, 2011).

LEGISLATION

Prior to the EPBD, there were no energy-specific requirements in Maltese construction legislation. The transposition of the directive commenced with Legal Notice 238 of 2006, The Minimum Requirements for the Energy Performance of Buildings Regulations. This was repealed following the enactment of Legal Notice 261 of 2008, The Energy Performance of Buildings Regulations, but the technical guidelines on minimum requirements established by the previous legal notice were retained. Legal Notice 376 of 2012, the Energy Performance of Buildings Regulations, was enacted to transpose the recast directive 2010/31/EC. This again repealed the earlier regulations but retained the technical guidelines on minimum requirements for the energy performance of buildings.

EPBD COST OPTIMAL REQUIREMENTS AND METHODOLOGY

The recast EPBD 2010/31/EC requires Member States to "assure that minimum energy performance requirements for buildings or building units are set with a view to achieving cost-optimal levels". Member States are also obliged to "take the necessary measures to ensure that minimum energy performance requirements are set for building elements that form part of the building envelope and that have a significant impact on the energy performance of the building envelope when they are replaced or retrofitted, with a view to achieving cost-optimal levels". Cost-optimal levels are specified in Art. 2.14 of the EPBD recast as "the energy performance level which leads to the lowest cost during the estimated economic lifecycle". Member States are also obliged to report on the comparison between the minimum energy performance requirements and calculated cost-optimal levels using the specific framework provided by the European Commission.

The comparative methodology framework requires Member States to:

- define reference buildings representative of their functionality and geographic location for both new and existing buildings,
- define energy efficiency measures to be assessed for the reference buildings. These may be measures for individual buildings as a whole, for individual building elements, or for a combination of building elements,
- assess the final and primary energy need of the reference buildings and the reference buildings with the defined energy efficiency measures applied,

- calculate the costs (i.e. the net present value) of the energy efficiency measures during the expected economic lifecycle applied to the reference buildings.

The Member States are expected to define cost-optimal levels of the minimum energy performance requirements by assessing the cost-effectiveness of different levels of these requirements on the basis of the cost calculations over the economic lifecycle.

Methodology

The steps required to derive the energy performance cost-optimal level for reference buildings are:

1. Establish reference buildings.
2. Identify energy efficiency measures, including measures based on renewable energy sources.
3. Calculate primary energy demand resulting from the application of measures and packages of measures to each reference building.
4. Calculate the global cost in terms of net present value for each reference building.

The guidance regulations for the definition of the cost-optimal levels of the minimum energy performance requirements stipulate that the reference buildings should be defined for two categories, namely, single-family buildings and apartment blocks or multi-family buildings. For each category, at least one reference building shall be defined for new buildings and at least two reference buildings should be defined for existing buildings subject to major renovation. The reference buildings should take into account the characteristics of the national building stock.

The selection of Maltese single-family buildings consists of terraced houses, semi-detached villas, and detached villas, with terraced houses constituting the majority of the building stock in this category. The selection of Maltese multi-family buildings consists of apartments and maisonettes. The reference standard for new buildings is compliance with Technical document F (BRO Malta, 2006) defining the existing minimum energy performance requirements which were introduced in 2006. Existing buildings are defined by the characteristic typology. Due to the restricted availability of building materials on the island, and the minimal changes in construction techniques over time, the diversity of building typologies is limited, with the main variation being different wall thicknesses. Table 1 summarises the selection of the different reference buildings for the Maltese cost-optimal calculation.

The scope of this analysis is to identify the cost optimal levels for the application of energy efficiency improvements to the existing building stock, as well as to assess the cost optimality of the current minimum requirements for new construction. Table 2 lists the different energy efficiency measures that were considered for application to new and existing buildings. The passive measures are those measures which improve the energy performance of the building envelope, decreasing the need for heating and cooling, whilst the active measures are the measures which enable the production of warmth, coolth, and domestic hot water in a more efficient manner.

SELECTION OF CALCULATION METHODOLOGY

The objective of the calculation procedure is to determine the annual overall energy use in terms of primary energy, which includes energy use for heating, cooling, ventilation, hot water and lighting. The main reference for this is Annex I to Directive 2010/31/EU which applies fully also to the cost-optimal framework methodology.

According to Directive 2010/31/EU definitions, electricity for household appliances and plug loads may be included, but this is not mandatory. It is recommended that Member States use CEN standards for their energy performance calculations. CEN technical report TR 15615 (Umbrella Document) gives the general relationship between the EPBD Directive and the European energy standards. Moreover, standard EN 15603:2008 provides the overall scheme for energy calculation

Whilst selection of the reference building and the energy efficiency measures is a straightforward procedure, directly related to the housing stock and the prevalent construction materials and methods, the calculation of the primary energy demand resulting from the application of the energy efficiency measures is somewhat more complex. The principal difficulty is the identification of the method to be used for this calculation. The primary choice is the current methodology used for the Maltese energy performance certificate, the Energy Performance of Residential Dwellings in Malta (EPRDM). However, since this methodology is relatively recent, only having been introduced in 2010, it was considered judicious to compare the results from the application of the energy efficiency measures using the EPRDM with the results from a established dynamic simulation software, IES-VE. IES-VE has undergone prescribed validation tests to ensure that test model results are either in exact agreement or within stringent margins of reference results. It has also been subject to additional testing according to defined procedures to ensure that the calculation algorithms are technically robust (Raslan et al, 2009). This comparative exercise was carried out using a single reference building, a modern post-war existing apartment, with a net floor area of 108 m^2. The building envelope is uninsulated and the calculated infiltration rate using the EPRDM methodology is 0.68 air changes per hour. The energy performance certificate of the apartment indicates a primary energy of 203 kWh/m^2yr. Further details of the apartment are tabulated in Appendix A. Three passive measures were identified for comparison, namely the application of roof insulation, the installation of different window types, and improvements to the airtightness of the property. The results of these comparisons are presented in graphical format in Figures 1 to 3.

Whilst the graphs clearly show that the two different calculation procedures show similar trends, they also demonstrate that the scale of the calculated energy savings is different depending on the methodology selected. For the purposes of this comparison, the energy measured is the heating load and the cooling load. This eliminates any variations that could be caused by differences in the way that the two software programmes simulate the operation of the heating and cooling plant.

The data presented in Figure 1 show that the EPRDM methodology calculates the decrease in heating load at 37 % more than IES for a 10 mm roof insulation thickness and the decrease in cooling load at 44 % more than IES. Although the difference between the heating loads reduces at higher insulation thick-

Table 1. Selection of reference building types for Maltese cost-optimal calculations.

Subcategory	Type	Period	Characteristic Features			
Single Family Buildings						
Terraced Houses	New	Compliance with Document F 2006 Regulations				
	Existing	Modern Post War	Single leaf walls in limestone and/or brick	Concrete roof slabs cast in situ with concrete tile finish	Unshaded single glazed windows with metal frames	
	Existing	Colonial Period Town House	Double leaf walls in limestone with air gap	Concrete roof slabs cast in situ with concrete tile finish	Single glazed windows, wooden frames and louvred shutters	Use of closed balcony
	Existing	Traditional Village House	Thick stone walls with rubble infill	Limestone ceiling slabs with torba finish	Single glazed windows, wooden frames and louvred shutters	Most apertures to internal open courtyard
Semi detached villas	New	Compliance with Document F 2006 Regulations				
	Existing	Modern Post War – Speculative development	Single leaf walls in limestone and/or brick	Concrete roof slabs cast in situ with concrete tile finish	Unshaded single glazed windows with metal frames	External staircase to roof
	Existing	Modern Post War – Owner designed	Double leaf walls in limestone with air gap	Concrete roof slabs cast in situ with concrete tile finish	Unshaded single or double glazed windows with metal frames	
Detached villas	New	Compliance with Document F 2006 Regulations				
	Existing	Modern Post War – Speculative development	Single leaf walls in limestone and/or brick	Concrete roof slabs cast in situ with concrete tile finish	Unshaded single glazed windows with metal frames	
	Existing	Modern Post War – Owner designed	Double leaf walls in limestone with air gap	Concrete roof slabs cast in situ with concrete tile finish	Unshaded single or double glazed windows with metal frames	
Multi Family Buildings						
Apartments	New	Compliance with Document F 2006 Regulations				
	Existing	Modern Post War	Single leaf walls in limestone and/or brick	Concrete roof slabs cast in situ with concrete tile finish	Unshaded single glazed windows with metal frames	
	Existing	Colonial Period Town Apartments	Double leaf walls in limestone with air gap	Concrete roof slabs cast in situ with concrete tile finish	Single glazed windows, wooden frames and louvred shutters	Use of closed balcony
Maisonettes	New	Compliance with Document F 2006 Regulations				
	Existing	Modern Post War	Single leaf walls in limestone and/or brick	Concrete roof slabs cast in situ with concrete tile finish	Unshaded single glazed windows with metal frames	
	Existing	Colonial Period Town Apartments	Double leaf walls in limestone with air gap	Concrete roof slabs cast in situ with concrete tile finish	Single glazed windows, wooden frames and louvred shutters	

Table 2. Energy efficiency measures to be applied for Maltese cost-optimal calculations.

Passive Measures	Roof Insulation	Typically polyurethane or polystyrene slabs placed between the floor finish and the structural slab during construction.
	Wall Insulation	Either mineral wool insulation inserted between double leaf wall during construction, or insulation slabs fitted externally with plaster finish for weatherproofing.
	Floor Insulation	Low conductivity flooring concrete for floor slab.
	Different window types	Double glazed windows, with or without thermal breaks, and with the option of low emissivity glass.
	Improving air tightness	Improved detailing in finishing of openings for apertures and type of apertures.
	Shading Elements	Overhangs on glazed apertures and shading structures on roofs.
Active Measures	Improving Efficiency of Heating Systems	Typically air cooled heat pumps with on/off or inverter control but gas heating also an option.
	Improving Efficiency of Cooling Systems	Inverter controlled air conditoning systems
	Solar Water Heating	Both flat plat and vacuum tube collectors used mainly for direct systems.
	Photovoltaic Systems	Both monocrystalline and polycrystalline panels without tracking systems.
	Energy Efficient Lighting	Compacy fluorescent and LED bulbs

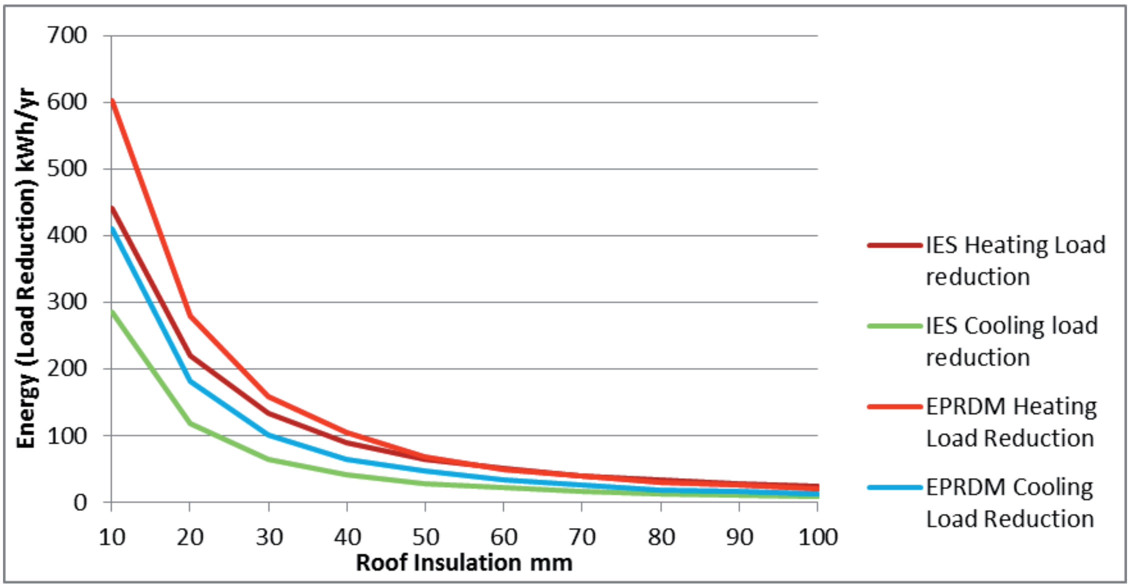

Figure 1. Reduction in heating & cooling load for application of roof insulation calculated using EPRDM and IES from reference point of no insulation.

nesses, with IES calculating a decrease in heating load of 13 % more than EPRDM at a 100 mm roof insulation thickness, the difference between the cooling load calculations does not vary in the same way. The average difference between the two calculations is 7 % for the heating load and 56 % for the cooling load.

The differences shown in Figure 2[1] are even more pronounced, particularly for the windows Type 3 and Type 4. This is a double glazed window with low emissivity glass for reduced solar transmission, with two different frame types. The IES method shows markedly higher decreases in the cooling load, with a minimal increase in the heating load, whilst the EPRDM method shows minimal changes in the cooling load, with slightly higher increases in the heating load. The decrease in cooling load for the Type 3 window is approximately three times larger when calculated by IES.

The ratio between the different results presented in Figure 3[2] is relatively constant. Improvements to the airtightness of the

1. Type 2 double glazed with air gap and metal frame, Type 3 same as Type 2 but with low emissivity glass, Type 4 same as Type 3 but with PVC frame (thermal break).

2. The unequal distribution of the steps on the x-axis defines the shape of the graph, as the heating and cooling load are actually directly proportional to the ventilation rate.

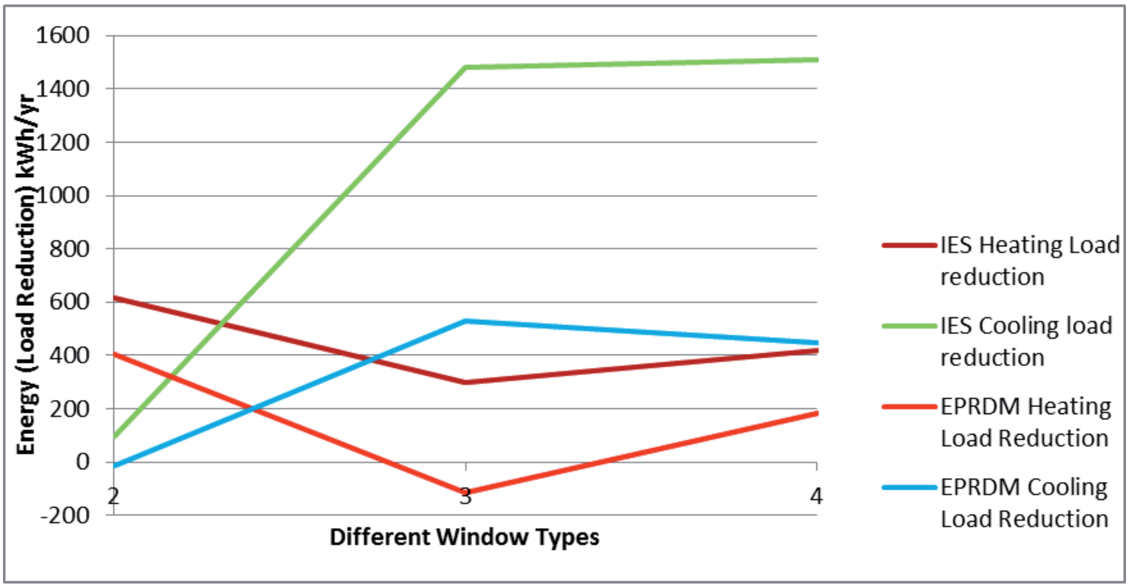

Figure 2. Reduction in heating & cooling load for application of different window types calculated using EPRDM and IES from reference point of window type 1 – single glazed metal frame no thermal break.

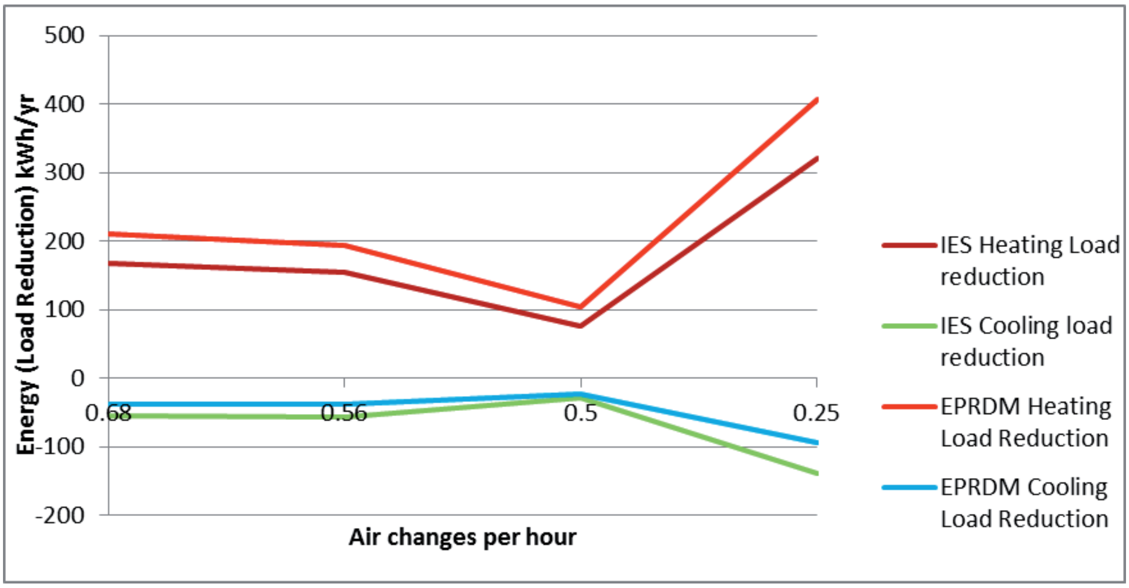

Figure 3. Reduction in heating & cooling load with improved airtightness calculated using EPRDM and IES from reference point of 0.81 air changes per hour.

structure, presented as a reduction in the number of air changes per hour, gives a consistently higher decrease in the heating load reduction (approximately 28 % more) and a consistently lower decrease in the cooling load reduction (approximately 30 % less) when calculated by IES as compared to EPRDM.

Clearly whilst ventilation appears to be consistently handled between IES and EPRDM, the transmission loads through the walls and roof particularly in the heating season are not being considered in an identical manner by the two approaches. The difference between the rate of decrease of heating load with increase in insulation is even more anomalous when considering that the net heating load for IES is approximately double that calculated by EPRDM, and hence one would expect the savings to be greater using the IES simulation, rather than less.

COST OPTIMAL LEVEL

The directive defines the cost-optimal level as "the energy performance level which leads to the lowest cost during the estimated economic lifecycle". Member states are obliged to define this level whilst taking into account the complete range of costs including, but not limited to investment costs, maintenance costs, operating costs, and energy savings. The economic lifecycle of the building or the building element is to be determined by each Member State.

The concepts of cost-effectiveness and cost optimality are related but different. Cost-optimality is a special case of cost-effectiveness. A measure or package of measures is cost-effective when the cost of implementation is lower than the value of the benefits that result, taken over the expected life of the measure.

Both are based on comparing the costs and (priced) savings of a potential action – in this case of introducing a particular level of minimum energy performance requirements for buildings. Future costs and savings are discounted, with the final result being a "net present value". If this is positive, the action is "cost-effective" (for the particular set of assumptions used in the calculation). The "cost-optimal" result is that action or combination of actions that minimises the net present value.

Cost optimality is relatively easy to determine for single measures operating in well-defined conditions – for example, the optimal insulation thickness for pipework operating at a constant temperature in a constant-temperature environment. It is a considerably more difficult process for complete buildings, and even more so for combinations of buildings such as a national building stock, due to the large amount of parameters involved. Figure 3 demonstrates as an example how measures that improve performance in certain circumstances, such as during the heating season, result in a decrease in energy performance levels in other circumstances, such as during the cooling season.

The question is how to derive consistent judgements on cost optimal levels when there is a huge diversity in methods, definitions and assumptions that dominate the outcome. The risk in this approach is that the validity of many national input variables and assumptions should be checked in order to validate the outcome of the comparison.

The Regulation states that cost data must be market-based (e.g. obtained by market analysis) and coherent as regards location and time for the investment costs, running costs, energy costs and if applicable disposal costs. This means that cost data need to be gathered from one of the following sources:

- Evaluation of recent construction projects;
- Analysis of standard offers of construction companies (not necessarily related to implemented construction projects);
- Use of existing cost databases which have been derived from market-based data gathering.

It is important that the cost data sources provide the cost of the constituent parts which is required to compare different measures/packages/variants for a given reference building. Benchmark databases which are commonly used for rough estimates of the investment and operating cost of buildings cannot be used for the purpose of cost-optimal calculations because their data are not sufficiently related to the energy performance of the building. These costs are aggregated and hence cannot provide the cost differentiations for different measures or packages of measures.

Results

STRATEGY

Table 1 defines five different types of new reference buildings and up to sixteen different types of existing reference buildings, whilst Table 2 lists eleven different energy efficiency measures which can be combined in a variety of different permutations. Clearly the identification of the cost optimal levels requires a substantial volume of calculations. The variations in the primary energy calculation due to the different calculation methodologies outlined earlier are expected to cause variations in the cost optimal levels. Prior to executing and analysing the calculations for the complete package of reference buildings, a single building and a small sample of measures was selected for a case study, to analyse the effect of the different primary energy calculations on the cost optimal levels.

The case study was carried out on a single reference building, an existing modern post war top floor apartment. Apartments and maisonettes constitute over 45 % of occupied dwellings in Malta (NSO Malta, 2005), and the post war construction typology is typical of approximately 40 % of the construction sector. This apartment is currently unoccupied and hence no actual energy data for the apartment is available. The actual characteristics of the apartment are tabulated in Appendix A.

Due to the large number of possible combinations of energy efficiency measures that could be applied, multi-stage optimisation methods have been proposed (Hamdy et al, 2013) to enable the effective grouping of these measures. The three stages recommended are:

1. Optimisation of the combinations relating to the building envelope and ventilation.
2. Combining the heating/cooling systems with the optimised building envelope solutions.
3. Integration of renewable energy sources.

For the purposes of this analysis the energy efficiency measures most appropriate to be fitted in a refurbished building were selected, namely:

- Installation of roof insulation in varying thicknesses from 10 to 100 mm (default no insulation).
- Installation of different glazing types, namely double glazed with air gap (Type 2), double glazed with low emissivity glass (Type 3), and double glazed with low emissivity glass and thermal break in frame (Type 4) with single glazing (Type 1) as the default.
- Installation of measures to reduce infiltration and improve airtightness, reducing from 0.56 to 0.25 air changes per hour (default 0.86 air changes per hour).
- Installation of improved heating and cooling systems (air-to-air heat pumps), with coefficient of performance for heating from 2.8 to 4 and for cooling from 2.6 to 3.6 (default electric heating and cooling coefficient of performance at 2.6).[3]

Measures related to the domestic hot water system and the integration of renewable energy sources were not considered at this stage of the analysis. These were omitted as the performance of these measures is to a great extent independent of the characteristics of the building and have little or no effect on the cooling and heating system operation. They will however be integrated in the comprehensive study currently underway to establish the national cost-optimal levels.

3. HVAC plant type 1 is electric heating and split type air conditioning with COPs of 1 and 2.6 respectively whilst other options are for heat pumps with improved efficiencies and COPs for types 2, 3 and 4 at 2.8/2.6, 3.3/3.0 and 4/3.6 respectively.

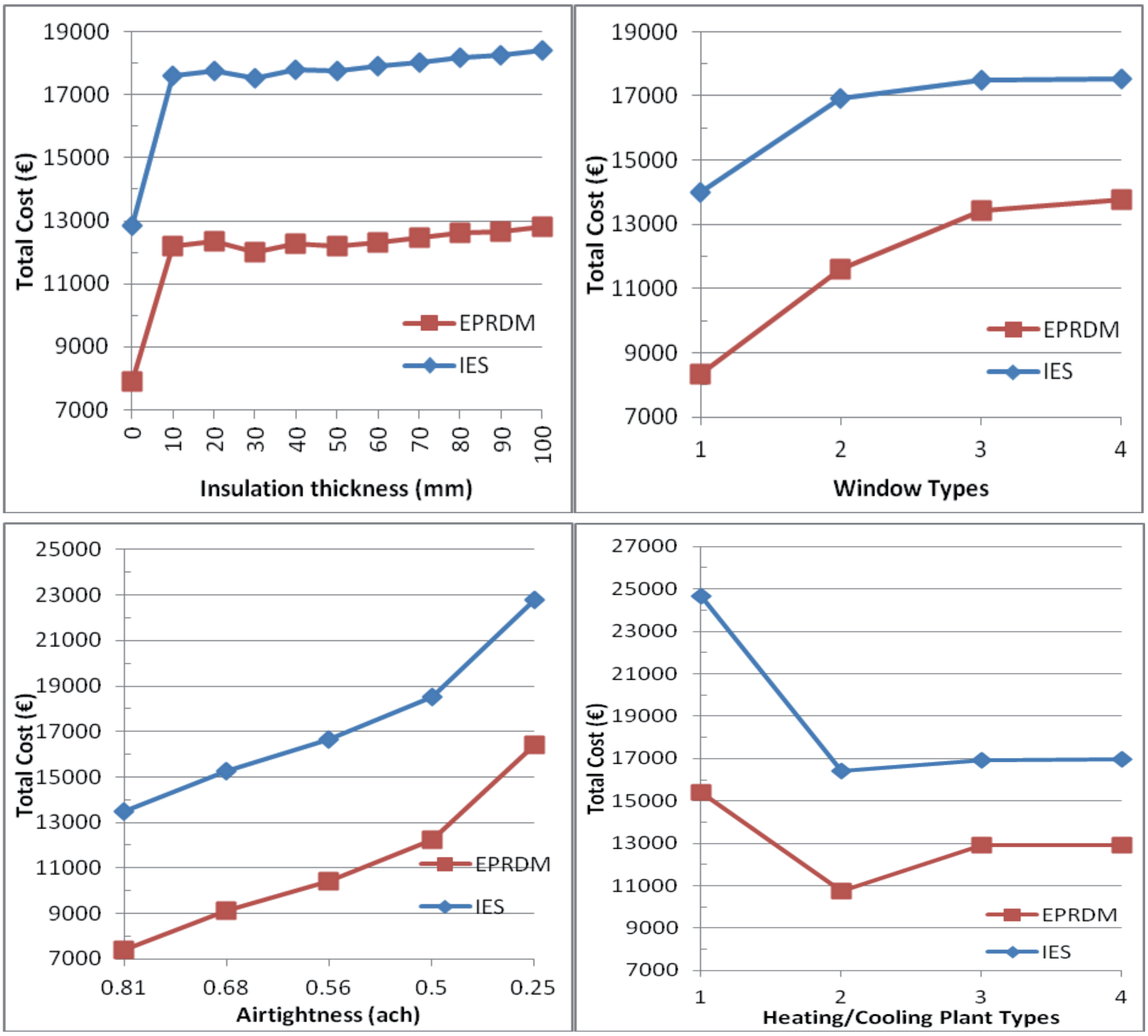

Figure 4. Global cost of various energy efficient interventions on an existing top floor apartment in Malta, over a thirty year period, with a discount rate of 6 %.

In April 2012 the EU published guidelines supplementing the directive 2010/31/EU on the establishing of the comparative methodology framework for the calculation of cost-optimal levels of minimum energy-performance requirements for buildings. In order to establish the cost-optimal methodology, the EU appointed a contractor, Ecofys, to oversee and support the implementation of the cost-optimal methodology. A training workshop was held in 2012 on the setting up of cost-optimal calculations and the calculation methodology proposed in this workshop was used for the global cost calculations.

FINDINGS

Since the apartment was refurbished in 2010, sufficient data was available to obtain costs for the various measures. The primary energy data was calculated using the two different methodologies described above, namely EPRDM and IES. The cost calculations were carried out over a thirty year period, using two different discount rates, 6 %, and 3 %, corresponding to private and societal discount rates respectively.[4] No residual value was assumed after thirty years, neither were any replacement costs assumed over the thirty year period. In the case of items for which the lifetime is less than thirty years, no replacement costs were assumed since these items are essential to the function of the building, and replacement could not be considered as an additional cost to the energy performance of the building. Similarly no maintenance costs were assumed since there is no practical differentiation in the cost of maintenance of the different options considered.

Figure 4 illustrates the effect of the selected energy efficiency interventions on the reference apartment, when a discount rate of 6 % is assumed. A number of characteristics are clear from this first set of graphs. It is clear that although the different energy calculation methodologies produce completely different results, the trends displayed by the two methodologies are extremely similar, with only the scale of the values being different. This seems to indicate that whilst it might be difficult to establish an exact prediction of the value of energy saved by a particular intervention, either of the two methods can predict whether or not the various interventions are cost optimal over a thirty year time frame. Contrary to expectations, the majority of the energy efficiency improvements to the property do not

4. The discount rate is the percentage rate required to calculate the present value of a future cash flow.

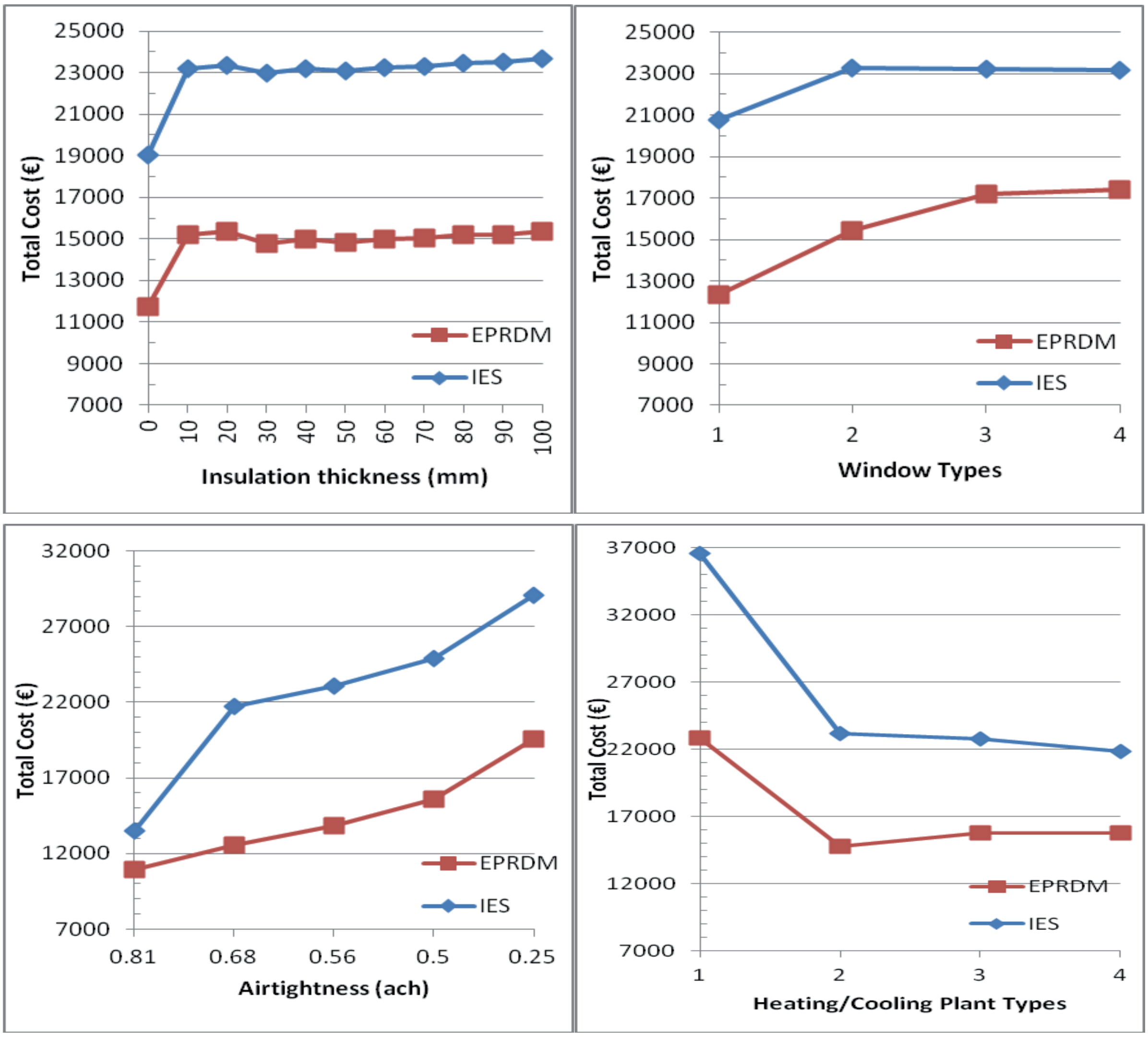

Figure 5. Global cost of various energy efficient interventions on an existing top floor apartment in Malta, over a thirty year period, with a discount rate of 3 %.

result in lower costs over the thirty year life, as in practically all cases as the curve moves to the right (for reduced energy use), the costs rise. The only instance where the global costs drop is in the transition from electric heating to air-to-air heat pump heating shown at point 2 on the heating/cooling plant curve. In most instances, except for the improvements in air tightness, the initial investment in energy efficiency results in a global cost increase, but further investments result in approximately the same cost, as the graphs tend towards a horizontal straight line.

Figure 5 displays similar data for the global cost of various energy efficient interventions on the reference apartment over a thirty year period, but this time a discount rate of 3 % has been applied. In this case, the characteristics of the graphs show marked differences from the first set of values.

The two different calculation methodologies show similar trends, although the absolute values of the global costs are markedly different, due to the higher energy requirements computed by the IES methodology. Unlike the other examples where the global costs increases or flattens out with improved energy efficiency, the IES methodology indicates that the global costs decrease and continue to decrease with improved efficiency of the heating and cooling plant, for the case of the lower discount rate.

Figure 6 presents the cost curves of primary energy against total cost for the 3 % discount rate. From this figure, the only cost effective energy improvement is the use of heat pumps for heating, whilst other improvements tend to increase the total cost of the building. Of course this is a case study, and further analysis is required, specifically for a larger range of buildings and improvements.

Conclusions

The results presented in this preliminary analysis cannot be expected to provide a conclusive definition of the cost–optimal minimum energy performance requirements for buildings in Malta. The limited selection of reference building and design solutions, although representative of the building stock, can only be considered as a case study for a more comprehensive exercise. One of the main challenges of the cost-optimal calculation is to ensure that, whilst all measures with an impact on the energy use of the building are considered, the calculation exercise remains of manageable proportion (Hamdy et al, 2013).

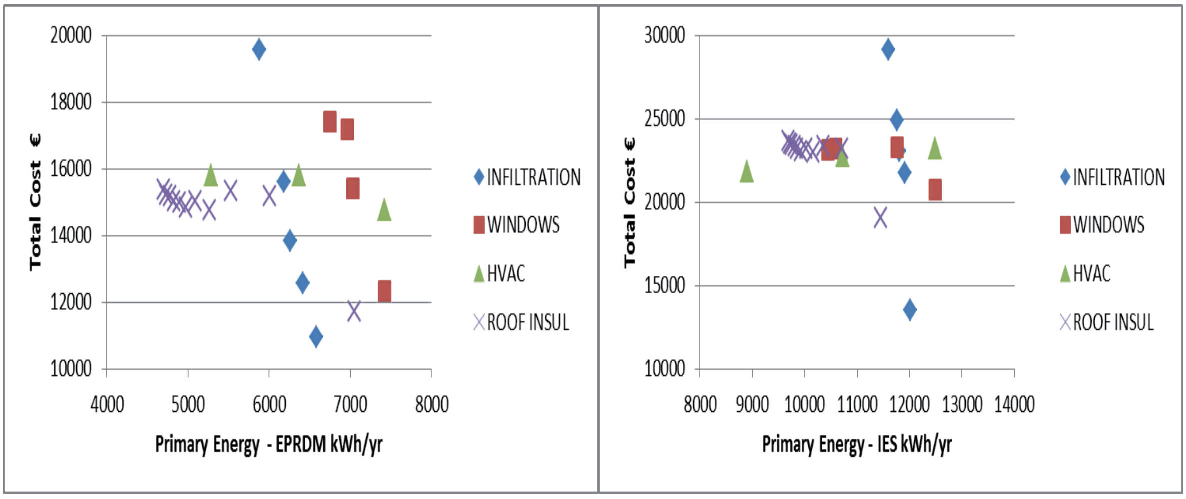

Figure 6. Global cost against primary energy for case study apartment using both EPRDM and IES for primary energy calculation and a 3 % discount rate for cost calculation.

The particular reference building selected for this exercise demonstrates a number of specific characteristics, namely:

- It is a single storey apartment, a category which includes over half of all occupied dwellings in Malta.
- It is from the post war period, representing over a third of the building stock.
- The construction elements and services are typical would no specific variances from common practice.
- It is an existing building, which is where the main focus for energy saving improvements is necessary to achieve energy reductions. Although new buildings are easier (and cheaper) to incorporate energy saving improvements, they account for a very small proportion of the building stock, and hence any significant improvements in the overall energy performance of a member state can only be made by focussing on existing buildings.

As a case study the analysis described has been carried out to demonstrate the characteristics of cost optimal minimum energy performance requirements in the Mediterranean climate of Malta. The results of this exercise show that:

- The definition of reference buildings for both new and existing buildings is a straightforward exercise that is limited by the minimal variations in construction materials and technologies.
- The curves plotted differ from the typical cost optimal curve suggested by the guidelines to the implementation to the directive, where a particular measure or package of measures results in the lowest global costs. In this case the case study analysis suggests that nearly all energy saving measures result in increased global costs.
- The economic advantages of energy efficient improvements to the case study are outweighed by the investment costs, and the data presented appears to justify the energy performance of the current building stock as cost-optimal. Higher energy-price escalation rates would encourage investments in energy saving measures.
- The two methodologies selected for calculation of the primary energy demands show considerable variation, with the dynamic analysis presenting consistently higher values for primary energy demand than the energy certification software.
- The cost-optimality of energy efficient improvements to the building envelope and the heating and cooling systems is directly related to the primary energy demand. The mild Mediterranean climate, with lower primary energy demands than the Northern European climate, presents a scenario where energy saving measures has a reduced impact on operating costs.
- Whilst this case study is simply a preliminary analysis to provide direction for a more complete analysis of the complete range of reference buildings and energy saving measures, it does seem to indicate a scenario where the cost optimality for refurbishment of existing residential buildings could be more heavily weighted towards the introduction of renewable energy sources, followed by improvements to the heating and cooling systems, with improvements to the building envelope to be given a much lower priority.

Although local legislation has been revised to comply with the new directive 2010/31/EC, the technical guidelines specifying the minimum requirements for the energy performance of buildings have yet to be revised. The preliminary work carried out in this analysis indicates that the revision should certainly include reference to the minimum performance of heating and cooling equipment, as well as reassessment of the current requirements relating to insulation of opaque elements, size and typology of windows. This is in line with the revised directive 2010/31/EC which includes technical building systems specifically in Article 8, after stipulating that minimum requirements should apply to both building elements and technical building systems in Article 1. The existing document also stipulates requirements for lighting and sub-metering and the former certainly offers scope for cost optimisation whilst the practical utility of additional metering requires further analysis before taking a decision in this regard. The inclusion of a minimum energy performance benchmark figure would certainly allow greater scope for architects and designers to consider innovative methods and materials in a very tradition-led construction industry.

This case study can be used to provide the framework for exploring the complete range of design option for new and existing building in the Maltese climate, which includes renewable energy systems, HVAC systems, domestic hot water systems, and improvements to the building envelope. The complete analysis is necessary to identify the optimal combinations that are both economically and environmentally viable. However this case study identifies the sensitivity of three specific issues namely:

1. The influence of the primary energy calculation methodology. Following the differences identified here, and although the EPBD is heavily weighted towards the energy performance of buildings under a standardised set of conditions, it is clear that the primary energy calculation methodology selected should have a justifiable relationship to actual energy consumption, i.e. metered energy.
2. The different cost factors applicable to the installation of energy saving measures in new buildings and in existing buildings. The case study identified that it might not be possible to justify improvements to the energy performance of existing buildings using the cost optimal yardstick.
3. The mild climate, which results in both a heating load and a cooling load of a smaller order, rather than a single predominantly heating load of a larger order, creates a scenario where the financial and the environmental aims tend to contradict each other. The cost effectiveness of energy saving measures is much more difficult to achieve in a landscape where energy demand is naturally minimised by the climate.

The lead author is currently researching the different EU certification methodologies applied in Mediterranean regions in relation to his doctoral study on Energy Certification of Residential Property in the Mediterranean. This work has been developed to provide the framework for the calculation of the cost optimal requirements for residential building for Malta, in compliance with the requirements of the recast directive.

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Appendix A: Details of the Case Study

In this case study, a top floor single storey three bedroomed apartment in a block of four located in Sliema, Malta was considered. The net floor area of the apartment is 108 m^2 with a total glazed area of 23.6 m^2 and a total exposed wall area of 77.9 m^2. The height of the storey is three metres. The windows are generally unshaded and the roof is partly shaded. Figure 7 shows the façade of the apartment block and Table 3 gives the details of the construction materials. Figure 8 shows the architectural plan of the apartment.

Figure 7. Façade of apartment block.

Table 3. Details of building construction material.

Building construction	Details	U- Value
Exterior façade wall	Internal light plaster (6 mm thick), inner leaf limestone wall (230 mm thick), uninsulated air gap (50 mm), outer leaf limestone wall (230 mm thick).	1.31 W/m^{2}K
Other external walls	Internal light plaster (6 mm thick), single leaf limestone wall (230 mm thick).	2.49 W/m^{2}K
Roof	Internal light plaster (6 mm thick), concrete slab (200 mm thick), sand/stone chipping screed (75 mm thick), concrete tile (25 mm thick).	1.73 W/m^{2}K
Glazing	Double glazed windows with air gap. Sliding windows with aluminium frames without thermal breaks.	2.47 W/m^{2}K

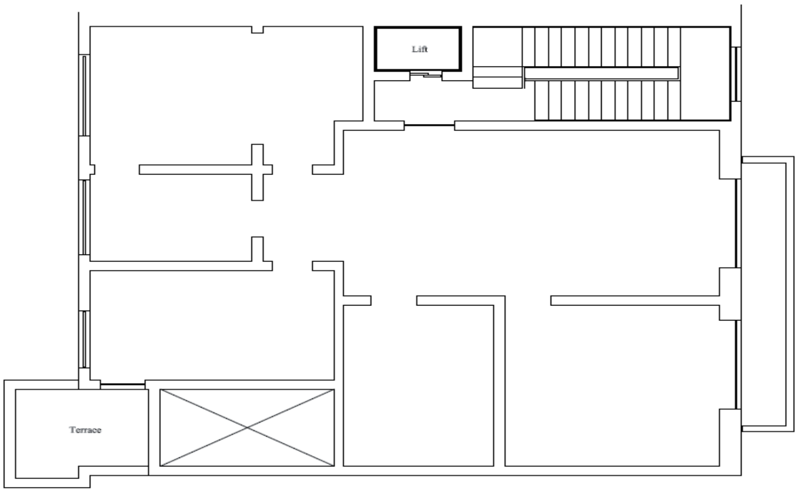

Figure 8. Architectural plan of case study apartment.